WINDS OF CHANGE
Ricardo helps develop next-generation wind energy technology

India opens up:
SIAM outlook for Indian auto industry
New Ricardo office

Hybrids:
Why an all new development process is needed

Biofuels:
Why automakers should be concerned

Interview:
Dr HS Lee, president, R&D, Hyundai
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Detroit’s green agenda

Detroit 2008 could go down in history as the event where North America at last showed it was taking energy saving – and even climate change – seriously.

Hybrids were on everyone’s stands, many of them volume production models; downsizing was much in evidence, with GM showing a fuel cell Cadillac and cancelling a V8 programme, and even Hummer was lured into the green camp with a bio-fuelled concept.

Notable, too, was the advance of eco thinking into the gas-guzzling world of the SUV. Land Rover struck the perfect note with its smaller, lighter LRX concept, its combined electric and diesel drive claiming enhanced off-road performance as well as the potential for 120 g/km CO₂ emissions. Production is likely early next decade, assuming Land Rover’s new owners approve the programme.

Ford’s Explorer America concept sought to redefine the iconic SUV, ditching the big V8 and weighty ladder frame chassis for a two litre, four cylinder EcoBoost motor and car-like unitary construction, giving a projected 30 per cent fuel saving.

Premium nameplate Cadillac took two major steps forward with its Provoq, another crossover SUV. It will be many years before the fuel cell powertrain makes it into production, but the smaller and lighter unitary platform offers useful downsizing of dimensions and consumption and will be in the showrooms – with gasoline power – next year.

However, just to prove business as usual continues in Detroit, Ford unwrapped a fresh V8 F150 pickup, Chrysler showed its big bold new Ram pickup and Chevrolet revealed its most powerful Corvette ever.

Chrysler shows eco concepts

Newly independent Chrysler LLC showed an eco-minded concept for each of its three brands. Jeep’s Renegade is electric, with a Bluetec diesel engine as a range extender, the Chrysler ecoVoyager (right) is a roomy electric people carrier with its batteries topped up by a fuel cell, while the all-electric Dodge Zeo is a sporty 2+2 coupe with a claimed range of 400 km.

News in brief

BMW joins DCT set

The new M3 convertible is the first BMW model to feature the company’s new M Double Clutch Transmission. The seven speed gearbox has six different shift programs, allowing the driver to fine-tune the change.

Ford: hybrids to make money

Ford’s hybrid vehicle operations will move into profit by the end of 2008, according to Nancy Gioia, director of sustainable technologies. The company has reduced the cost of hybrids by about 30 per cent since 2004.

Ferrari burns ethanol

Surprising the crowds at Detroit was a Ferrari F430 Spider tuned to run on E85 bioethanol. Race-derived modifications to the fuel feed and engine management systems allow the engine to produce an extra 10 hp.

Go-it-alone hybrid

Ex-Aston Martin and BMW designer Henrik Fisker has developed a pure electric luxury sports coupé for his California organisation Fisker Automotive. The Karma claims 0-100 km/h in 5.8 seconds.
$2500 People’s Car stuns auto industry

Perhaps for the first time ever, the world car business turned its focus on New Delhi in January for the presentation of Tata’s long-awaited People’s Car. Priced at $2500, a figure many analysts said would be impossible to achieve, the four-seater Nano has a rear-mounted twin-cylinder gasoline engine and CVT transmission. The four-door hatchback runs on tiny 12-inch wheels and, thanks to simplified equipment levels, weighs just 580 kg – enabling it to claim 5 litres per 100 km consumption. The gasoline version meets Euro 4 emissions standards as well as local Indian crash safety norms. Tata is working on a diesel version as well as better-equipped, more expensive editions for export. These will have airbags and other safety features not required for the Indian market. Tata Motors sees an eventual volume of one million units a year.

Technology trends

In what has been a remarkable few months for engineering innovations, new combustion systems and plug-in hybrids have emerged as important trends approaching production feasibility.

Mercedes-Benz claims a 127 g/km CO₂ emissions figure for its DiesOtto engine in the S-Class-sized F700 concept car: the 1.8 litre four-cylinder unit runs on gasoline but uses spark ignition only for start-up and under full load.

GM and Volkswagen have also shown combined consumption systems, allowing gasoline-type engines to use compression ignition under certain conditions; further away is VW’s CCS, which runs on special synthetic fuel for very low emissions.

Detroit saw the second showing of GM’s Flextreme plug-in hybrid proposal, this time wearing the US Saturn badge. The concept combines a lithium-ion battery with a 120 kW electric motor and a 1.3 litre diesel engine to give a range of 55 km in zero-emission electric mode before the combustion engine has to be fired up. Audi’s Metroproject quattro will be the basis for the new A1 small car, the Tokyo show concept being a through-the-road hybrid with a conventional 1.4 litre gasoline drivetrain at the front and a 30 kW electric motor driving the rear wheels.

Supersports cars go diesel

One trend, two extremes: Audi has created the world’s first diesel-engined supercar by installing its race-inspired V12 diesel into the R8 two-seater (far right), while Mitsubishi’s Concept RA (right), despite its mid-engined looks, uses the new Lancer four wheel drive platform with the 2.2 litre clean diesel mounted up front.

GM’s axes new V8

A high-technology V8 engine programme has been cancelled by General Motors. The DOHC unit, destined for luxury cars, was due to have entered production in 2009 to replace the current Northstar V8.

Fiat’s DCT programme

Italian carmaker Fiat will launch a new family of six-speed transmissions in 2010, according to Automotive News Europe. The three versions will include a manual, a dual clutch and an automated manual.

Racing greens

Automakers are partnering with US government bodies to launch a green racing series for sports cars using biofuels, energy-retrieval and other CO₂-saving technologies. The first race will be at Sebring in March this year.

20 per cent diesel in US?

One in five Mercedes-Benz sales in the US could be diesel-powered vehicles within a few years, Daimler chief executive Dieter Zetsche has stated. In 2007, slightly under five per cent of the brand’s quarter-million US sales were diesels.

RICARDO QUARTERLY REVIEW

The task of RQ is to highlight the latest thinking in automotive engineering and technology worldwide – both within Ricardo and among other leading companies. By presenting an up-to-date mix of news, profiles and interviews with top business leaders we paint an interesting and exciting picture of R&D activity at a world-class automotive engineering services provider. It is a formula that has certainly been a hit with the worldwide automotive community: in the five years since RQ was launched we have had to increase our print run to 14,000 copies to keep pace with the demand to read about Ricardo and its activities.

Client confidentiality is of the utmost importance to Ricardo, which means that we can only report on a small fraction of the work carried out by the company. So we are especially grateful to those Ricardo customers who have kindly agreed to co-operate with RQ and allow their programmes to be highlighted in print: without such help from customers it would not be possible to present such a fascinating insight into the way vehicles are conceived and developed.
HYUNDAI’S “Mr Engine”

HS Lee is the engineering visionary behind Hyundai’s spectacular rise to global status – and also the creator of the world engine used by Chrysler, Mitsubishi and Mercedes. Tony Lewin spoke to him as the Korean group presented its i-Blue fuel-cell concept and prepared to enter the luxury market with its Genesis line.

What is the top priority in your R&D work right now?
Our top priority is to develop a safe car, an environmentally friendly car, and a car that’s convenient and easy to use. Basically, it’s safety and environmental friendliness.

You haven’t mentioned performance, for instance. Is that no longer a priority?
These days, performance is the same for every car manufacturer. It’s pretty much standard now. It’s a baseline for the vehicle – it’s no longer a differentiator between brands. We can differentiate our products in two ways: how environmentally friendly the vehicle is, and how safe the vehicle is.

What is the key technology you are pursuing for environmental friendliness? Is it hybrids?
Hybrid is important, but it’s not the 100 per cent solution. The basic direct injection gasoline engine with turbocharger will be used; so will the diesel. CO₂ emissions are important, so we are applying all the state-of-the-art solutions to these conventional engines. On top of this we are working hard on hybrids and also fuel cell vehicles. Hyundai-Kia Motor is trying to come up with an even more light-weighted car, introducing aluminium body, optimized engine structures, new material and process methods.

Will you need hybrids to meet the European 130 g/km CO₂ fleet average standards?
Europe is a tricky market for hybrids. High-speed driving is still popular in Europe – and hybrid is not any help for this. We would be reluctant to introduce hybrid vehicles into Europe unless they were for customers who used them for downtown driving in heavily congested big cities.

If Germany introduced speed limits on its Autobahns, would hybrids stand a better chance in Europe?
Yes, the chances would be better, but hybrids are still best for the really congested city driving. In other respects I’d rather be driving a fuel efficient diesel.

What about a diesel hybrid, then?
That’s a possibility, but the issue is how we control the cost. This is the key factor. We need to develop a cost-effective hybrid system, otherwise it will be difficult to apply diesel hybrid to smaller vehicles.

Could you approach the €1000 target that has been mentioned by some manufacturers and suppliers?
That’s a tough target: we’d love to develop a hybrid with just the €1,000 additional cost. It will be very difficult – maybe €1,500 might be a [more realistic] target. That’s based on a production volume of about 100,000 vehicles a year. Right now, we are producing hybrids in Korea and the volume is just a few thousand a year – and the cost is high.

What about plug-in hybrids?
Plug-in hybrids are expected to play the role of a stepping stone leading to battery electric vehicles. Currently there exists a huge gap between the actual battery technology level and the desired one for electric vehicles to be put into practical use. The plug-in hybrid can help reduce this gap. And if a sizeable plug-in hybrid market is made possible, a positive feedback between technology development and market expansion can be created. Based on this scenario, the era of electric vehicles could come earlier than expected.

What are the prospects for diesel in North America?
A good question. Pick-up trucks have already started using diesel engines, and there’s a change among SUVs towards diesel too. The atmosphere is changing. Americans no longer resent diesel: they’re starting to calculate the costs and performance of the diesel system. Their diesel engines are currently large, around six litres: it will take them some time to accept small diesel engines for passenger cars and small SUVs. The emissions target is very tough and the additional cost is very high. The big issue for us is how to persuade customers to understand they’re getting an advantage by driving diesel.

Turning to fuel cell vehicles, you showed the i-Blue concept at September’s Frankfurt show. When do you expect a production vehicle?
We are participating in the Department of Energy programme in California, running 34 vehicles with Chevron-Texaco. We’re doing a similarly-sized test with the Korean government too. We’ve been investing a lot of research money and our technology level is pretty much the same as any other car manufacturer’s.

Is the fuel cell stack your own, or is it bought in from an outside supplier?
It’s developed in house – it’s our own stack.
Is extreme-temperature performance the biggest problem with fuel cell systems? So far, we’ve got the technology to go successfully to minus 10°C. We’re still looking into extreme conditions, but cost reduction is another big problem. The i-Blue is designed around the fuel cell system and has a running range of 600 km.

Planned global emissions standards are significantly different between Europe, Asia and North America. Do you think there can be any convergence towards a world standard in the future? I’d love to see that kind of development. I’d look forward to it: somehow, we’ve got to fix this problem. Not only emissions standards, but collision standards and safety standards – they’ve got to be globalised. All car companies are wasting resources trying to meet so many different standards: it’s a big problem. Cars could be cheaper if they only had to meet one set of standards.

If there is going to be convergence, which set of emissions standards should be the one to converge on? Another good question. Carbon dioxide emission regulation is really important for preventing global warming, and it is also easily understandable by customers and car manufacturers – although the Americans are still very reluctant to adopt regulations. We’d love to see just one globalised emissions regulation.

How important is the transmission and the rest of the driveline in the overall CO₂ equation? The transmission is also important in the reduction of CO₂. We are developing six-speed automatic gearboxes – also seven and eight-speed, too. Those technologies will give us better fuel economy and less CO₂; other kinds of technology are the dual clutch transmission and CVT – these are important options for us to consider seriously. The DCT and CVT shift systems give us huge benefits in fuel economy.

Are you developing all those in house, or in conjunction with outside suppliers? Mainly in-house, but for some projects we go outside.

Barely ten years ago, Hyundai was a small company with minimal engineering resources and models derived from other carmakers’ products. What has been the most important factor in the company’s progress? Our chairman invested huge amounts of money to build up our R&D capability. We have a huge R&D centre in Korea, with over 8000 engineers in one place. It’s an integrated campus, with all the functions working together. We’ve been able to develop our world powertrain and engine; we don’t just have our own technology but have been able to give it to DaimlerChrysler and Mitsubishi. The world engine programme really propelled our engineering capability. We feel very comfortable in the powertrain area: we can compete with any company in the world in powertrain. Now we’re developing world-class state-of-the-art vehicles like the Genesis we have presented at the New York Motor Show. That vehicle gives proof of our technological capabilities. This year (2007) is our 40th anniversary: through Genesis we would like to jump one step higher in car manufacturing technology.

Is Genesis the start of a big push into the premium segment? We will be introducing luxury – not premium brand, but luxury – vehicles for higher markets to enhance our brand image. So far, we’ve [mainly] been associated with small and medium vehicles, which is somehow tending to drag down our brand image; I think it’s time for us to move upwards, not just to improve our image but to improve our profitability too. We’ll keep the small car lines, but strengthen the larger car lines and add luxurious vehicles.

Will you leave the smaller vehicles to Kia in order to move Hyundai upwards? No: both companies will continue in the small vehicle market as this market is increasing rapidly, especially in Asia – China, India and now south-east Asia. The growth is extremely high, so we cannot ignore this market. Within this market we need to differentiate Hyundai and Kia by styling, performance and by price.

"We can compete with any company in the world in powertrain. Now we’re developing world-class state-of-the-art vehicles like the Genesis"
Issues of energy security and global warming are at the very top of the political agenda for governments of all major industrialised nations as well as those of the developing world. As a result, renewable energy resources are increasingly seen as an important contributor to the future of regional and national grid power supplies.

In Europe for example, EU leaders signed up in March 2007 to a binding target to obtain 20 per cent of their power needs from renewable sources by 2020. The UK’s industry minister further reinforced this commitment in December 2007, unveiling plans for an unprecedented 33 gigawatts of offshore wind power capacity within the same time frame. If constructed, this would represent a 60-fold increase in the UK’s wind-produced energy in relation to present day levels – and would be the power equivalent of the energy consumption of the country’s entire housing stock.

Enthusiasm for the development of renewable energy is also apparent in the United States, where Renewable Portfolio Standards mandate targets for the proportion of electricity sales which must be represented by renewable resources. These binding targets apply in 24 states plus the District of Columbia and together represent more than half of the electricity sales in the United States.

If the headline figures for aspirations of future renewable energy levels seem impressive based on today’s usage, they are even more so when taking into account projected increases in electricity demand. By 2030 total

Wind may be a completely renewable source of energy, but weather is unpredictable and wind power is not always available when needed. This intermittency of power supply has limited the contribution that wind turbines are able make to grid power supplies. Now, however, as Anthony Smith reveals, Massachusetts-based General Compression is using Ricardo’s automotive engineering and development expertise to develop new technology to store wind energy and provide something they call ‘wind energy on demand™’.
EU electricity demand is forecast by the European Commission to have increased by approximately 50 per cent compared with 2000 levels.

Wind’s inherent disadvantage: the weather
Of all of the potentially large-scale renewable energy resources, wind is perhaps the most universally available. While the generation of biomass-based fuels requires space for cultivation of feedstock and the various forms of hydropower require access to the sea or major river networks, virtually every part of the earth’s surface experiences the natural force of the wind.

But whereas many other renewable resources are predictable to a high degree – in the case of tidal power, over many years – the instantaneous availability of wind power has traditionally been subject to the vagaries of local weather conditions. Whether in the depths of a winter freeze when household heating is added to the grid baseload requirements for industry, or in the height of summer
when the air conditioning systems of the major commercial centres make similarly high demands, unless the wind blows in the vicinity of the wind farm, no power will be generated.

Massive grid networking on a national or continental scale could provide a theoretical solution – after all, even if one given location is becalmed, the wind is always blowing somewhere else. But the practical obstacles are such that wind energy has tended to be used to augment rather than substitute for base load power generation capacity.

The value of wind energy on demand

The problem is summed up in financial terms by David Marcus, CEO of wind energy company General Compression.

“Conventional wind turbines have gotten very efficient at taking intermittent wind and generating intermittent electricity. Intermittent electricity gets a lousy price in the market – nobody wants to pay for it, it doesn’t benefit from any time-of-day pricing, and it doesn’t use the transmission grid efficiently.”

It was this realisation which led to the formation of General Compression by four founding shareholders, which included Mechanology, Inc., a well-established developer of advanced compressors and associated technologies. Mechanology had the foresight to identify the opportunity to develop a compressor-based energy storage capability which could act as a buffer for wind farm output peaks. The company is responsible for the development of the compressor technology which will be used by General Compression in its proprietary Dispatchable Wind™ systems.

Summing up the overriding mission of General Compression, Marcus continues: “We’ve decided to focus on how to make wind storables so that we can sell it on demand when customers want it.”

As with many great ideas, the concept underlying General Compression’s Dispatchable Wind system is in essence very simple. In a traditional wind farm the wind turbines are used to generate DC current, which is passed to an inverter, matched to the system frequency and fed into the electricity grid. Power transmission is immediate, so the wind energy provider has to take whatever the current market clearing price is for grid electricity. In the Dispatchable Wind system, however, the DC generator on the wind turbine is replaced by an array of compressors and intercoolers which take atmospheric air and raise it to a given storage pressure. This high-pressure air is piped to a reservoir and stored, ready to be expanded through a turbine to produce electricity whenever needed.

The storage and expansion aspects of the Dispatchable Wind system are already well proven technologies. Compressed air energy storage (CAES) systems have been used for many years alongside pumped-hydro schemes as a means of enabling the large-scale buffering of grid electricity. These facilities purchase low priced, off-peak energy to compress and store air at high pressure (typically around 50-75 bar) in an airtight storage facility. The pressurised air is then kept until demand peaks, when it can be released through an expander plant in which it is heated and passed through a combustion turbine to create electrical energy. The waste heat of the exhaust is typically used to supply energy to the pre-heater or recuperator, before being released to the atmosphere, thus improving thermal efficiency.

Until now, CAES developments have been based in an opportunistic manner around favourable geological features such as impervious rock caverns and redundant mines. Examples include the 290 MW Huntdorf and 110 MW McIntosh plants respectively in Germany and Alabama, which use redundant salt caverns as their storage facilities. However, development work has also more recently been carried out on smaller-scale CAES systems which use fabricated storage vessels running at pressures in excess of 100 bar in order to reduce storage capacity requirements.

“When we examined existing CAES systems two factors immediately struck us,” explains Mechanology CEO, Eric Ingersoll. “Firstly, if you substitute a wind turbine instead of an electric...
motor to drive the input compressor, everything downstream of this in terms of compressed air storage and eventual expansion is known and well-proven technology. Secondly, we need a completely new and unique form of compressor technology in order to accommodate the practical demands of wind power generation.”

Size matters – so does weight
In order to meet the challenge of incorporating a compressor capable of delivering a service pressure of around 100 bar within the structure of a wind-turbine, a very high power density would be needed. The only plausible location for the compressor system would be in the nacelle immediately behind the rotor, which is used to house the gearbox and generator set in a traditional wind turbine.

The need for low weight is obvious for such a location, situated as it is at the top of the tower structure typically up to 100 metres from the ground. But size too is important as there are practical limits on the dimensions of the nacelle which cannot be breached.

“The limiting factor on the size of the nacelle is the maximum dimension you are legally allowed to place on a truck”, explains Steve Chomyszak, Mechanology engineering chief and co-founder. “Every country as well as each individual state in the USA has its own regulations, so you have to design for the worst case you will encounter between where the unit is manufactured and where it is installed.”

Other operating considerations are that the compressor must match the power input of the wind turbine almost instantaneously. While storage pressure changes very slowly, wind speed can change almost immediately. At the turbine this can range for example from a cut-in speed of typically 5 rev/min to a rated speed of 18 rev/min. While the gear train will take this up to a more amenable speed for compressor operation, the three-fold speed range is a fundamental challenge for the operation of the compressor.

As such, the system needs to handle rapid and substantial changes in speed and flow rate while maintaining its service pressure ratio. There are some very practical concerns too. The compressor needs to offer high levels of reliability, with no more than routine annual planned maintenance over a life span of 20 years. Above all, it needs to be affordable.

Having looked at the available compressor technology, Mechanology quickly established that while there were many available devices capable of delivering the basic functional pressure, flow rates and reliability targets, none of them had the potential to meet the power density, size and cost requirements of a commercial wind farm operation. Put simply, as Chomyszak explains, “they’re too big, they weigh too much and they cost too much for this application.”

“We’ve decided to focus on how to make wind storable so that we can sell it on demand when customers want it”
David Marcus, CEO, General Compression

Enter the Dragonfly™
Seeking to subject the Dispatchable Wind conceptual design to objective external peer review, General Compression and Mechanology invited a number of wind energy experts to participate in a seminar at Mechanology’s headquarters in Attleboro, Massachusetts. The advice was clear and unambiguous: the Dispatchable Wind conceptual design was potentially attractive for a wide range of wind farm types and locations. There was one problem, however: none of the then-available compressor technologies identified by Mechanology would meet the combination of performance, cost, power density and reliability requirements identified.

The answer – the invention of the Dragonfly compressor – came as a spark of inspiration. The basic design for this innovative machine arose from something of a eureka moment between Steve Chomyszak and Alex Doohovskoy, a mathematician and colleague. In discussion with Doohovskoy over a suggested improvement to another product, Chomyszak attempted to sketch what he thought his colleague was recommending. As it turned out, the two of them were completely at cross purposes and the sketch bore no relation to the discussion at hand. It did however represent the concept of what could be a potentially high power density compressor.

While the detail design of the Dragonfly is subject to international patent applications and must thus remain confidential, Ricardo engineers found that the Dragonfly is inherently mechanically elegant and appears to offer a viable solution. Proving its robustness on a large-scale application requires an equally elegant development process.

As a first step Mechanology produced a small-scale 37 kW proof-of-concept demonstrator, named the ‘V0’, in the company’s own workshop. While this machine confirmed the basic principle of operation, a rather more significant challenge would be to transform it into a production device of approximately ten times this rating. Only an up-scaling of this order would enable the Dragonfly to form one of the four compressor stages in the nacelle which would be capable of handling 1.5 MW – the typical power rating of a commercial wind turbine – and delivering reservoir compressed air in excess of 100 bar.

Engine engineering skills and technology

It is often said that a good compressor design plus a fuel system and means of ignition can be the basis of a good engine. While the similarities may be more obvious between a reciprocating compressor and a conventional automotive gasoline or diesel engine, the basic physics of the pumping process are also broadly similar even for a machine such as the Dragonfly.

The choice of Ricardo to assist in the detail design and development of the machine and its associated hardware was thus an obvious one. Dan Acker, programme manager at the Ricardo Detroit Technology Campus, takes up the story:

“The Ricardo engineers working on this project have been closely integrated with Mechanology’s own engineering team, focusing on those areas where state-of-the-art automotive engine design, analysis and engineering skills and processes can be of greatest assistance. The technical challenge was in taking this well-established know-how and applying it in a unique situation.”

One of the most fundamental considerations was in the detailed design of the various components and sub-systems of the Dragonfly, enabling it to be taken from a 37 kW proof-of-concept model to a 375 kW production device. Ricardo’s Computer Aided Engineering (CAE) technology was used to great effect in examining the overall gas dynamics and possible drive mechanisms of the Dragonfly.

Like any compressor, the Dragonfly generates its own pulsed flow with consequent pressure wave dynamics. Ricardo’s WAVE software, more typically applied to engine, intake and exhaust simulation, was an ideal choice to simulate the complete system of four compressor stages and associated manifolds, ducting and intercoolers installed in the nacelle. While the primary mechanical system is in itself fundamentally in balance, WAVE enables the far more complex system-wide gas dynamics to be considered and optimised.

The Dragonfly drive system also benefited from Ricardo CAE technology in the form of the VALDYN package, more usually applied to optimise the valve train and belt and chain drive systems of automotive engines. While the original drive system as used for the initial ‘V0’ prototype is being scaled up, at least in design terms for the first full-size ‘V1’ prototype, Mechanology requested that Ricardo investigate two alternative designs in parallel for possible substitution at a later stage of product development. The use of Ricardo’s VALDYN software allows engineers to calculate critical parameters such as bearing loads, contact stresses, and resonant vibration modes in a wide variety of configurations very quickly. The overall benefit is a more robust design in a much shorter time period.

Development process

The detailed engineering of the Dragonfly components and sub-systems has utilised a range of CAE and design technologies of the automotive industry; the prototype development process too would be familiar to many automotive design engineers. However, whereas multiple engine prototypes will usually be produced to fulfill a range of separate test development applications such as thermal and durability assessment, calibration development and ultimately, in-vehicle prototype development, the scale of the Dragonfly and its intended wind energy application are such that all work will need to be carried out on a single prototype of each version in an integrated manner.

For the next stage of Dragonfly prototype development, Mechanology has built its own 525 kW compressor test facility at its Attleboro base. It is planned that the first full-size prototype Dragonfly, named ‘V1’, will be tested there during 2008 in parallel with commencement of engineering design work on the next stage prototype, ‘V2’. To improve the efficiency of the development programme, however, Mechanology has implemented a parallel learning and improvement process in which high-risk sub-systems or problems identified are spun off from the main programme for intensive work while the prototype itself proceeds with the best available technology. Chomyszak cites the example of the drive system, where Mechanology has tasked Ricardo engineers with the concept design of a range of possible alternative solutions based on automotive-style technology, while the V1 programme continues based on the original system of the V0 machine.

Full-scale system evaluation

The ambitious plans of Mechanology and General Compression aim to bring Dispatchable Wind to commercial readiness on an extremely tight timescale. Following testing of the ‘V1’ prototype Dragonfly, Mechanology intends to work with Ricardo and other partners to prepare the next full size prototype, ‘V2’, which is intended for evaluation as a complete General Compression compressor array including all four compressor stages and intercoolers. This will be too big for the company’s in-house test facility, so will instead be tested at a Department of Energy laboratory.

Development timeline: Following the testing of the V1 and V2 Dragonfly prototypes, General Compression plans a full scale array test in 2009 and wind farm trial in 2010.
– one of very few installations globally capable of accommodating a 1.5 MW, nacelle-sized machinery installation. Testing of this array is planned for 2009, following which General Compression intends in 2010 to commission the first Dispatchable Wind prototype, featuring three commercial-size turbines. The scale of General Compression’s investment in commercialising Dispatchable Wind is no less impressive than the elegance, simplicity and attractiveness of the concept itself. The company is funding the entire development process – from the detailed design and prototype testing of the Dragonfly compressor on which it is based, through to the construction of the first three prototype wind turbines – from its own resources. However, the potential attractiveness of a technology which can deliver wind energy on demand is perhaps best demonstrated by the apparent ease with which the company raised its first $8.1 million of external capital in April 2007. The enthusiasm of Mechanology and its partners, including the Ricardo engineering team, is palpable – yet it is also soundly based on the implementation of a methodical and rational approach to design and testing, using the best available technology and support.

Chomyszak is confident that Dispatchable Wind will deliver: “Our analysis of current CAES systems shows that they have a system efficiency of around 45%, whereas our system will be around 55%.” Crucially, however, the Dragonfly™ compressor aims to offer a practical package which can be installed in the nacelle of a wind turbine and cope with the severe environmental and operational demands that arise from this. If the Dispatchable Wind development and validation programme proves successful, the idea that wind energy is intermittent energy may once and for all be consigned to the history books.

Steve Chomyszak, Mechanology and General Compression

Steve Chomyszak was raised in a rural up-state New York farming community where his early practical skills and interest in all things mechanical was particularly useful.

“I grew up knowing about how to drive tractors and perform various farm-related jobs. In that environment when something breaks, you’ve gotta know how to fix it.” He was able to bring these practical skills with him throughout his education. “In high school, I was equally at home taking machine shop and art classes as well as advanced placement classes in math and science”. Following high school he studied for a Bachelor’s degree in industrial design at Syracuse University, a profession which he describes as “an ideal blend of my artistic and mechanical talents”. By a stroke of good fortune he was invited to attend graduate school at Stanford University in Palo Alto California by his mentor, Professor Rolf Faste, to study Product Design at Stanford is one of the world’s leading research and teaching institutions. While there, he also discovered an equal love for engineering and manufacturing. To fund his studies he took a part time job as a teaching assistant in manufacturing technology. He confesses that having access to a machine shop as well as a design studio was perhaps too tempting an alternative to some of his more formal lectures.

But in describing this period he also makes a very salient point about education in general, one which seems to define much of his career as an entrepreneur: “As a graduate student, I didn’t feel that I was necessarily there to be taught – I was there to learn. In my view, education is a process of not only building knowledge, but of also building the skills necessary to put that knowledge to work. Learning how to learn is the most important skill that one can take away from one’s education.”

As an entrepreneur he credits his long-time friend and Mechanology co-founder, Richard Hagan, for encouraging him in his work and providing the highly necessary emotional fuel and entrepreneurial skills essential for keeping a startup company operating.

In 2003 Eric Ingersoll, the company’s CEO, came up with the idea of putting compressors into wind turbines and storing the energy as compressed air. Two of Mechanology’s principal investors, brothers Michael and David Marcus, already had interests in wind energy and in 2006 they, Mechanology, and power plant developer Summit Power Group became the four founding shareholders of General Compression, Inc., the company formed to develop and commercialise the Dispatchable Wind system.

In its first round of funding in April 2007 General Compression raised $8.1M from over 70 investors.
What is India’s future as a manufacturing base, perhaps for more than just low-cost vehicles?

Although the history of Indian automobile industry is long, it is only since the 1990s that the industry started developing subsequent to the 1991 liberalization policy of the Indian Government.

All segments are showing robust growth, with production growing at an average rate of 15 per cent over the last five years. The financial year 2006-07 showed an encouraging performance of the vehicle industry, with production growing at 14 per cent, domestic sales registering a growth of over 13 per cent in number terms and more than 15 per cent in value terms.

All segments have shown growth, led by commercial vehicles at 33 per cent, three wheelers at 28 per cent, passenger vehicles at 18 per cent and two wheelers at 11 per cent. Exports have also grown remarkably with the growth rate being more than 25 per cent.

The Indian automobile industry has witnessed huge investment announcements in all the segments since last year; close to $15 billion is expected to come in over next three to five years. The investments are in all segments of the industry.

The industry has immense potential and is developing 100 per cent indigenously designed vehicles at highly competitive prices.

What about CVs and two-wheelers? Is there export potential here and, if so, to which markets?

The commercial vehicles segment in India is also upbeat; the segment grew the most – 33 per cent in 2006-07. This growth was led by the most important sub segment under this category, goods carriers or trucks, which grew at 38 per cent.

In the commercial vehicle segment, especially in LCVs, the industry is exploring new markets. Sub-one tonne trucks have created an interesting niche in recent years and it is expected that this sub-segment will become important in future.

India is number two in two wheeler manufacturing in the world, after China. The world’s number one motorcycle manufacturer is already present in India. Countries like Vietnam and Indonesia are huge prospective markets.

A tenth of Indian vehicle industry’s production, over one million vehicles, is being exported. Exports have shown remarkable performance during the year 2006-07, with the growth rate being over 25 per cent. Last year, three wheeler exports grew the most at 87 per cent, followed by two wheelers, commercial vehicles and passenger vehicles exports at 26 per cent, 22 per cent and 13 per cent respectively.

Exports are to varied regions and countries, including South Asia, the EU (Germany, UK, Belgium, Italy), the Middle East, North America, Russia and South Africa. [The table opposite gives the Indian vehicle industry’s overseas sales].

Can India compete with China on cost of production? How long will this last?

What types of manufacturing – engines, transmissions, or complete vehicles?

India and China are as distinct as far as their unique advantages are concerned. Indian industry does not get any subsidy from the Government but has competed with the rest of the world on the basis of quality and economy achieved by the local entrepreneurship.

While companies are already exporting transmissions, engine parts and other systems and parts, India is slowly developing into a manufacturing base for complete vehicles too. Last year, almost 200,000 cars were exported from India.

Will India enjoy a long-term advantage in costs over China once Chinese government subsidies and incentives have ceased?

Companies based in India should enjoy an advantage over their
current competitors. More so because the government of India has now become sensitive about the systemic deficiencies, especially the disadvantages related to the cascading effect of embedded taxes, and we hope government will take steps to address those issues and make manufacturing competitive.

Is India happy with western and Japanese OEMs setting up solo operations, rather than JVs as in China? What’s in it for Indian industry?
One hundred per cent FDI (foreign direct investment) is allowed in the automotive sector. Solo operations and joint ventures are company decisions and there should be no concern about solo operations as long as India gains in terms of local value addition and employment.
Incidentally all Japanese companies in India are joint ventures – Maruti-Suzuki, Toyota-Kirloskar, Hero-Honda, Honda-SIEL, Mahindra-Nissan, Swaraj-Mazda, HM-Mitsubishi. Even European companies in India are joint ventures: Tata-Fiat, Mahindra-Renault.

What can India teach the world about low-cost cars?
Tata Motors is developing a low cost car in India, which will to come to the market later this year. However, looking at the potential, Renault has also expressed a desire to develop low cost cars and is evaluating various options. India has a big labour pool, which gives it advantage from cost side; it is a growing market, too. Its main competitive advantage is in entrepreneurial skills which help to integrate small innovations.

Can India remain a sustainable location for worldwide low-cost car production as prosperity increases and wage costs rise?
India should remain competitive compared with other competing countries in the foreseeable future.

What will be the factors constraining the current sales boom?
Currently, macro economic factors like rising interest rates, reduced availability of finance, the appreciation of the rupee and rising commodity prices are exerting upward pressure on the cost of production and are affecting demand.

Can a 1-lakh car sell beyond the sub-continent?
We feel there are many people for whom a car is only a means of transportation, and such people exist in all countries. A low cost, fuel-efficient car without many frills should be attractive to many people across the globe.

In terms of safety standards, how feasible is it to have cars that are both cheap to buy and safe to travel in?
We understand that any vehicle developed in India would meet all emission and safety standards prevailing in the market. There should not be any restrictions on adding features.

Will the low-cost cars be available with features such as airbags, ABS, and ESC? What emissions level will they meet initially and eventually?
Any vehicle sold in India would meet all emission and safety parameters mandated by the government of India. Currently we have Euro III equivalent standards in cities and Euro II equivalent standards in the rest of the country. We are expecting to have Euro IV equivalent standards from 2010. Airbags and ABS are not standard features of basic models of most cars sold in India. These extra features normally come at a cost.

What will be the impact of these tightening emissions standards in India?
The Indian automotive industry is committed to the roadmap laid down by the government of India. Stringent emissions standards are being enforced increasingly all over the world, and Indian industry would not remain in isolation.
The India Automotive Mission Plan (AMP) 2006-16 in January 2007. The plan sets targets for the industry in the next 10 years and recommends suitable interventions from various departments. This is an initiative of the Ministry of Heavy Industries & Public Enterprises, which is responsible for the development of this industry. This document is a follow-up of Government of India’s Auto Policy published in 2002 and has been prepared with close cooperation between industry and academia.

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Dilip Chenoy is Director General of the Society of Indian Automobile Manufacturers, which is the industry body representing 38 leading vehicle and vehicle engine manufacturers in India. Prior to joining SIAM in 2004, Chenoy was responsible for several key sectors, including agriculture, life sciences and ICT, within the Confederation of Indian Industry. Previous to this appointment, he worked with Harvard Business School Professor Michael Porter on a study of the competitiveness of Indian industry.

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**Firms in India are designing, developing and producing vehicles at a cost which is a small fraction of the global cost of such developments. Many of them have found global markets.**

Firms in India are designing, developing and producing vehicles at a cost which is a small fraction of the global cost of such developments. Many of them have found global markets. India has a substantial share of world software and accountancy work for big corporations. What’s next in the automotive sector?

The auto industry is expected to grow rapidly in future and set to double its contribution to GDP, from the current level of 5 per cent to 10 per cent and provide employment to 35 million persons over next ten years.

Will India implement any policy regarding technology transfer from foreign companies or the sharing of intellectual property rights?

We have an IPR regime in place in India. We do not think Government will come with any mandate on technology transfer. Development of the automotive industry in India is essentially based on private initiatives and the role of Government is likely to remain passive.

**Where do Indian vehicle producers fall short of global standards – and how can this be remedied?**

The vehicles produced in India meet all global standards and are exported to various discerning markets, including in Europe. Some may not be known as made in India brands.

Firms in India are designing and developing and producing vehicles at a cost which is a small fraction of global cost of such developments. Many of them have found global markets.

However, the Indian industry is still in the developing stage and would require improvements in [vehicle] finish and other softer issues.

What does India lack in terms of vehicle development capability?

Testing infrastructure – this becomes more important in the light of future expansion plans of companies. Adequate testing infrastructure is not yet in place.

Industry and Government are working in close partnership to overcome this inadequacy. The setting up of the National Automotive Testing and Research and Development Infrastructure Project (NATRIP) marks a very important step in overcoming this and ensuring competitiveness in manufacturing and technology.

The project will be important in the harmonisation of Indian standards with international norms. As identified in the 2006 Automotive Mission Plan (see left), NATRIP could play a co-ordinating role for all activities requiring data collection and in promoting Centres of Excellence.

To what extent can vehicle development be localised if vehicles are to meet global standards?

The Indian industry is manufacturing world class vehicles and developing hi-tech engineering products. However, in the automotive space most of the patents are held by developed countries and, as such, for such technologies Indian manufacturers would have to depend on outside sources until they catch up on technologies.

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What additional aspects of vehicle development and manufacture could India begin to offer the global industry?

All items related to fuel efficient vehicles.

How long before India has a global vehicle brand? What type of vehicle will this be?

India is already developing global brands. Indigenously developed vehicles like Scorpio and Indica are sold not just in India but in other markets as well.

However, cost of establishing a vehicle brand is significantly higher than other products as it includes the setting up of networks of service chains in countries. It will take time to establish these across the world as offering full sales and service backup to the products takes time.

What are the key advantages that SIAM brings to the Indian auto industry?

SIAM activities revolve around its three main agendas - economic, technical and public policy. Its main objective is to promote sustainable the development of Indian automobile industry.

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Ricardo’s decision to establish a wholly-owned subsidiary in New Delhi shows a major commitment to India as one of the world’s biggest and most vibrant markets and is a key element in the Group’s global strategy. RQ reporters look into the thinking behind the decision.

November 2nd 2007 will come to be seen an important day in the roll-out of Ricardo’s strategy to become a truly global services provider to the automotive and associated industries. In celebrating the founding of Ricardo India Private Ltd and the opening of its offices in New Delhi, Ricardo is cementing its commitment to one of the largest potential markets on the globe, as well as focusing its renowned emissions-reducing expertise on an area of the world in desperate need of cost-effective environmental solutions.

Speaking at the official ceremony inaugurating the new division, Nobel Peace Prize laureate Dr Rajendra Pachauri praised Ricardo’s record in mitigating pollution and climate change: “The challenge of CO₂ reduction concerns us all,” he told the assembled guests, who also included Richard Stagg, British High Commissioner to India, and Ricardo Group CEO Dave Shemmans. “I am excited by the prospect of a company such as Ricardo applying its product engineering skills from the auto industry to accelerate developments in the renewable energy sector and energy-efficient transport solutions.”

Dr Pachauri leads the UN Intergovernmental Panel on Climate Change which shared the 2007 Nobel Peace Prize with ex-US vice president Al Gore.

Ricardo has of course been an active force in the Indian automotive engineering sector since December 1986, with noted customers such as Tata Motors, Mahindra and Mahindra, Greaves Cotton, Eicher, Hindustan Motors, TVS Motors, Bajaj Auto and others benefiting from its expertise in engine development, transmissions, hybrid engineering and calibration work. Over a span of 20 years Ricardo’s representative office in New Delhi has done an excellent job in attracting engineering work, communicating with Ricardo personnel in locations as varied as Detroit, Chicago, Prague and the UK, and in seeing programmes through to successful completion.

Global working patterns
However, to cope with the demand for expedient planning and development of new products to keep pace with global competition and in the round-the-clock work pattern to which the international industry has become accustomed, it was becoming clear that response times had to be accelerated and liaison further improved. The obvious solution offered itself: a wholly-owned Ricardo organisation on Indian soil, allowing Indian customers to deal direct with Ricardo engineers, and enabling Ricardo to ensure that clients receive long-term proactive provision of the very latest services.

“In truth, the idea of a fully established office in India had been on the table for some while,” commented Surjit Kalra, the Chairman of Ricardo’s long established representative organisation in India and now chairman of the newly-established organisation. “We’ve just been waiting for the right moment.”

Ample evidence that this is indeed the right moment is provided not just by the growing presence of Indian automakers and suppliers on the world stage – Tata’s bid for Jaguar Land Rover is just one example of this – but, even more vividly, by the huge influx of inward investment from European, Japanese and Korean carmakers. Today, the Indian automotive industry is in the international spotlight as never before.

“The volume of business has certainly been a factor,” says Kalra. “The representative system worked well, but we knew we could do better.”

In particular, expects Trevor Downes, executive vice president of Ricardo India, the new organisation will be better able to understand the precise requirements of its Indian customers. “Today many of the client engineers are highly qualified and have years of work experience in the world’s best OEMs in US and Europe,” notes Kalra. “They are a highly motivated group of people. The Indian auto industry has developed over the years and the CEOs are fully abreast with the latest international practices and trends – as much as anyone else in the world.”
WHY NEW DELHI?
Over the years the Indian auto industry has grown up all over the country, often driven by tax concessions offered by the individual states for setting up plants in economically disadvantaged areas. New Delhi enjoys the best links to all such locations and has good internal communications too. There are also a number of existing and planned plants for manufacture of whole vehicles and auto components. “New Delhi is an automotive hub,” points out Surjit Kalra, chairman of Ricardo India. “Some large manufacturers are there, and as the capital city it’s of course the administrative and financial centre of the country.” Seminars, exhibitions and shows are invariably in and around New Delhi, notes Kalra, and New Delhi is the kindest environment for expatriate employees – a key consideration when running a world-class organisation.

WHO’S WHO IN RICARDO INDIA
Chairman: Surjit S Kalra, BSc (Engg) Hons, MIE, FIV, FPWI
Experience: 12 years with Indian Railway Service of Engineers (IRSE), eight years with US aid programmes and CEO of an Export House. 25 years representing several foreign companies in India including UK companies: Ricardo for 21 years and Balfour Beatty for 24 years.
Executive Vice-President: Trevor Downes
BEng (hons) CEng MIMechE
11 years experience with Ricardo (since September 1996). During this time Downes has held operational management as well as specialist engineering roles within the company.
Vice-President: Indeep S Madan, B.Eng (Hons)
Studied engineering at Coventry University, worked for three years at Ricardo Shoreham and four years with Kalra Consultants.
Marketing Engineer:
Col JBS Rekhi, BE Mech
30 years service as an engineer in the Indian Army.
Marketing Engineer:
Saad Ashraf, B.Tech (Mech)
Two years’ marketing CAD/CAM/CAE software; one year with KCPL.

“Ricardo’s contribution to reducing exhaust pollutants is world renowned – and I am very pleased that the launch of Ricardo India is making these capabilities more accessible to Indian customers”
DR RAJENDRA PACHAURI, HEAD OF UN INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE AND NOBEL PEACE PRIZE LAUREATE

“Need we a strong network to service this type of customer,” continues Kalra. “The pace of response needs to be upped and the flow of latest information maintained on a continuing basis to service an intelligent and aggressive market such as the India of today – and that’s exactly why we are changing the Ricardo India format from representation to official presence.”

Quality of programme delivery
While in the short term there will be continuity in the type of work handled through the New Delhi office, the direct presence of Ricardo will permit important enhancements in quality of delivery as well as a key change of emphasis in the nature of the business development activities centred on India.

“One of the major benefits is in the connection between the market and the engineering operations and the technologies Ricardo is choosing to pursue,” says Downes. “We can establish the relevance of technologies to the market because we are close to it – and we can then push these forwards to the customer, explaining why they ought to have these technologies.”

Speed of response will be noticeably quicker, says Downes: “All communications will in effect be internal communications.” In addition, says Downes, the many informal relationships within the organisation can be exploited to get things done more quickly.

Customer base
“Indians are becoming a lot more entrepreneurial in the way they do business,” says Kalra. “We’re experiencing this mushrooming of growth of financially strong people getting together and forming auto companies. These kinds of companies are relationship based, and having a local office and primary relationships makes all the difference. With the establishment of the Ricardo office in India – at their very door steps – these new companies will have a greater comfort level in going ahead with their aspirations and plans.”

This is something that is frequently seen, adds Downes. “There are a number of cash-rich manufacturing companies in India who are now looking to engineer their own products and increase their product ranges. These manufacturing companies who are now turning to engineering are very much potential customers for us.”

Increasing business
The volume of Ricardo’s business with Indian customers has increased fourfold over the past three to four years and currently accounts for about 3 per cent of Ricardo group turnover.

“If you look at China and Korea, they’re closer to 9 or 10 percent,” says Downes, “and it is entirely reasonable that India should approach those sorts of proportions as well. Over a two to three year timescale we could certainly be looking at a doubling – there’s nothing wrong with ambition.”

What’s the plan?
“Anyone hoping to see a neat predetermined stage-by-stage plan for the rollout of Ricardo’s facilities in India is destined to be disappointed. Flexibility, adaptability and response to customer needs are the name of the game in a fast-expanding market such as India, and for that reason Ricardo India is adopting a listening and analysing attitude when it comes to deciding in which on-the-ground engineering facilities it will invest in India,” says Kalra.
Why India matters

Tony Lewin provides a perspective from the world’s automotive media

Three years ago, all eyes were on China. Carmakers, truck builders, component suppliers and engineering specialists were swept along in the headlong rush to cash in on the biggest vehicle-building boom of recent times. But the new-found focus on Shanghai and Beijing has allowed India to spring a surprise on the global auto industry as major players – both Indian and international – slipped in under the radar to set up operations that in the long run could become even more significant than those in China.

An avalanche of announcements from companies such as Renault-Nissan, Fiat, Suzuki and Tata have ensured that India is suddenly the big talking point in auto business circles: in particular, the realisation that Tata’s 1-lakh ($2500) Nano will be a production reality next year has done much to convince analysts and commentators that India is a potent source of enterprise and ingenuity, rather than just a vast pool of cheap labour.

Fresh from the success of its mid-sized $5000 Logan, Renault-Nissan, too, is keen for a slice of the ultra low-cost action: its deal with Mahindra and Mahindra to build a 400,000 unit capacity plant in southern India was hailed by Thiru Dayanadihi Maran, Union Minister of Communications and Technology, as “a watershed agreement … that will set new benchmarks for Indian manufacturing industry and the state.”

The new facility at Chennai will build vehicles of all three brands, possibly including the $3000 car currently under study with motorcycle maker Bajaj, as well as engines for Renault and Nissan. Renault will build the Logan in conjunction with Mahindra, while Nissan has a separate deal with Ashok Leyland for the production of light commercial vehicles.

“Indian companies like Mahindra, Tata Motors, (Ashok) Leyland, Bajaj Auto are doing a wonderful job,” Renault-Nissan CEO Carlos Ghosn told the Indian media last April. “Why should we reinvent the wheel when we can simply learn from them? Bajaj sells three wheelers for $2000 and I would lose my shirt if I try to do that. Only an Indian company can achieve that kind of a thing. If I have to fight on cost, I would rather partner with an Indian company.”

Japan’s Suzuki, the long-standing market leader that is reaping the benefits of its pioneering investment in Maruti, is tooting up for an output increase to almost 1m units by 2010. Many of these, along with engines and transmissions from Maruti Suzuki’s Indian facilities, will find their way to European and other export customers.

So too will the all-important small gasoline and diesel engines from Fiat’s joint venture with Tata, a facility which it is reported will build the Grande Punto and Linea, as well as new-generation Tata models.

India’s increasing emphasis on exports was thrown into even sharper focus in October last year when Jae Kook Choi, CEO of Korea’s Hyundai—which is currently India’s second-biggest carmaker – declared that as Hyundai’s global hub for small-car manufacture, India would account for 30 per cent of Hyundai’s overseas production by 2009 and that half of all output would be exported. The new i10 hatchback would only be made in India, he said.

A more recent arrival is BMW, which will make 3- and 5-series models in Chennai. “Particularly in the premium automobile segment, India offers big opportunities for growth,” declared BMW CEO Norbert Reithofer in March this year. “Opening this plant underpins our long-term route to profitable growth.”

And with even Porsche and Rolls-Royce enjoying healthy order banks in India, few would disagree.
Biofuels: friend or foe?

Biofuels are widely perceived as an environmental asset capable of cleaning up vehicle emissions overnight. But in reality, reports Jesse Crosse, first generation biofuels may cause as many problems as they solve.

Of all the methods for reducing CO₂ emissions available to the automotive industry, the use of biofuels is proving to be one of the most challenging. Biofuels are being widely touted as an easy way of cutting emissions of greenhouse gases – irrespective of whether those fuels are the product of a sophisticated manufacturing process or derived from recycled cooking oil in a back-street lock-up.

But nothing could be further from the truth: biofuels vary enormously in their environmental impact and in the other concerns they raise. In fact, there is growing unease in the automotive industry that the unregulated use of biofuels could lead to widespread engine failures and warranty claims. Lack of regulation may also mean that while biofuels help to reduce CO₂, some may actually cause other types of harmful emissions which until now have remained unregulated.

Perhaps the biggest problem is that while gasoline and diesel are two distinct fuels manufactured to exacting, recognised standards on a global basis, the term 'Biofuel' does not represent one fuel or even two. In fact it refers to any fuel manufactured from an organic feedstock. Biofuels can take the form of ethanol-based fuel blended with gasoline, or oils either blended with or used as a substitute for diesel.

European gasoline and diesel may contain up to five per cent ethanol or biodiesel (the latter officially defined as baseline EN590 diesel and rapeseed methyl ester/RME blend) respectively without the base fuel standard being affected and are quite safe to use in standard engines without ill effect.

Much more than that, however, and the situation becomes more complicated.

Standards – or lack of standards
Each family of biofuels can be manufactured using different techniques, yet despite active work in this area there are no real standards in place for biofuel and no specifications governing their formulation other than...
for constituent parts. While ethanol is a fairly standard substance whatever the feedstock or manufacturing process used to make it, the chemical make-up of biodiesel can potentially be extremely varied, having been derived using anything from animal carcasses to rape seed. In the real world this could mean one point of sale may be offering a biodiesel fuel with completely different properties, formulation, additives and contaminants to another across the street.

The situation was summed up by Angela Johnson, principal engineer, technology and systems department, at Ricardo when she declared simply, “all biofuels are not equal.” Indeed, they are anything but equal, and the implications for engine, fuel systems and aftertreatment manufacturers are potentially serious.

Johnson is part of a Ricardo team charged with staying one step ahead of the biofuels phenomenon, providing information, analysis and advice to many vehicle and component manufacturers in the automotive sector whose products are becoming affected by the new fuels.

“Part of my role has been to look at biofuels from a strategic point of view,” she explained, citing a long list of areas of concern: “The markets, the well-to-wheel implications, the variability among fuels (in particular fuel quality), the processes involved, issues faced by vehicle makers, security and sustainability of raw material supply for production, the blending of fuels and its variation across the supplier base, fuel distribution and the impact on consumers (too much choice is confusing) and the vehicle parc. There’s a huge degree of variability across the whole subject.”

In road fuel terms, the large scale adoption of biofuels would represent a huge cultural upheaval in the industry. “The question is,” Johnson continues, “how can we practically use this? Is it a short term measure or a sustainable long term solution?”
Mechanical implications
There are two sides to the challenge which biofuels present. The first is their true value in reducing emissions on a well-to-wheel basis. The second relates to the mechanical implications of using biofuel either blended with conventional fuel or, in particular, when it is in concentrated or pure form. Biofuels can be powerful solvents, flushing deposits from fuel systems to potentially block or damage injection systems. Alcohol based biofuels are often hygroscopic, absorbing moisture which can in turn cause corrosion; they can also attack seals in the engine and fuel system.

Put simply, there are huge incompatibilities between current engine technologies and biofuels when those fuels are used in high enough concentrations. Ethanol is not so much of a problem and is much the same molecule whether cracked from hydrocarbons or fermented from sugar cane. As a result, there are few issues with bioethanol fuel as far as specification is concerned, and standard engines can run on gasoline containing up to five per cent ethanol without a problem. Beyond that, flex-fuel vehicles are needed: these are vehicles whose engines have modified components to resist chemical attack from the fuel and can adapt to the different combustion characteristics resulting from a higher ethanol content.

Apart from technical considerations, there are other factors that may affect the consumer too. Because the existing European gasoline standard EN228 includes fuel blended with up to five per cent ethanol, the fact that that fuel contains ethanol at the point of sale is not necessarily publicised to the customer. Yet ethanol contains less energy than gasoline by volume.

Research is actively being pursued in this area. In the US, Ricardo is working with Bosch and the University of Michigan on Department of Energy sponsored research to develop an optimised flex-fuel vehicle capable of running on any blend of ethanol up to and including E85.

Biodiesel: the main worry
Biodiesel is a different matter and is where most of the concern lies. Again, the EN590 standard for conventional

### Table: First and Second-Generation Biofuels: Sources, Characteristics

<table>
<thead>
<tr>
<th>Biofuel</th>
<th>Use</th>
<th>Name</th>
<th>Generation</th>
<th>Feedstock</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BIOETHANOL</strong></td>
<td>Primarily as E85 or low level blends (E5, E10), or converted into ETBE* which is used to improve the quality of gasoline</td>
<td>Ethanol</td>
<td>First Generation</td>
<td>Corn (US), sugar-beet, sugar cane (Brazil), potatoes, wheat, alcohol (Europe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Cellulosic” Ethanol</td>
<td>Second Generation</td>
<td>Biomass (straw etc.)</td>
</tr>
<tr>
<td><strong>BIOETHANOL</strong></td>
<td>As B100 or other blends in conventional diesel (B5, B10, B30)</td>
<td>FAME (Fatty Acid Methyl Esters)</td>
<td>First Generation</td>
<td>Rapeseed, sunflower (Europe), soybean (US), palm oil, jatropha (India)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BTL (Biomass-to-Liquid) or Synthetic diesel</td>
<td>Second Generation</td>
<td>Biomass (wood, straw etc.)</td>
</tr>
</tbody>
</table>
diesel allows it to be blended with up to five per cent biodiesel. But unlike ethanol used in gasoline, globally the term ‘biodiesel’ can be applied to a wide range of substances and the difficulties arise with blends above five per cent – or even the use of 100 per cent (B100) biodiesel.

Commonly used feedstocks are rape seed from Europe and palm oil from Indonesia and Malaysia, while the USA relies heavily on soya. Different types of oil each have a different chemistry, explains Jon Andersson, manager, chemistry department, at Ricardo. “If not properly eliminated in the production process, each will contain a different set of contaminants that may affect engine performance and durability. The fuels can also degrade over a period of time or through exposure to heat and light.”

A typical problem scenario is the traveller who drives hard and fast to the airport, arriving with a hot engine and warm fuel. Worse still, the tank may be left almost empty, the remaining dregs left exposed to air in the tank and possibly hot sunshine in the summer. “When the blend was mixed it was one thing,” explains Andersson, “but two weeks later it may have become something completely different.”

Points of sale may suffer similar problems. For the large supermarket selling large quantities of fuel quickly, fuel quality could remain fairly consistent. But at smaller sites, fuel may degrade in underground tanks over a longer period. This potential for fuels to change character makes them almost impossible for manufacturers to deal with. Combustion properties vary too, so accurate engine calibration becomes an issue.

**In road fuel terms, the large scale adoption of biofuels would represent a huge cultural upheaval in the industry. The question is how can we practically use this?**

Angela Johnson, principal engineer - technology and systems department, Ricardo

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### Key nations are setting biofuel targets

<table>
<thead>
<tr>
<th>Country</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>Binding commitment to 10 per cent market share of biofuels in transportation by 2020</td>
</tr>
<tr>
<td>USA</td>
<td>Renewable Fuel Standards stipulate 25.7 billion litres biofuel by 2010, 227 billion by 2030</td>
</tr>
<tr>
<td>China</td>
<td>Objective set for biofuel to meet 15 per cent of transportation energy by 2020</td>
</tr>
<tr>
<td>India</td>
<td>Considering a 10 per cent target by 2010</td>
</tr>
<tr>
<td>Brazil</td>
<td>All gasoline contains 24-27 per cent ethanol; 2013 target of 2.5 billion litres biodiesel</td>
</tr>
<tr>
<td>Australia</td>
<td>2010: 1 per cent biofuel; 2020: 5.75 per cent biofuel</td>
</tr>
</tbody>
</table>

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### ADVANTAGES AND DISADVANTAGES

<table>
<thead>
<tr>
<th>Comments</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercially available now</td>
<td>Modest GHG reductions</td>
<td>Competing land use issues - food vs. power generation</td>
</tr>
<tr>
<td>Limited small-scale production, such as Choren’s Sundiesel</td>
<td>No competition with food crops</td>
<td>Higher cost than conventional fuels</td>
</tr>
<tr>
<td>Commercially available now</td>
<td>Significant fossil energy savings</td>
<td>High variability</td>
</tr>
<tr>
<td>Pilot plants producing cellulosic ethanol, such as logen</td>
<td>No competition with food crops</td>
<td>Non-ideal fuel molecules</td>
</tr>
</tbody>
</table>

**Advantages**

- Modest GHG reductions
- Avoids imports into Europe
- No competition with food crops
- Lower land use
- Wide range of biomass feedstock components
- Relatively simple low-temperature, low-pressure processes
- Potential for better fuel characteristics (BTL)
- Higher energy per litre (synthetic)
- Significant fossil energy savings
- Modest GHG savings, but not all sources equal
- New source of support for farmers
- Better than first-generation GHG reductions using different processes
- Lower land use
- Potential to tailor fuel specification to precise requirements

**Disadvantages**

- Competing land use issues - food vs. power generation
- Higher cost than conventional fuels
- High variability
- Non-ideal fuel molecules
- High costs compared with conventional fuel
- Technology new and unproven at an industrial scale
- Energy-intensive production process
- Contains less energy per litre than conventional fuels
- Energy-intensive production process
- Higher costs than first-generation fuels
- More complex production process than biodiesel
- Energy-intensive production process
a moving target. Fuel systems can be affected by corrosion and deposits, with serious consequences for manufacturer warranties.

Instances of drivers using crudely recycled vegetable oil, harvested from restaurants, in modern diesel engines have produced some alarming results. Unburned fuel mixing with the engine’s lubricating oil is already a problem in conventional cars but the use of unmodified vegetable oil fuels (non transesterified) without fuel-enhancing additives can react with the lubricating oil to form polymers with very different lubricating properties.

There have been similar occurrences in fuel systems, raising the spectre of increasing numbers of warranty claims from disgruntled customers who may have unwittingly damaged their otherwise perfect engines by using incompatible fuel. Some component suppliers are already coming to Ricardo seeking clarification on whether specific failures were caused by suspect fuel.

Too much variability

Even with well-produced fuels, pinning down calibration standards is proving very difficult. “In the diesel arena,” says Johnson, “ultimately, it may be possible to make synthetic diesel (a second-generation fuel which can be better quality than the standard diesel we have today) on a large-scale production basis. What we don’t like at the moment are the fuel variability and quality issues associated with first-generation biodiesels. Nobody has enough money to develop and validate their engines to be capable of coping with all the types and blends that are out there. There’s a risk of spending a lot of money developing engines to run on fuels that may only be around for a decade or so until more stable, second generation fuels come on stream.”

Currently, some heavy duty engine manufacturers will warrant their engines for use with B100 but with specific conditions regarding fuel standard, service intervals and driving conditions. Emissions can vary wildly too. A variety of fuels were tested on Ricardo’s heavy-duty Euro VI diesel development project recently conducted with AECC. “We looked at running B30 (30 per cent biodiesel),” said Andersson. “There were apparent reductions in HC and CO in response to reductions in engine power. Particle number emissions increased and effects on NOx emissions were uncertain, though PM levels and the effectiveness of the emissions control system was unchanged.”

High percentages of biodiesel have a dramatic effect on the way the fuel is combusted. Andersson digs deeper into the detail of what can happen inside the engine: “Biodiesel is more dense, with a heavier hydrocarbon component, a proportion of which can survive combustion. We’ve seen different effects with different engines, but these components can hang around in the combustion and provide a degree of quenching – which reduces NOx. “But they can also end up deposited on the combustion chamber walls, creating higher levels of particulate matter. There are a number of different effects and it depends on the individual design and how well the injection system is coping. That is why it is so difficult to contemplate a single generic engine design to cope with all biofuels.”

Ricardo: research for UK government

In 2001 Ricardo undertook some research for the UK Department of Transport into burning vegetable oil. It has also tested a wide range of blends – including B10, B20 and B30 – for various vehicle makers, investigating jet deposits, general durability and the effect on DPF regeneration. Ricardo has also undertaken substantial research into the use of B30 in heavy duty engines, looking at effects of unregulated emissions.

“All of these tests have tended to be...
"bolt-ons", to test programmes running on conventional fuel," Andersson continues, "but a major issue is the inconsistency and uncertainty with biofuel quality and longevity for engine type approval because the pass-off tests for emissions regulations are based on conventional fuel." The auto industry is currently requesting that type approval be permitted on either current reference fuels or B5 and E5. If granted, this will not become law for at least a year.

“We are trying to open the window of understanding on the implications of running these fuels in modern engines – what we really lack is information on the durability impact of these fuels. We have to nail down what the properties of the fuels are and how they degrade in order to understand how we can create a matrix that is realistic.”

Tying down standards is proving difficult. The oil industry does not have the engineering expertise and legislators don’t view biofuels from the same perspective as either the oil or automotive industries. With over 25 years experience in biofuel research, this puts Ricardo in a key position in terms of knowledge – and all of its courses and seminars on the subject have been oversubscribed. Its biofuel specialists also spend a great deal of time working with EU legislators and talking to trade groups. “Our first approach,” Andersson continues, “is to help the standards regulators.”

**Second-generation biofuels will be the answer**

Most of the problems will be addressed by the introduction of so-called second-generation biofuels. Most of the biofuel produced today is first generation, produced in the case of ethanol by fermenting crops, or from a wide range of different types of organic oils when it comes to biodiesel. Second-generation fuels will be produced using Fischer-Tropsch gas-to-liquids (GTL) technology. This involves specialised heat treatment of biomass to generate a ‘dirty’ producer gas. After cleaning, the producer gas is converted to a synthesis gas of carbon monoxide and hydrogen. This is then processed to form liquid fuel. It is not a new process and was developed in the 1920s, but it produces accurately formulated ‘designer’ fuel to tight standards. “In this way it is possible to build fuels from very small molecules,” Andersson continues, “producing a high quality substitute for either gasoline or diesel.”

The likely source material or feedstock will be biomass. This can comprise a wide range of waste material including wood chips as well as varied organic waste. Relatively few companies are using the process commercially today and there is some way to go, perhaps 10 years or so, before commercially-produced designer fuel is available in larger quantities. When it does, the true well-to-wheels and emissions benefits of biofuels can be realised properly, without any damaging side-effects to engines and their components.

In one sense, that time can’t come soon enough – but the intervening period can be put to good use. “It’s sufficiently far away,” concludes Andersson, “for both the automotive and oil industries to specify exactly what they want.”

**Key challenges for energy suppliers and distributors**

**Blending**

Significant issues can occur in the blending of ethanol and gasoline; suppliers may need to use Refinery Base Oxygenate Blendstock (RBOB) rather than standard gasoline.

**Distribution**

Fuels containing bio-content (especially ethanol) cannot be transported through multi-product pipelines. Biofuel use requires extensive cleaning programmes at filling stations to remove all water in gasoline tanks prior to using ethanol blended fuel. Ethanol is hygroscopic (draws in water), which can lead to corrosion issues in vehicle fuel systems.

**Quality and availability**

There is a general lack of fuel standards covering biofuels – currently no standards exist for E10, E85 or B10, B30 or other combinations.

**Cost and complexity**

Considerable cost will be incurred installing dedicated pumps. Many forecourts do not have enough space to permit additional pumps for E85 and other incremental fuels: too much choice could be confusing for the consumer, heightening the risk of using the wrong fuel.

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**Well-to-Wheels Greenhouse gas emissions versus energy per 100km**

Source: Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. EUCAR, CONCAWE & JRC
If a new car company were to be created today, it would look dramatically different to today’s auto companies, especially in the way product development would be organised and conducted.

Much of the discussion on energy-optimised vehicles has been focused on the underlying alternative propulsion technologies such as high energy density batteries, more efficient electric motors, fuel cell infrastructure and other material factors. However, these vehicles will potentially have an even more dramatic impact on how product development may be conducted in the future as they become mainstream products rather than ‘skunk works’ one-offs or derivatives of existing products.

Automotive product development has been fundamentally formulated according to the way vehicles have been designed and developed over the past 100 years. Vehicle systems are broken apart along arbitrary lines and the organisation is set up to develop product along these demarcations. However, given the extreme integration required by the new technologies to optimise energy usage and consumption, a trigger point exists to revamp the basic automotive product development process.

Viewed holistically, automotive product development spans many elements including organisation, skill sets, intellectual property, and process. Ricardo Strategic Consulting has begun studying how a 21st century automotive OEM, faced with the challenge of developing and producing high volume energy-optimised vehicles, might be structured. This article examines how product development may be conducted in the interim while OEMs retool their product development organisations to accommodate the demands of a new generation of vehicles.

What’s different?

Technology aside, the biggest step-change that alternative propulsion introduces into vehicle product development is the importance it places on integration and optimisation of the various systems across the vehicle. Weight is now at a premium as it has a direct impact on range and performance. Auxiliary systems that draw power no longer can operate semi autonomously but rather must be continuously monitored in operation and adjusted to optimise the vehicle’s energy footprint. Functions like braking interact with the energy balance by providing a way to recover kinetic energy and return it to propulsive power.

Even driver controls and instruments have an impact by providing the driver with information on how to draw power most efficiently from the vehicle as well as providing a feed-forward (as opposed to feedback) information loop to anticipate and handle upcoming energy demands in an optimum fashion.

In the interim environment where the current method of product development has been adapted to meet the challenge of achieving greater integration and optimisation, some common practices stand out among makers of energy-optimised vehicles.
“Automotive product development has been fundamentally formulated according to the way vehicles have been designed and developed over the past 100 years”

Stringent requirements development and flowdown process

Requirements flowdown is an aerospace and software concept that has been adopted to varying degrees of consistency in the automotive industry. In an energy-optimised vehicle programme, the order of magnitude increase in system interaction and integration compared with a conventional vehicle requires a much stronger and more rigorous requirements flowdown from vehicle-to-system to subsystem-to-component level. Whereas in the past the interdependency between disparate vehicle systems could be managed by relatively low speed, low reliability asynchronous communications, real-time energy flow management requires much more sustained interaction and thus a better description (encompassed in the specification and requirements documents) of how previously loosely connected vehicle systems like multimedia and energy storage systems will work dynamically together to optimise energy expenditure.

Viewing requirements flowdown from the classic V-model product development perspective (requirements and specifications cascade in descending order on one leg of the V and are linked to their associated validation activities on the other leg), more descriptive and richer component, system and vehicle-level specifications allow much more work to be done on allocating functionality throughout the vehicle, better planning in terms of system interaction and more efficient validation, particularly of the various dynamic operational modes which involve cross-vehicle system interactions. Other benefits include a significant reduction of in-field warranty issues.

Platform re-use strategies

A platform and technology deployment strategy is critical to efficiently setting up the necessary supporting infrastructure (software, systems development and more) and ensuring that sufficient flexibility is incorporated to allow for scalability as the underlying technology implementation changes. Robust platform strategies will help to alleviate the redesign required by made-to-order solutions that then need to be completely redesigned with little to no re-use for a new application.

For example, the new systems in energy-efficient vehicles have given many leading OEMs the opportunity to fundamentally re-architect their software control strategy. Historically, vehicle software has been organised into a series of loosely ‘federated’ systems with loose rules for interaction, primarily in response to the differing rates of electronics penetration into the different vehicle partitions. Energy-optimised vehicles represent an application where a top-down software architecture and strategy can be applied at a vehicle-wide level across all partitions and systems.

Software module functionality can now be predefined based on an overall architectural strategy and plan rather than being an outcome of precedent and current practice. Improved re-use of software ‘objects’ rather than re-writing modules for each new application is greatly facilitated, significantly reducing software development resource requirements and, more critically, reducing or eliminating the level of unanticipated post-launch customer satisfaction issues due to partially validated software. A trickle-down beneficial impact of the top-down software and electronics architecture definition effort is the substantial cost-reduction benefits accruing from consolidating the various on-board modules into a smaller number of more integrated controllers.
Organisation structure
Organisationally, for the first generation of energy-efficient vehicles OEMs have accommodated alternative propulsion technologies by treating them as another system to be incorporated into the vehicle. The role of the integration engineer has been expanded to include optimising energy flow and overseeing and arbitrating that the proper trade-offs are being made to ensure system optimisation. Rather than managing plug-and-play types of components, the higher level of integration and combined/shared functions have made this role much more complex. This overlay construct allows the gap to be bridged between the traditional product development organisation and the new requirements imposed by this new type of vehicle.

For one OEM’s hybrid vehicles programmes, the integration function is incorporated into the powertrain organisation. This structure may be more appropriate in the case where an alternative propulsion system is incorporated into an existing vehicle platform, but it still points to a mindset that views energy efficiency as a separate responsibility rather than as a function that is relevant to each system that consumes or generates energy.

In the next generation of vehicle programmes this role is already being moved to a whole vehicle function as well as much further upstream as new components and systems are being developed exclusively for energy-optimised applications.

Intellectual capital management
Traditionally, powertrain control strategies have been considered the crown jewels of the automotive OEM. Energy management and power storage strategies have become the new crown jewels in the energy-optimised vehicle space.

OEMs, particularly Toyota, have aggressively patented many of the energy management strategies they have developed for their hybrid products. While initially used as a barrier to entry, this intellectual capital is being increasingly farmed as a source of revenue through licensing agreements with other OEMs.

In the short term, aggressive intellectual capital management and protection may serve as a temporary barrier to OEMs that are late entrants to the energy-optimised vehicle space. However, in the longer term, it is more likely that the dissemination of this knowledge will follow a path much like the emissions catalyst intellectual property of the early 1970s. These were initially patented and even branded by the various OEMs, but soon ceased to be a unique product differentiator and became part of the basic knowledge required for vehicle development.

A more sustainable competitive advantage may be found in the race to capture and disseminate knowledge of best practices in order to engineer and develop an energy-optimised vehicle more effectively. Systematic development and use of design practices and integration rules explicitly embedding trade-offs are becoming more prevalent in upfront energy-optimised vehicle development.

Process-based OEMs may have an advantage over OEMs that are more heavily reliant on individual effort and knowledge, especially as the number of these types of vehicle programmes increase as a percentage of the product portfolio.

Given the amount of new knowledge that is being learned with each generation of energy-optimised vehicles, an efficient and effective method to systematically capture this knowledge and redeploy it on programmes is a means of offsetting the global shortage of engineers.

“A key question to be asked is this: if a brand new mass-market automotive company were to be formed today to design, develop and manufacture alternative propulsion vehicles, what would it look like?”
“A thought to consider is that while the evolution of the modern vehicle has driven engineers towards increased specialisation, energy-optimised vehicles may reverse this trend”

possessing alternative propulsion and systems engineering knowledge.

**Supplier relationships**
More collaborative supplier relationships signify one of the most sweeping changes introduced by the current generation of energy-optimised vehicles. True supplier co-development is now part of almost every programme, particularly in the area of alternative propulsion technologies. The business relationships OEMs have developed with battery and energy storage suppliers are good examples of this trend.

Vehicle OEMs rely on both large and small suppliers as significant technology contributors. A variety of different business models, ranging from traditional sourcing to joint-ventures and taking equity stakes in suppliers, are being pursued.

These are often found together within individual vehicle manufacturers as they strive to balance achieving a unique technology-based competitive advantage while also trying to share economies of scale from the multitude of ‘green’ initiatives underway across all industries.

It will also be interesting to see whether the strategy of restricting technology to a single OEM or allowing development costs to be spread among multiple OEMs is the business model that will ultimately prove successful.

**Skill sets**
In addition to the obvious requirements for personnel with experience in the various alternative propulsion technologies, systems engineering competence is becoming a skill set that will be even more heavily in demand. However, the change in this case is that systems engineering skills must also be complemented by a suitably deep understanding of how systems and even components operate (when, as well as how), given the integration requirements demanded by new these new vehicles.

A thought to consider is that while the evolution of the modern vehicle has driven engineers towards increased specialisation, energy-optimised vehicles may reverse this trend; this would lead to the resurgence of individual engineers who are both broad and deep in technical knowledge and who could capitalise on optimisation and integration opportunities. This harks back to the days of the technical giants who founded the automotive industry.

**Looking forward**
OEMs have adapted their current organisation, processes and skill sets to accommodate the special needs of developing energy-optimised vehicles. However, with the amount of change needed to bring vehicle integration and optimisation to significantly higher levels than at any time in the past, it is not clear that a simple evolution of the current method of product development is best for these vehicles.

A key question to be asked is this: if a brand new mass-market automotive company were to be formed today to design, develop and manufacture alternative propulsion vehicles, what would it look like?

While some would argue that such examples exist today in the form of new entrants developing electric and fuel cell vehicles, their methods do not appear obviously scaleable to the demands of a high volume car manufacturer.

Within Ricardo Strategic Consulting, we plan to continue to investigate the impact of these vehicles on how automotive product development is conducted. Potentially, this may be the ultimate benefit of the race to develop high volume, consumer and commercially viable energy-optimised vehicles.
Plug-in hybrid programme delivered in five months

The North American International Auto Show held in Detroit in January saw the unveiling of the XH-150™, the first vehicle to feature AFS Trinity Power Corporation’s Extreme Hybrid™ technology. The advanced demonstrator was one of two developed by AFS Trinity and built by Ricardo under contract. The vehicles were ready for testing in just five months.

Plug-in hybrids offer the prospect of dramatically extending the all-electric vehicle (EV) mode of hybrid vehicles through the use of high capacity energy storage systems which can be recharged using grid electricity (typically overnight using discounted off-peak power). AFS Trinity Power’s patent-pending Extreme Hybrid™ technology employs a proprietary dual energy storage system that combines lithium-ion batteries and ultracapacitors with proprietary XH™ power and control electronics, with the aim of satisfying performance expectations of consumers and providing extended vehicle range in a highly energy-efficient and cost-effective package.

In mid July 2007, AFS Trinity Power asked Ricardo to help integrate the Extreme Hybrid™ system into two identical XH-150™ demonstrators using two 2007 Saturn Vue Greenline SUVs as host vehicles. Ricardo responsibilities included integrating AFS Trinity’s proprietary power and control electronics module into the vehicles, incorporating off-the-shelf ultracapacitors and batteries selected by AFS Trinity, designing and developing a completely new Ricardo transmission for the vehicles, modifying the host vehicles’ suspension and chassis control and, finally, building the vehicles.

The results of road tests carried out by AFS Trinity in December 2007 at Michelin’s Laurens Proving Grounds in South Carolina are highly impressive. In simulated urban/highway conditions the XH-150™ achieved an all-electric range of 41.9 miles and a top speed of 87 mph. In acceleration tests the company reports an all-electric zero to 60 mph time of 11.6 seconds. The most interesting 0-60 acceleration time, however, was that for the XH-150™ in full hybrid mode, which was a stunning 6.9 seconds.

Ricardo CEO Dave Shemmans commented: “The need to improve vehicle fuel economy is of paramount importance to automakers, governments and consumers in all parts of the world. Plug-in hybrids offer an attractive solution in the urban environment and are likely to play a significant role in the future. We are proud to have been asked by AFS Trinity to assist in producing the first demonstrator based on AFS Trinity’s Extreme Hybrid™ technology and to have delivered the vehicle ready for testing in only five months. The latest in a long line of hybrid programmes delivered successfully for our clients, this project further demonstrates Ricardo’s position as a leader in this field and underscores the company’s impressive vehicle integration capabilities.”

Looking to the future, AFS Trinity CEO Ed Furia said: “Our primary goal now that we have succeeded in developing, demonstrating and testing the XH-150™ is to license our XH™ system to automakers around the world who would like to have this exciting fuel-efficient drivetrain in their vehicles. Who better to help integrate the Extreme Hybrid™ technology into the vehicles of the world’s automakers than Ricardo.”

Billboard advertising: AFS Trinity announces the XH-ISOTM based on a Saturn Vue Greenline SUV.
Reduced cost battery technology for hybrids

Lithium-ion (Li-Ion) battery technology shows significant promise for hybrid and electric vehicle applications in terms of its comparatively high power and energy density, and its ability to retain charge for extended periods. However, commercial challenges remain in terms of both cost and weight. Ricardo and leading international defence and security technology company QinetiQ have embarked on a two-year collaborative project which aims to dramatically reduce the costs of lithium-ion batteries for hybrid vehicles while maintaining or further improving vehicle performance.

The specific objective of the Reduced cost Li-Ion (RED-LION) project is to demonstrate the application of new Li-Ion cell chemistry in a hybrid vehicle battery with an estimated production cost one-third that of conventional battery technologies and around half the weight. If successful, this breakthrough technology could make hybrid and electric vehicles commercially more attractive and hence make a significant impact on global CO2 emissions.

In June 2006 Ricardo, QinetiQ and PSA Peugeot-Citroën unveiled their 100 g/km CO2 Efficient-C full hybrid diesel demonstrator vehicle based on a Citroën Berlingo Multispace (above). While this vehicle provided an uncompromised package and superior performance compared to the equivalent current production turbo-diesel model, the project partners estimated that its incremental manufacturing cost needed to be reduced by around 50 per cent (to approximately €2000) for the technology to become fully commercially viable based on prevailing fuel prices and consumer fiscal incentives.

The battery system represents around one third of the incremental manufacturing cost of a typical hybrid vehicle as well as a considerable addition to the vehicle mass. If successful, the RED-LION project will demonstrate commercially viable technologies that are capable of delivering sub-100 g/km CO2 emissions with superior performance compared to the equivalent current production vehicle.

Mel Brooks, managing director of QinetiQ’s Energy and Materials business, said: “QinetiQ has a strong track record in delivering high-energy lithium-ion battery technology to military customers. This leading-edge battery technology emanating from defence is now poised to make a significant difference to the viability of hybrid vehicles, with the RED-LION project helping to ensure that cost does not stand in the way of more widespread commercial adoption.”

Commenting on the research programme, Neville Jackson, Ricardo technology director, said: “By incorporating the very latest high performance Li-Ion battery technology, which offers the potential for significant reductions in both manufacturing cost and weight, we aim to demonstrate that we have made progress in developing the commercial case for hybrid diesels. With this project we aim to show that it can be made commercially viable, too. This promising battery technology could deliver significant benefits to many vehicle types including electric and plug-in hybrid, as well as full diesel and gasoline hybrids.”

The RED-LION project is part-funded by the by the Energy Saving Trust’s Low Carbon R&D Programme on behalf of the UK government’s Department for Transport, with balancing contributions made by the participating companies. The Energy Saving Trust is a non-profit organisation, funded by both the government and the private sector.

Intelligent transport initiative

A unique collaboration has been announced between Ricardo, Orange Business Services, Land Rover, British mapping agency Ordnance Survey and TRL (Transport Research Laboratory). The Sentience initiative aims to improve the efficiency and reduce the environmental impact of road transport through Intelligent Transport Systems (ITS). This unusual partnership has been partially funded by Innovites, the UK centre of excellence for transport telematics and sustainable mobility.

Ricardo, together with Land Rover, is looking at how to make the vehicles more fuel efficient. In particular they will investigate the improvements in hybrids which may be possible if the vehicle’s control systems could be aware of the vehicle’s surroundings and hence adapt its mode of operation depending on upcoming gradients, junctions, and known areas of congestion.

Tom Robinson, senior product group manager, control & electronics, Ricardo, commented: “Even with the green push towards getting people off the roads or using alternative modes of transport, we are seeing an increase in vehicles on the roads and even more traffic. A two-part system – which looks at the way vehicles are engineered and routed as well as how our roads are monitored and managed – offers a realistic long-term pathway to help alleviate the UK’s fuel emissions and reduce congestion. Sentence brings together the best automotive knowledge and advanced tracking and mapping technology.”

Orange and Ordnance Survey are leading the telematics and mapping part of the project, utilising their breadth of network to develop GPS, machine-to-machine and mapping applications to provide the vehicles with the information they need to optimise their performance and reduce their emissions. TRL will be contributing to the research throughout the project and will be leading the testing and assessment phase. This will involve undertaking trials at the TRL test track at Crowthorne, near London, to assess the benefits of the vehicle fitted with the prototype engine control system.
Export award, contract win and customer success for Ricardo motorsport

With its production output increasing threefold in the past four years – and over 50 per cent of that output being export sales – Ricardo’s high performance driveline and transmission business has been recognised with the Motorsport Industry Association (MIA) business excellence award for export achievement.

The MIA’s awards recognise excellence at all levels within the motorsport and high performance engineering industry, and the presentation to Ricardo was made on 10 January at the dinner of the Autosport International Show in Birmingham, UK.

“We are honoured to have been recognised with the MIA business excellence award for export achievement,” said Ricardo’s director of high performance transmissions products, Mark Barge, on accepting the award. “This accolade underscores the hard work and commitment of the Ricardo team to provide the most competitive performance driveline and transmission systems and components to our motorsport customers in all parts of the world.”

New transmission for Formula Nippon

Ricardo has been announced as the exclusive supplier of transmissions to Swift Engineering, Inc of California, for the new chassis that will see action starting in the 2009 season of Formula Nippon, Japan’s premier open-wheel series. This contract award builds on the established reputation of Ricardo as a transmission, driveline and engine technology supplier to the highest levels of international competitive motorsport.

The company already supplies transmissions for Japan’s Super GT series as well as single-make series including the World Series by Renault and the Indy Pro Series. Work has already commenced on the design and development of the transmission for the future Formula Nippon chassis and the first Ricardo transmissions for the new generation of Tier 1 supplier

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“Delta is a global leader in electronics supply. This alliance will let us devote more of our advanced technology and efficient manufacturing capability to the automotive electronics field,” said Simon Chang, corporate vice president of Delta Electronics. “Working with Ricardo, we can offer customers advanced, independent R&D capability plus our core benefits of high quality and good service while maintaining a single customer interface.”

Alliances in electronics and manufacturing

Leading international electronics company Delta Electronics Inc and Ricardo have formed a joint-development alliance which aims to challenge the current paradigm of automotive electronics supply. By combining their respective strengths in advanced electronics R&D and high quality manufacturing capabilities, the Ricardo-Delta alliance will create an entirely new business model to provide total solutions.

Customers will still be able to work with a single point of contact for the purchase of new modules and systems; crucially, however, in doing so they will also benefit from the independent R&D expertise – and associated IP protection – of dealing with one of the world’s leading independent technology developers. While both partners will continue to operate independently as dictated by the needs of their respective businesses, they both believe that the benefits of the alliance will be extremely attractive to potential customers.

New generation of Tier 1 supplier

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Swift 017.n are due to be delivered in June 2008. “Formula Nippon is a highly prestigious project for Swift Engineering and we are very pleased to have Ricardo partner us for the supply of transmissions” said Casper van der Schoot, Swift Engineering, Inc, programme director. “Ricardo has a proven track record in the highest echelons of motorsports and will be able to provide us with first-rate products and support in this programme. We are very excited about this new relationship and are looking forward to seeing the results when the 017.n first hits the track in the fall of this year”.

Second successive victory for BP-Ford
The BP-Ford team secured a back-to-back World Rally Championship (WRC) manufacturers’ title victory at November’s Rally Ireland. The Focus RS world rally cars of the BP-Ford team are equipped with an advanced performance transmission and driveline system.

The result of an extensive design and prototype development collaboration between Ford, M Sport and Ricardo (see RQ Q1, 2007), the advanced competition transmission of the Focus RS rally cars had its debut at the end of the 2005 season. High levels of design optimisation and precision manufacture are crucial for the successful design of a competitive WRC transmission such as this: the system is required to operate between maximum torque and maximum power conditions for most of its working life, placing exceptional demands on its gears, bearings and shafts.

Commenting on BP-Ford’s success, Ricardo director of high performance transmissions systems, Mark Barge, said: “We are proud to have acted as the technical partner to M Sport and Ford on the transmission of the Focus RS World Rally Cars. With the BP-Ford team having secured a back-to-back victory with the 2007 manufacturer’s championship as well as outright wins in 8 of the 16 events of the 2007 season, we congratulate the team and are pleased to have contributed in some small way to this success.”

Ricardo motorsport transmissions director Mark Barge (right) accepts the prestigious MIA export award.

US manufacturing collaboration
In the United States, Ricardo Inc and MAG Manufacturing have signed a Memorandum of Understanding (MoU) to collaborate on offering cost-effective engineering and manufacturing programmes for low- to medium-volume propulsion systems. A leader in the global metalworking and processing market, MAG has a large portfolio of highly recognised and well-respected machine tool brands including Hueller Hille, Excello, Lamb, Cincinnati and many others.

In addition to its impressive breadth of industrial coverage, MAG also has key capabilities in areas such as the machining of compacted graphite iron (CGI), which is being used widely in the design of cylinder blocks for the next generation of high-performance automotive engines.

The collaboration between MAG and Ricardo combines the companies’ respective strengths in technology, innovative powertrain system design and advanced manufacturing tools, systems and processes. Together, Ricardo and MAG will offer their customers a comprehensive design-through-production solution for the production of powertrain systems and components.

The MoU signed by Ricardo and MAG provides a collaboration framework within which the two companies will operate to provide this new level of service to powertrain customers in all parts of the world, yet which also allows the companies to respond flexibly and independently as customer and market requirements may dictate.

Senior Ricardo appointments
A number of key appointments have been made by Ricardo since the last issue of RQ. In Germany Dr Peter Heuser has been appointed as managing director of Ricardo Deutschland GmbH. Heuser has been the director of Ricardo’s Global Heavy Duty Diesel product group since 2005 and has also carried responsibility for all engine engineering activities for Ricardo in Germany, a role in which he has had a significant and positive impact in growing the business in terms of both volume and customer base.

A further strengthening of the board of Ricardo Deutschland GmbH came with the announcement that former executive vice president of DaimlerChrysler AG and head of Mercedes Car Group R&D, Professor Dr Hans-Joachim Schöpf, has been appointed as a non-executive director and will also become a member of the Ricardo plc global technical strategy group. With an automotive career spanning 38 years and including some of the most senior positions in the German automotive industry, Professor Schöpf is one of the leading influences on modern automotive R&D. Having retired from DaimlerChrysler in 2004, Schöpf holds directorships in MAHLE, BEHR, TK Bilettein and Ballard Power Systems in addition to Ricardo Deutschland.

In the USA the board of Ricardo, Inc. is similarly strengthened with the appointment of Dr David E Cole, chairman of the Center for Automotive Research (CAR), as a non-executive director of the company. Dr Cole has spent a long and distinguished career in the North American automotive industry, working extensively on internal combustion engines, vehicle design, and automotive industry strategic trends. In addition to his work for CAR, Dr Cole is a director of the Original Equipment Suppliers Association, as well as a non-executive director of companies including Campfire Interactive and MSX International.
A significant milestone was reached by Ricardo in late 2007 with the achievement of Tier II Bin 5 emissions from an automotive diesel engine without the use of NOx aftertreatment.

This research continues with the aim of demonstrating clean diesel technology capable of achieving US Super Ultra-Low Emission (SULEV) and Tier II Bin 2 requirements. By achieving this milestone Ricardo has positioned the advanced diesel alongside gasoline hybrid and fuel cell powered vehicles as high fuel-economy, environmentally friendly automotive products of the future.

Started in late 2005, the early stages of the research project has been focused on developing technologies to deliver engine-out exhaust emissions without NOx aftertreatment that achieve the stringent Tier II Bin 5 US emission requirements, delivering NOx levels approximately one-sixth those of Euro 5. These technologies include advanced air handling systems, two-stage series-sequential turbocharging, advanced exhaust gas recirculation, and application of closed-loop cylinder pressure-based engine controls.

In parallel an advanced exhaust aftertreatment system has been developed; this combines a diesel oxidation catalyst (DOC) and diesel particulate filter (DPF). When combined with engine optimisation, this has delivered Tier II Bin 5 emission levels without NOx aftertreatment. Further research has established the feasibility of adding a lean NOx trap (LNT) into the system. And, through simulation and test results, early predictions indicate that the diesel will be capable of meeting the requirements of US SULEV/Tier II Bin 2 emissions standards, thereby achieving NOx levels less than one-tenth of the Euro 5 levels.

Clean, but fun to drive
Throughout the project, a major emphasis has been placed on achieving low emissions under transient conditions to maintain or improve the fun to drive responsiveness of the engine without deteriorating emissions performance. The engine has been developed with a competitive power rating of 65kW/l to meet U.S. emissions regulations for both sea level and altitude compliance. Having demonstrated these accomplishments on the test bed, the powertrain has now been installed in a test vehicle to enable calibration refinement and validation. In the coming months Ricardo intends to carry out extensive vehicle testing to validate the achievement of SULEV/Tier II Bin 2, currently the world’s cleanest emissions standard. In doing so, the research team aims to maintain or improve engine responsiveness and customer appeal, while also delivering a significant fuel economy and CO2 improvement over current US equivalent gasoline engines.

Commenting on the achievement of this significant clean diesel research milestone, Dean Harlow, president of Ricardo, Inc., said: “The achievement of Tier II Bin 5 engine-out emissions without NOx aftertreatment is a major breakthrough and puts us squarely on the path to achieving our ultimate objective of Tier II Bin 2, the world’s cleanest emissions standard. By applying a systems engineering approach which combines engine-out optimisation with advanced aftertreatment, we have demonstrated that the diesel can provide a clean, fun to drive, cost-effective, fuel-efficient and environmentally friendly solution for the vehicles of tomorrow. While there clearly remain many challenges in translating this research into high volume production solutions, this achievement provides significant new confidence in the future viability of clean diesel in north America.”

Global potential
Regarding the international applicability of the developed technology, Ian Penny, Ricardo’s global diesel product group director, said: “The advanced diesel technologies developed and demonstrated through this research project are extremely attractive in the European as well as the north American market. While the future emissions regulations are different for both regions, the technology we have demonstrated as being capable of achieving Tier II Bin 2 US emissions standards is also highly applicable to the challenge of providing cost-optimised CO2 reduction solutions for EU6 and beyond in Europe.”
Seminars & Events
Related to the automobile industry

Advanced technology seminars, workshops and training courses

Ricardo is recognised worldwide as a leading authority in the development of the latest powertrain and vehicle technologies. While perhaps best known for our engineering and consulting programmes, an increasingly popular service is our regular series of seminars and training courses through which aspects of the company’s knowledge and expertise can be shared with customers. These events are typically hosted at Ricardo Technical Centres and are led by some of our most experienced engineers and research scientists.

We constantly strive to develop new seminars and courses reflecting the very latest thinking and most topical areas of automotive technology and product development. We also strictly limit delegate numbers in order to create an environment conducive to discussion of aspects of particular interest to participants. Modestly priced, our Ricardo seminars and courses provide exceptional value for money but are consequently in high demand.

Our current programme of seminars is listed below. Most of these will be hosted at the Shoreham Technical Centre on a number of dates during this time, and further presentations may also be made at other Ricardo facilities or at customer sites subject to demand.

Seminar programme:

- Internal Combustion Engine Fundamentals
  Two one-day seminars covering the fundamentals of gasoline and diesel engine technology
- Basic Introduction to the use of Biodiesel by OEMs
  Half day seminar
- Introduction to Noise Vibration & Harshness (NVH)
  Two-day workshop
- Diesel Particulates and NOx Control
  One-day seminar
- Introduction to Hybrids
  One-day seminar
- Introduction to Onboard diagnostics
  One-day seminar
- Diesel Engine Calibration training
  Two-day workshop
- Manufacturing training course
  Two-day course covering the manufacturing processes and techniques used by Tier 1 and OEMs in the automotive industry
- High Voltage Electrical Awareness
  Half-day seminar

For more information about our current seminar programme or to discuss any company-specific training requirements, please contact

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- Technical due diligence
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- Product development planning
- Design, design analysis, prototyping
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- Quality improvement, cost reduction, FMEA & design for manufacture
- Supply-chain organisation
- Validation & launch

Wind turbines
Marine / tidal power generators
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Flywheel energy storage systems
Domestic CHP systems
Fuel cells & hydrogen infrastructure
Batteries & electric inverters
Hybrid-systems for vehicles
Application of bio-fuels
Solar thermal electricity generation

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