

Ricardo Quarterly Review

Q2 2019

# RQ

A focus on the latest in technology,  
innovation and sustainability



## Interview

**Marek Reichman,**  
Chief creative officer,  
Aston Martin Lagonda

## Carbon-free railways

Why smart electrification and  
hybrid trains could be the answer

## Shipping and CO<sub>2</sub>

A promising climate-neutral  
fuel is on the horizon,  
says Ricardo report

# Smart, urban – and every inch a BMW

Ricardo's long-standing co-operation  
with BMW moves into the mid-sized scooter  
segment - with premium results





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The task of RQ is to highlight the latest thinking in global engineering and technology in the transportation and clean energy sectors and related industries.

We aim to achieve this by presenting an up-to-date mix of news, profiles and interviews with top business leaders, as well as in-depth features on programmes – both from within Ricardo and other leading companies.

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 development of new products, technologies and innovations.



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# RQ INDUSTRY NEWS

The latest in technology, innovation and sustainability across world industries

## Focus turns to batteries

Global automakers are moving fast to secure battery manufacturing capacity to cope with the expected sharp rise in sales of electric and hybrid vehicles in the next decade.

The Volkswagen Group, which aims to be a world leader in electric vehicles, has teamed up with Swedish start-up Northvolt and the European Investment Bank to build a large-scale battery plant in northern Sweden, close to the Arctic Circle. The plant, running on fully renewable electricity, will produce 32 GWh of batteries annually – enough for around 640,000 EVs – when it reaches full capacity.

VW has also launched its own in-house production of battery cells and is promoting the European Battery Union to take in all aspects of the battery value chain. Also involved are BMW, Siemens, Scania and ABB.

Volvo, for its part, has signed battery-supply deals with both CATL of China and Korea's LG Chem. It expects half of all its sales to be pure battery-electric vehicles by 2025. Daimler has laid the foundation for a

major battery plant close to its Stuttgart headquarters; the facility will be carbon neutral and be part of a worldwide network of nine factories on three continents.

JP Morgan has analysed the manufacturing costs of a typical 2018 BEV and calculated that 25 percent is accounted for by the battery cells, 15 percent by the electric motor and power electronics, 10 percent for battery integration, and the remaining 50 percent for non-powertrain costs. And MIT and Toyota are using machine learning to predict the lifespan of different battery

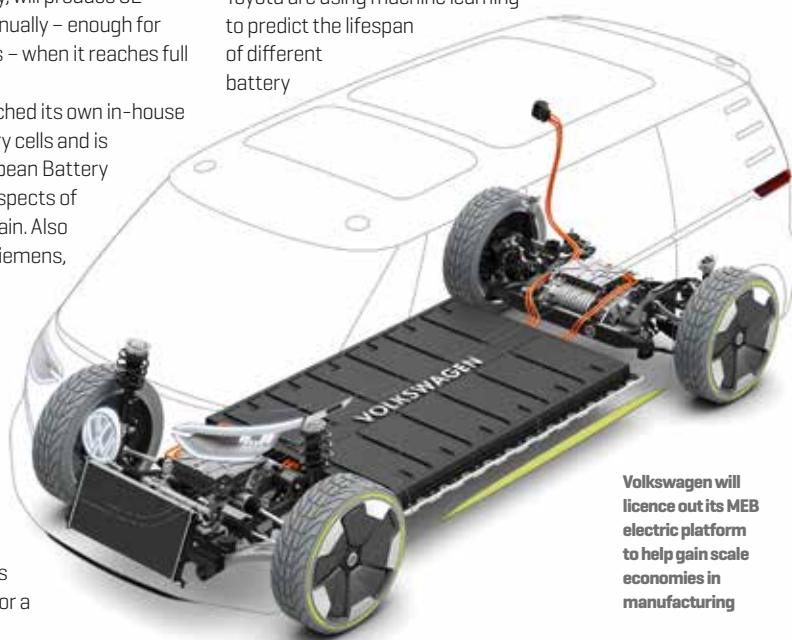
types – including the effects of fast charging in 10 minutes.

Fisker, which has investment from Caterpillar, has further postponed the launch of its solid-state battery to 2022, while Piech's Mark Zero concept car, displayed at the Geneva motor show, has a new type of battery cell which is claimed to provide 80 percent recharging in under five minutes.

### Hydrogen steps up

Hyundai is positioning itself as a global leader in hydrogen fuel cell development and is inviting other automakers to buy its complete hydrogen powertrain, as used in the NEXO flagship model. This parallels Volkswagen's offer to share its MEB platform [pictured], and Toyota's opening up of its hybrid and fuel-cell patents for broader use. Promoting the hydrogen cause, Hyundai has also launched a joint venture to build up a fuelling ecosystem in Europe and is embarking on a pilot project in Korea to supply power to some 2200 homes using 1 MW container-sized modules employing NEXO fuel cell stacks.

Toyota, meanwhile, has developed the SimpleFuel hydrogen filling station for use within its Motomachi plant; each station uses solar power from the factory roof to generate enough hydrogen to power seven or eight forklift trucks for a whole day.



Volkswagen will licence out its MEB electric platform to help gain scale economies in manufacturing

## Citroën reshapes its future

To celebrate its centenary this year, Citroën is presenting a concept car that it hopes will serve as a "brand manifesto" for the future and reaffirm the company's reputation for innovation in the same way as the DS did in 1955. The 19\_19 Concept's suspended capsule fuselage is said to be inspired by aviation, and its interior by the world of furniture design. The fully electric powertrain, with a claimed range of 800 km, is housed in a skateboard-like chassis below, its suspension and components visible from the exterior. Riding on skinny 30-inch wheels and promising minimal noise and vibration, the 19\_19 offers a "mental detox" for its occupants. Unlike its DS forebear, however, it is not ready for production. "The 19\_19 Concept is our technological and innovative vision of the automotive future," said Linda Jackson, CEO of Citroën.





## Ferrari's sign of the times

Created to salute the 90th anniversary of the founding of Scuderia Ferrari, the SF90 Stradale marks a paradigm shift in the company's top-end supercar thinking. It is the first eight-cylinder model to serve as Ferrari's flagship, with a plug-in hybrid drivetrain packing 220 hp of electric power and a turbo gasoline engine of 780 hp; it is the first with four-wheel drive, two motors on the front axle giving it torque vectoring capability; and its eight-speed DCT transmission has no reverse gear: that function is exclusively electric.

Four powertrain modes include eDrive and 'qualify', which prioritises absolute

performance over battery recharging; the battery, of unspecified capacity, gives a 25 km zero-emission range as well as an electric top speed of 135 km/h. Ferrari says the kerb weight has been kept to 1570 kg, despite the extra 270 kg for the hybrid system.

Sweden's Koenigsegg has already sold all 125 planned examples of its new Jesko supercar. The reworked V8 engine gives 1280 hp on gasoline or 1600 on E85 fuel, and its innovative transmission has nine ratios and no fewer than seven clutches, enabling it to make skip-shifts as well as normal sequential changes.

## Vienna fires up combustion prospects

Against a generally accepted background of climate neutrality by 2050, this year's Vienna Motor Symposium nevertheless delivered encouraging messages for the future of the combustion engine. Market leader Volkswagen's eighth-generation Golf, due this summer, will major on 48-volt mild hybrid electrification of gasoline engines, providing a fuel saving of 0.4 l/100 km, and sister brand Audi presented a new 3.0 litre V6 diesel with a 48-volt electric supercharger to complement its turbocharger. And Hyundai announced a new 2.2 litre four-cylinder diesel using 2200-bar injectors and both high- and low-pressure EGR. Due next year, the engine will meet Euro 6d norms.

## Audi's city concept

Audi chose April's Shanghai auto show to present the third of its so-called use-case electric concept vehicles, appropriately enough aimed at mobility within the restricted confines of a congested megacity. The AI:ME, standing for Audi Intelligent, me, is a 4.3 metre compact city car capable of Level 4 autonomy, with a flexible interior configuration based around two armchair-like seats in the front and a curving bench for several more passengers in the rear. The 125 kW motor drives the rear wheels and the 65 kWh battery is claimed to offer 'long periods of operation' in the 20-70 km/h traffic that is expected to be the AI:ME's

main habitat. Among the design's other novelties, which could be a sign of things to come in future vehicles, are retracting controls, 3D monitors, VR goggles for all occupants, magnetic cup and plate holders for onboard dining, a concert hall quality audio system with external noise cancelling, and even an onboard garden stocked with plants to help improve internal air quality.



## NEWS IN BRIEF

Highlighting the latest thinking in automotive engineering and technology worldwide

### Premium EV co-operation

Jaguar Land Rover is to join forces with Germany's BMW to help bring down the costs of electric vehicle hardware. The two organizations will also pool elements of their research and development and purchasing activities. BMW is four times the size of its UK-based competitor.

### London slows down to 15

The City of London, the financial district of the British capital, is considering imposing a speed limit of 15 mph, or just under 25 km/h. Certain streets may be closed to traffic in the middle of the day, too. Though car numbers in the City's narrow streets have halved, average vehicles speeds are below 16 km/h and air quality is poor.

### Toyota enters space race

JAXA, Japan's space agency, is teaming up with Toyota to explore designs for a moon rover. The pressurized vehicle will be powered by fuel cells and expects to be able to cover 10,000 km on its store of hydrogen.

### EV margins to match standard cars' by 2025, says Volvo

Volvo, which is spending \$1 bn a year to bring five EVs to market, is confident of the business case for electrification. Speaking to *Automotive News Europe*, CEO Håkan Samuelsson said he expected profit margins on EVs would equal to those on hybrid models by 2025. By then, half of Volvo's sales will be pure electric.

### Degradable bioplastic

Researchers at Lithuania's Kaunas University have developed a biodegradable bioplastic which will compost completely within two years. The transparent cellulose material is derived from timber and is initially designed to replace the non-degradable foils used on food packaging.

### Amazon and VW in cloud venture

Volkswagen and Amazon are to launch the Volkswagen Industrial Cloud as a key step in moving to industry 4.0 processes. The cloud will house data from all the machines, plants, systems and facilities across the VW Group, and in the longer term, members of the organization's supply chain will be brought in too.

### 500-bar GDI cuts particulate emissions

Presenting its new 500-bar gasoline direct injection system at the Vienna Motor Symposium in May, supplier Delphi claimed the higher pressures would reduce raw PM emissions by 50 percent compared with today's state-of-the-art 350-bar systems. The system will appear in production models from 2022.

# Heavy vehicles go green

Truck and construction industry trade fairs this spring have brought a spate of announcements relating to zero- and low-emission machinery, ranging from power modules to complete excavators and from 70-passenger buses to compact eight-seater people carriers.

Volvo CE, which began showing battery-powered machine concepts some years ago, has expanded its zero-emission range with a compact wheel loader (pictured) and a mini-excavator. Each can run for eight hours on a full charge and dedicated e-motors for drivetrain and hydraulic pump functions improve efficiency. Significantly, Volvo CE says it will discontinue diesel engine development for this type of machine.

John Deere, a major player in the off-highway sector, is launching a range of electric drives for off-highway applications, including e-motor and electric pump drives. The units are scalable up to 200 kW. AxleTech has presented its AFE series electric axle and Deutz has countered with a range of modular products which allow operators to specify the combination of diesel, gas, hydrogen or electrification that is best for their requirements. Deutz is collaborating with Japanese manufacturer Kobelco on a mini-excavator concept using these technologies.

Allison now has a range of electric propulsion hardware for commercial vehicles and is collaborating with leading bus maker Alexander Dennis on low-floor applications. Still in the bus sector, Hyundai has shown an all-electric double-decker seating 70, including two wheelchair positions and

ramps on the lower deck. With a 348 kWh battery it can run for 300 km and has a claimed recharge time of 72 minutes.

At the opposite end of the scale is Ford's new line-up of electrified light commercials. The ubiquitous Transit will be available from 2021 as a full electric or plug-in series hybrid, with a three-cylinder gasoline engine as a range extender to top up the 13.6 kWh battery. Drive is exclusively via the e-motor to the front wheels. The same powertrain is available in the Tourneo Custom people carrier, and Ford has for some while been building a version of the German StreetScooter electric light van (developed by RWTH Aachen for Deutsche Post DHL) aimed at the last-mile delivery sector.



Battery power is reaching off-highway equipment such as Volvo's wheel loaders and excavators, but buses still lead the electrification movement

## Renewables slow down

Investment in new renewable energy generation has fallen for the second year in a row, despite record levels of CO<sub>2</sub> in the atmosphere and shareholder pressure on fossil fuel companies to disclose their plans to meet the goals of the Paris Climate agreement.

The bulk of the 2.3 percent increase in

overall global energy demand was met by new fossil fuel investment, with gas extraction spending up by 3.7 percent and coal mining by 2.6 percent. The figures, published by the International Energy Agency, also show that the burning of coal was responsible for one-third of the increase in global CO<sub>2</sub> emissions

between 2017 and 2018.

Analysis of the renewable capacity added in 2018 shows a quickening trend towards solar photovoltaic generation. Of the 177 GW installed during the year, 55 percent were solar, 30 percent wind and the remainder in technologies such as hydropower.

## Automakers face huge fines

New European corporate average CO<sub>2</sub> emissions rules coming into force in 2021 will severely penalize automakers whose ranges emit more than their allocated targets.

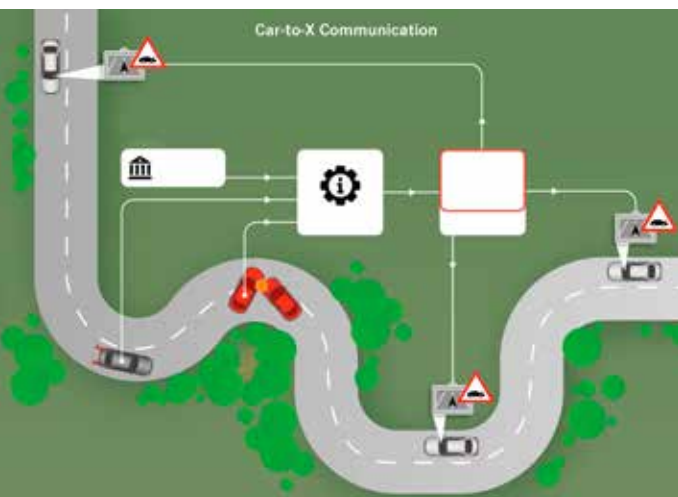
The target across the whole industry is 95 g/km but each producer has an individual figure that takes into account the weight of its models. For every gramme of CO<sub>2</sub> above the new target, the automaker pays a fine of €95, multiplied by the number of cars sold that year. During the phase-in period, manufacturers will be able to discount the most pollutive 5 percent of their sales. Even so, multi-billion euro fines are in prospect for some groups.

CEOs face the dilemma of whether to drop high-emitting models, pay the fines, or invest in new technology to curb CO<sub>2</sub> output. Another tactic is to team up with a producer with a low emissions profile – as Fiat Chrysler has done with Tesla.



Porsche's 75 percent cut in emissions since 2014 will not be enough to help parent company Volkswagen avoid hefty fines





## Networking for safety

Vehicles that warn each other of hazards on the road have long been a subject for discussion among safety experts. Now a new European research project is going a step further and testing out Car-to-X communication, where vehicles are networked with the road infrastructure and navigation services.

Daimler, BMW, Volvo and Ford, along with navigation providers TomTom and HERE, will develop communication protocols that allow warning messages to reach large numbers of users in real time. The technology will build on existing systems such as the Europe-wide eCall and other systems which trigger alerts when hazard warning lights are activated. Other hazards such as mobile road works or icy roads could be broadcast, too.

Mercedes-Benz cars, as well as Volvos in Sweden and Norway, already share information of this type, but a major task for the project will be to navigate Europe's complex rules on data protection and individual anonymity.

## Industry faces net-zero future

**Leaders of Europe's largest industry groups have been vying with one another to endorse the 2015 Paris Climate Agreement and offer promises of a sustainable future and a route towards net-zero emissions of greenhouse gases.**

**The Volkswagen Group, promoting its multi-billion euro electrification offensive, has even gone to the length of announcing its last combustion engine programme, set for 2026, and undertaking to make its entire production network carbon neutral by 2050.**

**Leading supplier Bosch has decided to go one better, aiming for climate neutrality across its 400-plus locations worldwide as early as 2020. This will make it the first large automotive business to achieve this goal.**

**Daimler's Ambition2039 will see the Mercedes-Benz new car fleet become completely carbon neutral over the next 20 years, representing three model generations. Its European production will hit neutrality as soon as 2022, and new CEO Ola Kallenius will link management remuneration to the company's emissions performance.**

**Most of the major players are already exerting pressure on their suppliers to cut or eliminate GHG emissions, and help may be at hand from a Swedish project, Hybrit, which has developed a CO<sub>2</sub>-free value chain for steel production. Even cement and concrete, long seen as the most intractable heavy emitters of GHGs, could take steps towards CO<sub>2</sub> reductions, according to a group of researchers at Swiss universities.**

# VIEWPOINT

## Compostable bioplastics can cut pollution and benefit the economy

**Jamie Pitcairn** – technical director, Ricardo Energy & Environment



There can be no doubt that society worldwide is beginning to wake up to the challenge of managing plastic waste. Plastics have revolutionised the modern world, bringing lower-cost products and enabling foodstuffs to be packaged in a manner that maintains freshness, thus reducing waste in both the supply chain and in the consumer's home.

But as David Attenborough has shown to the world's TV viewers, waste plastic packaging is finding its way into every part of every ocean. And as if to validate this view in perhaps the most extreme of possible locations, a plastic bag was even reportedly found by Victor Vescovo during his record-breaking 10,900 metre submarine dive to the bottom of the Pacific Ocean's Mariana Trench, the deepest point in the world, in April this year.

While the negative effects of such plastic pollution are bad enough, it also represents a significant economic waste. According to the Ellen MacArthur Foundation, most plastic packaging is used only once as a single-use item, and 95 percent of the value of this material is lost to the economy annually, representing a staggering US\$ 80-120 billion globally.

In response to the environmental harm caused by plastic pollution, the UK government is taking a fundamental look at its regulations and policies relating to plastic packaging. In addition, the UK Plastics Pact – a cross-industry collaboration across the entire packaging supply chain – includes the targets that 100 percent of packaging should be recyclable, compostable or reusable, and that no more than 30 percent should go to waste by 2025.

This is a perspective and an initiative that I and my team at Ricardo wholeheartedly agree with. Compostable bio-based plastics offer potential for a more sustainable alternative to petroleum-based counterparts which are more persistent in the environment – particularly for applications such as food packaging. In our recently published report *Plastics in the Bioeconomy*, which we produced on behalf of the Biomass Biorefinery Network, we have found that there is the potential for a tenfold increase in the UK compostable

packaging market. There is a demonstrable need for this material to substitute for petroleum-based plastics, especially for applications in which food waste might otherwise be trapped and hence contaminate the residual plastics recycling stream. Compostable packaging would actually help capture the food waste attached to packaging – think about the film covering ready meals – which would ordinarily contaminate conventional plastic packaging and end up in landfill, causing further emissions of greenhouse gases through methane production. In our analysis, we demonstrate the positive

## Compostable packaging would actually help capture food waste which would otherwise contaminate plastic and divert it to landfill

economic impact that a transition to compostable bioplastics for food packaging could deliver for the UK market. By 2025 the net annual benefit to the UK bioeconomy of a transition to compostable plastic packaging would be in excess of £267 million through biopolymer material sales alone. Additionally, there would be wider economic benefits to be realised through cost reductions in the collection and processing of hard-to-recycle plastics that have been substituted with bioplastics, particularly those that are heavily contaminated with food waste or comprised of multi-layer plastics.

Such a transition would, of course, require investment in infrastructure, a new value chain of crop residue-derived polymers, and the crucial public education needed to drive the behavioural change that will facilitate appropriate segregation and effective collection of compostable wastes and other recyclates. As our report shows, however, there are significant sustainability and economic benefits to be had, as well as a reduction in the tonnage of persistent plastic wastes reaching the world's natural environment and oceans.



# Designs on an electric future

Freshly listed on the London Stock Exchange, Aston Martin is branching out from its globally celebrated front-engined GT sports car portfolio and adding top-flight mid-engined hypercars as well as SUVs and its all-electric super-luxury Lagonda brand. **Tony Lewin** asks chief creative officer **Marek Reichman** how the transformation will unfold



**You are in charge of three brands – Aston Martin's familiar GT models, its new mid-engined supercar range, and Lagonda as the all-electric nameplate. Which is the most exciting to you as a designer?**

They all feel very different, particularly because of the direction of Lagonda. This gives you more of a global relevance as a designer, and this year, for example, in Shanghai we showed AM-RB 003, some of our core cars – DBS Superleggera and Vantage – and the Lagonda All-Terrain Concept. We also launched Rapide E there. Of course, there was excitement around AM-RB 003, but the focus was Rapide E and Lagonda because of the electrification in China. Which is the most exciting? As a designer, I'd have to say Lagonda: it's the biggest change the industry will see.

**An exciting task, or an exciting product?**

If I look at the rear mid-engined cars, it's exciting because they are the ultimate in performance and Valkyrie provides the DNA and the link [to everything else]. I can't think of two more disconnected yet connected products than Valkyrie and the Lagonda All-Terrain Concept. Yet if I think of what they both need, it is efficiency: in a battery vehicle the enemy is mass and

poor aerodynamics, and its visual offering is so different. The Valkyrie is all about efficiencies, too, so we transfer the learning from one product into our others. The core of Aston Martin is at a brilliant inflection point: the next generation of our traditional GT cars will change. It's a brilliant point to be a designer: we're seeing electrification, the move to zero emissions, more and more cities talking about no-go zones, and all the talk about autonomy, geofencing, connectivity, cyber – they all bring a different offering and therefore a different visual language. Because if I'm offering Level 5 autonomy, why do I need a windscreen? Glass is heavy. And why do I need headlamps? After all, there's talk of dark factories where robots work without lights because they would waste electricity.

**How does this challenge the design process?**

As a designer, this is the best place to be – and the image of a cello and a robot illustrates it. This is the world as I see it: the cello we can't lose because it symbolises emotion and will continue to create emotion; but the robot is an inevitability. [The challenge] is finding how to continue the emotion when we have an autonomous world.

**How are electrification and composite structures changing your designs?**

Nobody has yet taken full advantage of the benefits of electrification from a packaging perspective, but we will [soon] see products that do it. It's absolutely brilliant because the weight and the power can sit at almost the wheel-centre height: all your batteries and motors can sit at or below this height, which means you have a very low centre of gravity, which is good for the dynamics of the vehicle. It also means that you have a skateboard [chassis] that you can apply a language on top of: it kind of goes back to earlier times when you had an individual chassis and people put the body on top. The advantage is that you can offer unique forms that still meet that golden proportion but which have a different bias. You are giving the consumer something that is very different inside, and carbon allows you more freedom in the form factor – and exposing it [as structure] as we do on the Valkyrie.

## The portfolio

### Aston Martin

Vantage	Potent V8-engined two-seater sportscar
DB11	V8 powered GT
DBS Superleggera	V12 Super-GT
Rapide S and E	Four-door coupé, now also with electric power
DBX	Elegant SUV, launches late 2019
Vanquish	Mid-engined Ferrari rival, due 2022
AM-RB 003	Mid-engined, more extreme, due 2021
Valkyrie	Road-legal V12 racer with Red Bull F1 DNA

### Lagonda

All-Terrain Concept	First über-luxury electric SUV, due early 2020s
Vision Concept	Introduced new Lagonda design language, launch plans unknown



**When the [production] Lagonda appears, will it be a shock? Can it have different proportions thanks to the skateboard chassis?**

Yes, almost anything is possible. Obviously you still have to meet the on-road standards such as crash and side-pole [impact]. I believe some of those standards may change as we get closer to autonomy: cars won't crash, they won't hit pedestrians, which means we can save weight and be more efficient. Yes, we will see some very radical things happen because of the Lagonda brand.

**Are luxury customers open to such radical change?**

Some are, some aren't. What we have said is that Lagonda is not pitched at the traditional luxury customer: there are only two brands in that space at the moment - Bentley and Rolls-Royce. Those are traditional customers, and I can't imagine a Silicon Valley entrepreneur or a Shanghai tech entrepreneur driving round in a [Rolls-Royce] Phantom. But I can see them in a Lagonda. It's a different luxury customer. But what always happens is that you eventually flip the traditional luxury customer so that becomes the norm in luxury. We're in a strong position because our two competitors are not going to get to an electric platform in the timeframe that we can.

**Some of your new sports cars make use of flexible body surfaces to improve aerodynamics. Do you see their use spreading into larger-volume vehicles?**

Yes, we are using them on our special models. The great benefit of specials is that they are relatively short timeframe cars - their development cycle is on average a year faster than our core products. The lower production volumes mean that we can introduce new technologies that will then filter down to the core [models]. For us the core is circa 6500 cars, so it's still not a mass market product - but it is a way to develop new ideas and test the supply chain. So yes, we will see that idea spreading downwards.

**Will you need to distinguish electric vehicles visually?**

The shapes will speak for themselves. There are some unique features: if we look at grilles, those on Lagondas are not so traditional. With the GT cars and the DBX [upcoming SUV] the grilles come from the tradition of the grille being the radiator for cooling, and thus the face of the car; the mid-engined cars are different as they don't have radiators there. The whole point of Lagonda is not to have a traditional grille - it's to design around the attributes needed, the fact that you want something that's efficient through the air, that doesn't disturb the air, and you need a low centre of gravity, a low CdA so it's



**“It’s a brilliant point to be a designer: we’re seeing electrification, the move to zero emissions, more and more cities talking about no-go zones, and all the talk about autonomy, geofencing, connectivity, cyber – and they all bring a different offering and therefore a different visual language”**

Diversification: Aston Martin's display at the 2019 Geneva motor show presented four all-new models





Aston Martin DBX, shown here in camouflage wrap, brings the company into the booming SUV segment. It will be fully revealed at the end of this year

slippery and has good battery life. If you think of downhill speed skiers and even cyclists, with their aero suits and blended-in helmets, they wouldn't look right without them. Electrification needs to have that element of efficiency showing through its [design] language.

**Are you where you want to be in terms of electric technology?**

Yes, we are. We understand our IP and what we would need to do in house and what we need to buy in as a technology. It's the same as with engines now: we have our own V12, we buy in a V8 from Daimler, and we will have our own V6. Because of our size it's a question of what becomes [our] IP and what we can just buy in. We are never going to make our own [battery] cells, but we may pack them ourselves because that could be part of the structure. Rapide E accelerates the curve, but we haven't selected cell supplier or the battery supplier yet. The great thing is that we're independent: we have access to Daimler's technology but we're not obliged to use it.

**In the face of increasing automation and autonomy, how can you preserve the thrill of driving?**

The hardcore car is the one where you receive feedback, the one which you drive, you feel the road; this might be the Vantage, and it might be the Vanquish Vision Concept in the future. You're in control of everything, but legislation in the future might determine that you have to have certain things – in hardcore cars you have to be able to turn that off. Now GTs might show more of a crossover with that true feeling, but remaining sporting. With GTs you may not want that interaction all the time; you may want to relax, or say 'hey, drive me' part of the time. Über-luxury becomes Lagonda, and Lagonda is always saying 'drive me'. It is more about the inside, and the feeling of being driven in your capsule – that's how we spread the difference between our brands.

**How will interiors change? Does autonomy give you more freedom?**

Yes, it does. There will be more flexibility. The tradition is always the tradition, and when it comes to Aston Martin, for as long as it possibly can be, it will be all about your driving position, the A-pillar, the view out, the steering wheel and what you see. But with Lagonda it will be less so, and in the concepts we've shown, when they are in autonomous mode the seats swivel and the steering wheel disappears. I think we'll see more and more of that, and one of the other advances we'll see more of in interiors is in the 3D manufacturing of parts. No longer are you making a substrate and trimming it or moulding or machining something, you're actually printing the part. It's starting on small volumes, but it will grow.

**What is the minimum acceptable range for an electric luxury car like the Lagonda?**

There are two elements here: what research with consumers says they think is a reasonable range, and our own findings. I think for Lagonda we've got to be talking circa 400 miles range, to allow the owner to drive from London to Edinburgh for instance. And in that luxury space we know that the average journey is 15 miles [25 km] per day. Sometimes there is a spike, perhaps as they travel from one estate to another, but we know the average is less than 20 miles a day. So we will provide two battery solutions for exactly that. ☑

**Marek Reichman, Aston Martin Lagonda vice president and chief creative officer**

Born in 1966, Reichman graduated in industrial design and began his design career with Rover in 1991, moving to BMW Designworks in California in 1995, where he worked on the third-generation Range Rover and Rolls-Royce Phantom. Following a spell with Ford's Lincoln and Mercury brands he joined Aston Martin in 2005, shaping a new identity for the sports cars, establishing a style for Lagonda and developing a new range of mid-engined supercars as well as DBX, Aston Martin's first SUV.

## Aston Martin Lagonda

Aston Martin Lagonda is the world's only independent luxury car group and it floated on the London Stock Exchange in October 2018. Aston Martin's powerful sports cars are best known as James Bond's preferred transport, and the company has built a second factory in Wales to expand into SUVs (the DBX) and to revive Lagonda as the world's first all-electric luxury marque. In 2018 the group sold some 6500 vehicles, 26 percent up on the prior year.





# On track for carbon-free rail traction

With the world now focused on the need to reduce carbon emissions and improve sustainability, railways around the globe are busy devising smarter approaches to electrification. **Anthony Smith** explains how these new developments can also tackle the parallel issues of air quality and noise



Rail electrification has long been seen as a means of improving the energy efficiency of passenger train propulsion in relation to the alternative of diesel traction; more recently, it has come into favour as a means of removing air pollution at point of use.

These benefits make it easy to see why this form of traction is favoured: on a like-for-like basis, electric trains are lighter in weight, accelerate more quickly, have lower maintenance costs and consume less energy than diesels.

Moreover, electric traction also benefits from the ongoing efforts to decarbonize grid power generation. In the UK, for example, this improvement has been significant. Coal-based power generation, once the predominant source of energy for the power grid, has been dramatically scaled back in favour of renewables such as wind energy and solar. As a result, by 2018 the average carbon intensity of the electricity supply in mainland Great Britain had fallen to just 270 g/kWh CO<sub>2</sub>e –

approximately half the prevailing level at the start of the decade. In fact, the first week of May 2019 saw the country reach the milestone of its first week without coal-generated electricity since the 1880s.

But while electrification may have distinct benefits once in place, it is far from a low-cost option in terms of upfront capital investment. Installation and commissioning costs vary widely depending on many factors, not least the need to accommodate overhead catenary systems into legacy infrastructure such as overbridges and tunnels. Where height is restricted, the additional cost of lowering the track bed and its foundations to accommodate the increased headroom requirement – or rebuilding those structures completely – can be significant and may also incur financial penalties for line closures during reconstruction.

In the UK there has also been something of a feast or famine approach to electrification strategy over the past

50 years: the length of track completed per year has varied from zero to in excess of 800 single-track kilometres (stk). This compares with an almost constant 200 stk per year in Germany over a similar period. This unpredictability is widely thought to have exacerbated the situation, requiring supply chains to be reconfigured for each major new electrification project. This combination of factors results in a current UK cost of approximately £2.5 million per single track kilometre for electrification as opposed to around £1 million per stk for other major European networks.

## Pragmatic and smarter electrification

Yet while significant efforts are being made to reduce installation costs, it is almost inevitable that most mixed networks of urban, intercity and rural routes will include regions for which the case for conventional overhead

The solar roof of London's refurbished Blackfriars Station (above). Renewable energy can provide a valuable means of augmenting power supplies in areas where the grid is restricted (see p14)

electrification cannot be made.

In these circumstances, argues Jon Brown, UK business development manager for Ricardo Rail, a smarter and more pragmatic approach is required: “A key challenge for the rail industry internationally is to look at how we can accommodate gaps in electrification while still maximizing the proportion of electric traction. This might be anything from short section-gaps in overhead line through bridges or tunnels to avoid the costs of reconstruction, to longer sections that remain non-electrified.”

The rationale for allowing such longer gaps in electrification can be varied. As examples, it might be for aesthetic considerations around installing a catenary system for a light rail or tram system in a historic city centre, or it could be the lack of commercial justification for the investment required for a rural route with lower traffic volumes and load factors.

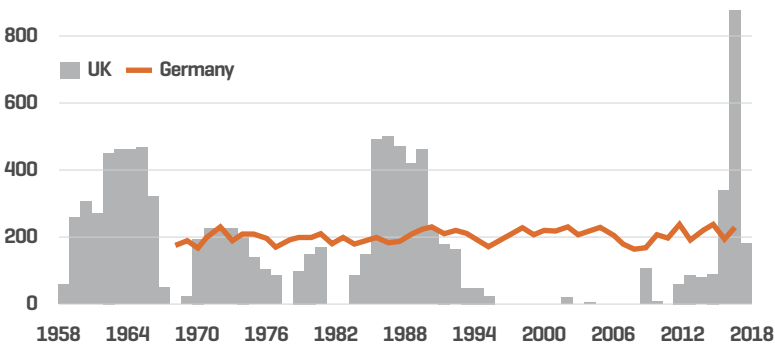
“Either way,” continues Brown, “the key enabling technologies for maintaining zero emissions at point of use are those of on-board energy storage and range extenders: these allow electric trains to operate beyond the reach of catenaries.”

Route diagrams for Options 1-3 (below table) showing in red the extent of line beyond the reach of battery operation. Option 3, comprising a total partial catenary length of 10.5 km or 4 percent of the seven routes served, enables full battery train operation

Developing zero emissions rail in the Netherlands

The Ricardo Rail team based in Utrecht was asked to investigate exactly this approach to electrification of the Dutch rail network by the northern Netherlands provinces of Fryslân and Groningen, explains Ricardo sustainability consultant, Martijn Wolf.

New electrification – single track kilometres



“There is a strong regional imperative to reduce emissions, with the provinces having taken the political decision to aim for zero emissions public transport – both in terms of point of use and generation of the energy used – by 2025. This is quite an ambitious target that cuts across both buses and trains,” he says.

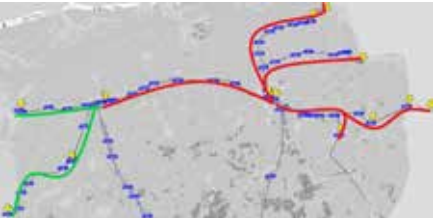
“The region is unusual in that its rail lines are part of only 5 percent of the Dutch network that remains unelectrified,” continues Wolf, “but we had previously conducted a study that demonstrated that full conventional electrification of the lines in this region was not cost-effective due to the comparatively light load factors



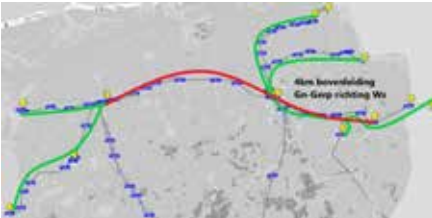
Predicted depth of discharge of on-board batteries based on three recharging scenarios

Routes modelled	Option 1 – station-based recharging only		Option 2 – additional 4 km partial catenary		Option 3 – additional 4 + 6.5 km partial catenaries	
	[kWh]	[%]	[kWh]	[%]	[kWh]	[%]
Leeuwarden – Harlingen Haven	296	30	180	57	180	57
Leeuwarden – Stavoren	115	73	115	73	115	73
Leeuwarden – Sneek	329	22	252	40	252	40
Leeuwarden – Winschoten	-38	109	157	63	157	63
Leeuwarden – Groningen Europapark	-623	248	95	77	116	72
Delfzijl – Veendam	-858	304	166	60	166	60
Eemshaven – Leer	-145	135	87	79	87	79
Leeuwarden – Groningen Europapark (Snelrein)	-3556	947	-722	272	129	69

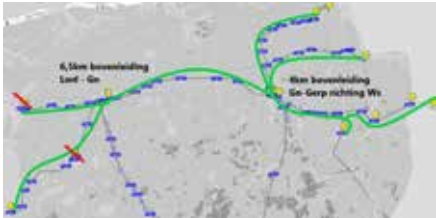
Option 1



Option 2



Option 3







**“A key challenge for the rail industry internationally is to look at how we can accommodate gaps in electrification while still maximizing the proportion of electric traction”**

**Jon Brown, Ricardo Rail UK business development manager**

and train frequencies. From the outset of this study, therefore, we needed to explore alternative approaches.”

The study, which was carried out in collaboration with infrastructure consultancy Arcadis, focused in particular on evaluating different options for range-extender solutions based on hydrogen fuel cells used in the form of a hybrid propulsion system, or for partial catenaries in combination with higher capacity on-board battery energy storage. With recent improvements and the reduced cost of battery systems, the latter was clearly identified as the more attractive solution.

Initially, a proposal was considered to use charging points at station stops, in a similar manner to some battery-operated bus networks. However, as Wolf recalls, there were challenges in this approach: “A train has a much higher charging requirement than that of a bus, due to its size and weight. Using the type of discrete charging points that are available for commercial buses would have been impractical due to the positioning of stations and the length of time that would be required for recharging. Instead, we looked into the options for partial electrification.”

### Station-based ‘opportunity’ charging

The team modelled a range of scenarios combining station-based recharging with partial electrification. In the partial electrification zones, trains use the overhead line for both their immediate tractive power needs as well as for battery recharging. This is augmented in the non-electrified sections with station-based recharging points similar to those used for battery bus networks.

The simulation of daily train usage was based on a standard reference train representing a Stadler GTW 2/6 articulated rail car, typical of the worst case (in terms of its likely energy storage requirement) of rolling stock used on the lines in the region. In order to test the feasibility of running battery trains using only station-based opportunity charging, the team calculated the required battery capacity per route to run the specified timetable, including an allowance for the weight of the installed pack. This required fitment of a 535 kWh pack, based on the specified end of life capacity of 420 kWh. Charging was assumed to be carried out at a maximum rate of 4C, meaning that a full recharge cycle could be carried out in a minimum of 15 minutes. To accommodate this high charging rate the team viewed LTO (lithium titanate) as the most effective cell chemistry, a type that the rail industry in general seems to be converging upon. Despite their high cost in comparison with other cells, LTO batteries provide high C rate charging capacity, high power transfer and very long cycle lives which, coupled with exceptional safety characteristics, provides an attractive business case for rail.

“The initial scenario we assessed revolved around solely station-based recharging without any electrification beyond the existing network,” explains Wolf. “However, the analysis of this mode of operation showed that the trains’ on-

board batteries would be fully depleted on all but three of the seven routes modelled, so some level of additional power supply for recharging would be required.”

### Addition of partial catenary

In a second scenario, the same seven routes were assessed with the inclusion of a 4 km length of overhead electrification – representing approximately 1.5 percent of the non-electrified network covered by the seven routes. Current would be collected via a pantograph sized to accommodate the requirements of 4C battery recharging in addition to immediate traction power needs of the vehicle. The results of this intermediate scenario indicated that the use of the battery-equipped train would be sufficient for all the timetable requirements with the exception of an express service between Groningen and Leeuwarden.

In a further optimized scenario, the length of partial catenary was extended by a further 6.5 km – representing a total of 10.5 km or approximately 4 percent of the network covered by the seven routes. “This final scenario demonstrated sufficient capacity to operate the entire timetable,” concludes Wolf. “Moreover, through the inclusion of this additional length of overhead line, the simulation showed that two station-based recharging facilities could be deleted, thus mitigating part of the infrastructure investment required.”

On the south of England 750V DC network, Ricardo is exploring the use of its IGNITE software to investigate power-restricted pinch points and make more effective use of regenerative braking







**Station air quality can be problematic where topology is challenging, such as Birmingham's New Street (above), where the platforms are situated beneath a major shopping centre and are used by many diesel-operated cross-country services**

In addition to the assessment of zero-emissions solutions based on partial catenary and station-based opportunity charging, the Ricardo-Arcadis team also assessed options for hydrogen fuel cell propulsion using a battery-hybrid powertrain solution. Armed with the information generated from the study, the provinces of Fryslân and Groningen and the regional rail operator Arriva can now make an informed choice about the possible roll-out of a battery-powered fleet, with greater insight into the costs and the modifications required to trains and infrastructure.

### Optimizing the power supply

High-voltage overhead AC electrification systems such as the 25 kV standard used in Great Britain have a high transmission efficiency. The use of regenerative braking processes can therefore be highly effective within these systems as a vehicle returning energy back into the overhead line as it brakes can be geographically remote from another vehicle drawing power for traction.

However, this is not the case for the 750 V DC third-rail electrified routes of London and the South of England, as John Brown explains: "The voltage fall-off on DC systems restricts the usefulness of regenerative braking where energy is fed back into the track. Typically, such energy that is regenerated in braking will have a useful range of around 1.5 km on this type of third-rail system; beyond this, DC voltage drop means that it is merely dissipated and lost."

Even more crucially for operational efficiency, many traffic pinch points on the third-rail network are restricted by electrical capacity rather than by signalling. This is particularly the case at busy stations or complex junctions where multiple trains might be accelerating simultaneously. "To address this issue and see how we can perhaps co-ordinate

local scheduling to gain more effective use of the available capacity, we are exploring the modelling of power flows at such pinch points," he continues. "To do this we're using the Ricardo IGNITE software – a physics-based package developed for complete system modelling and simulation of complex systems that has been successfully used in both automotive and water industry applications. This may well provide opportunities to alleviate some of the challenges presented by power-restricted pinch points, while also making more effective use of regenerative braking on this type of DC network."

### Incorporating renewable energy

Elsewhere on the UK rail network, Ricardo is assisting in the Green Valley Lines project to incorporate community renewable energy schemes into the proposed smart electrification of the commuter lines running to and from the Welsh capital, Cardiff. Aside from its benefits in reducing the carbon intensity of rail traction, this approach can be particularly attractive in areas where the power grid is restricted and would otherwise require significant upgrades to supply such electrification schemes.

Working with infrastructure owner Network Rail and the Energy Saving Trust, the Ricardo team is identifying potential sites to install community-owned solar, wind or hydroelectric generators next to railway lines in the region. These sites would directly supply the new overhead lines with low-cost, low-carbon electricity, at the same time providing financial benefits to local communities who would own the generators. The study is also scoping technical solutions for directly connecting renewables to overhead electrified lines and analysing how best to integrate new energy storage technologies to help keep

electrification costs down.

Elsewhere, Ricardo is also collaborating on a research project to incorporate local solar PV generation capacity into the electrical distribution system of the DC third-rail network south of London. In this case the objective is both to provide a source of geographically distributed demand to match local solar farms, while also enabling the railway's own distribution network to act as a shadow grid where connectivity to the main distribution grid is difficult.

### Air quality – the big unspoken issue

Given the patchwork nature of electrification in the UK, a significant and increasing cause for concern is the exposure of passengers and staff at major stations and railway depots to pollution such as diesel exhausts and other particulate emissions in the working environment.

In 2012 the World Health Organization's International Agency for Research on Cancer (IARC) re-classified diesel exhaust emissions and related ambient air pollution as carcinogenic and associated with increased mortality from lung cancer. Employers are responsible for managing the risk from exposure to this and other hazardous substances: this applies to both workers and others who might be affected; in the case of railway stations, this means the travelling public. So, station and train operators who have employees working on site have a legal duty, so far as is reasonably practicable, to manage the risks to the health of their employees and passengers resulting from exposure to hazardous substances as specified by the regulations for the Control of Substances Hazardous to Health.

"It might be concluded that the worst incidences of station air quality would be found in major termini served by diesel fleets," explains Brown, "but station



topology can have a very significant impact too.”

He cites the case of Birmingham’s New Street Station, which, despite having overhead electrification as part of the West Coast Main Line network, is also served by numerous cross-country and local services which cover non-electrified lines for at least part of their routes and are hence operated using diesel-powered rolling stock. “Many of these services will change direction at New Street and remain at the platform for an extended period,” he explains. “To compound the situation, the station itself is approached through a cutting and has a major retail development above; as such, it is in effect a large underground station.”

Ricardo’s rail and air quality teams are researching the issue of such pollution hotspots, and are examining potential abatement options for the immediate, medium and longer term. And examination of this issue goes beyond consideration of diesel emissions. In the Netherlands, for example, where diesel usage is comparatively low, discussions are currently focusing on non-exhaust sources of PM2.5 emissions from rail, such as those arising from the wheel/rail interface, the action of pantographs on the overhead contact lines, and from friction-based brakes.

### Hybridization and last-mile zero emissions operation

While partial electrification schemes coupled with battery-equipped trains as modelled by Ricardo in the Netherlands may provide a long-term means of removing diesel exhaust from hotspots such as stations and depots, a more immediate solution is needed in order to alleviate the worst cases within a shorter time horizon. One innovation being actively explored by Ricardo in the UK is that of the hybridization of the existing diesel-powered fleet.

Ricardo is working as part of the

**“The UK has many diesel vehicles on its network. This is an opportunity to show they still have a viable long-term future as hybrids, offering reduced NOx, carbon and noise emissions as well as providing the potential for lower operating costs”**

**Olivier André, Ricardo Rail UK MD of consulting**

HybridFLEX project with UK-based rolling stock owner Porterbrook to provide engineering support with the integration of an MTU hybrid powerpack into a converted Turbostar diesel multiple unit train. This is a first in the UK rail industry. The HybridFLEX concept aims to eliminate diesel operation in built-up areas where there is no electrification of the rail network, through the use of battery operation during the last mile of running in the vicinity of urban areas, as well as during station stops. In addition to reducing diesel emissions in such urban areas, a further benefit will be to significantly reduce noise.

When diesel power is required for propulsion of the train it will be provided by an engine conforming to the latest EU Stage V emissions standards [due to come into force in 2021]. With the on-board batteries capturing the energy usually lost when slowing the train through braking, coupled with a more efficient engine and transmission, the overall CO<sub>2</sub> emissions will be reduced by as much as 25 percent when the train enters service in 2020. The initial trial period should also confirm the higher performance and capability of the hybrid systems compared to the standard variant of the Turbostar train.

Ricardo’s engineering team is performing all the integration engineering and safety assessments of the bare hybrid powerpack provided by MTU for the existing Turbostar train for conversion into the first HybridFLEX vehicle. Ricardo

is also overseeing integration of all the mechanical, electrical and critical control systems, committing teams from its Rail and Automotive divisions to support all the engineering tasks; the teams will also cover the relevant safety, certification and approvals activities to ensure the safe and successful operation of the train during public trials.

“The UK has many diesel vehicles on its network,” explains Olivier André, UK MD of consulting, Ricardo Rail. “This is an opportunity to show they still have a viable long-term future as hybrids, offering reduced NOx, carbon and noise emissions as well as providing the potential for lower operating costs.”

Once the completed trial confirms the expected performance advantages of the hybrid system, Porterbrook will work with existing and future Turbostar customers to evaluate conversion of these fleets to HybridFLEX, accelerating the move away from diesel-only trains in advance of the UK Government’s stated 2040 target.

### Innovation focused, technology neutral

Decarbonizing the railways is clearly a complex challenge for which there are multiple potential technological solutions; each is appropriate to different passenger network types and locations – from light rail, trams and tram-train networks through to high speed intercity trains, and from the highly electrified lines of Europe to the patchwork electrification of the UK. Inextricably linked to this challenge is the requirement to provide a safe working environment for staff and passengers, as well as value for money for fare payers and governments and regions investing in new infrastructure.

As the work of Ricardo in this area is showing, innovations in simulation technologies, power networks, renewable energy, and air-quality monitoring and control can offer significant advantages when considered in parallel with efforts to decarbonize rail travel. This is only half of the rail picture, however, and in a future feature we will consider the emerging opportunities to further reduce the carbon intensity of rail freight operations. 

**The HybridFLEX concept (left) aims to eliminate diesel operation in built-up areas where there is no electrification of the rail network. It does this through the use of battery operation during the last mile of running in the vicinity of urban areas, as well as during station stops**



# Smart, urban – and every inch a BMW

Building on more than a decade of co-operation with BMW Motorrad, Ricardo Motorcycle has partnered with the premium bikemaker to develop a new generation of mid-sized scooters that distil the qualities of the highly successful C650 range of maxi-scooters into a smaller and more accessible format.

**Jesse Crosse** reports on the creative processes behind the new and innovative C400 series scooters aimed at the expanding urban and touring markets



BMW's C650 range of luxury maxi-scooters, co-developed with Ricardo Motorcycle, has been a major critical and commercial success, prompting an initiative to extend the premium concept into the heart of the sector.

However, the global market for smaller scooters in the 400 cc category is already well served by a number of established manufacturers, and to enter it and succeed is a daunting task – even for a company of BMW's stature and standing. Yet, with the help of Ricardo, that is precisely what BMW Motorrad is aiming to do with its new C400 scooters.

The challenge, put simply, was to design and manufacture a scooter that could

not only achieve a competitive price point in this tightly fought market segment, but also gain best-in-class status for refinement, performance, handling and premium design values. For Ricardo, it was to be the most daunting task yet in a relationship with the German motorcycle manufacturer that has already spanned more than a decade.

#### Successful partnership with BMW since 2006

Ricardo first began work on BMW Motorrad products back in 2006 when it took on the upgrade programme for the four-cylinder K1200 superbike engine to produce a new range of K1300

motorcycles to be launched in 2009. The programme drew on Ricardo's extensive resources in Shoreham and Leamington Spa in the UK, Prague in the Czech Republic and Schwäbisch Gmünd in Germany, making for a truly multinational project.

The result was a resounding success and since then the relationship has gone from strength to strength. Ricardo's engineering of the six-cylinder K1600 touring bike engine led to this new BMW earning rave reviews in the motorcycle press. The first luxury maxi-scooters, again developed with substantial Ricardo input, arrived in 2012 and continue to be available as the C650 Sport and C650 GT





- and since 2017 there has also been an electric version, the C Evolution.

### Mid-size market: a logical step

With approximately 30,000 units worldwide annually, the mid-size scooter sector is about two-thirds of the size of the maxi-scooter market, explains BMW's project manager Dr Joerg Reissing. "Yet over the years it has proved very stable, so it was a logical step to downsize our maxi scooters, so we can attract new and different target groups - there is a healthy market demand."

Nevertheless, the pressure was on to produce a premium machine that met

customer expectations for the BMW brand. "This mid-size segment is more competitive, with many more people competing in that space," observes Ricardo's head of motorcycle strategy and business development Paul Etheridge. "The price point is much more competitive too, so the product has got to be the best in its class and it's got to be correctly priced. Overall, it's a lot more challenging to make a successful product in this segment."

"BMW's aim is to expand the offer on the market," adds Ricardo's Massimo Lotti, responsible for the project's styling team. "The big scooter segment is limited, mainly because of the cost comparison with 650 cc motorcycles: a big scooter can

cost substantially more than a Japanese naked 650 cc motorcycle."

Careful thought went into the positioning of the two C400 models, adds Reissing. "Firstly, we wanted an attractive sport version that competes with our competitors' offerings, and secondly we needed a smaller version of our big C650 GT tourer, but in this lower displacement category."

The concept for the C400 was very similar to that of the larger scooter. "So, starting from the same base, we aimed to produce a sport version and a GT version," explains Lotti. These became the C400 X [sport] and C400 GT [touring]. Yet even though the 400 parallels the thinking of the 650, the



## Innovative engine mount gives smooth ride, quick handling

A scooter differs from a motorcycle in that the engine assembly also doubles as the rear swinging arm and is continually moving when the scooter is being ridden. "This kind of application," says chief chassis engineer Massimo Lambertini, "is difficult to do well because you have to decouple the vibration coming to the rider and passenger from the engine via the frame.

"To do this, the pivot would normally have a rubber-mounted hinge point with two degrees of freedom. The rubber mounting introduces flexibility between the engine and the frame, and this gives riders a feeling that the rear wheel is steering while they are cornering. You get the feeling that the rear of the scooter is not following you," he explains.

Ricardo was able to channel its considerable simulation skills into developing a coupling system that provides a very high pivot point for the engine. "This gave us riding characteristics similar to that of a motorcycle," continues Lambertini. "There are some rubber elements but compared to all the competitors with the same kind of engine and rear wheel design, this is widely acknowledged as being best-in-class."



→ two platforms are completely different and there is no similarity or carry-over between the maxi-scooter and the mid-size one. Interestingly, the idea of producing a sport and GT version from a single platform originally came from Ricardo at the beginning of the maxi-scooter project.

### Urban agility and GT cruiser off one platform

The challenge, says Massimo Lotti, is to use scooters based on a single platform to compete against the best seller in each of the sports and tourer categories: "We were up against two different models from two of the world's top manufacturers, Yamaha and Suzuki, and now Honda is in the market too," he explains.

This would be tough enough as it was, but to mount that dual challenge from a single platform would be tougher still, particularly as the underlying chassis and suspension design would have to deliver two distinctly different sets of vehicle dynamics. By contrast, the competitors' machines were designed from scratch to deliver those respective attributes. But the outcome, Lotti recounts with some satisfaction, is that independent reviews rate the C400 X as the best in class in the 'Sport' category,

while the GT version has received very positive feedback as a 'tourer scooter' – a very good result.

As the brief evolved, the decision was taken to dial back the sporting attributes of the C400 X to retain an urban focus, creating a scooter with a lighter and more agile feel than the grand tourer. The approach is what the designers call 'cross-city.' In that urban segment a true sports scooter makes less sense because it does not need to be uncompromisingly sporty, and it must appeal to a city-based customer. The idea was to make a vehicle that felt light and agile to the touch – one that could easily take on the cut and thrust of urban traffic and allow the rider the freedom to make rapid progress through the most crowded streets.

The feeling of agility riders get from the nimble C400 X is engineered into the chassis, and the scooter is also 8 kg lighter than its GT sister. "That is mainly due to differences in the body parts," explains Massimo Lambertini, who was responsible for chassis design and development.

### Design cues from legendary GS BMWs

On both the C400 X and C400 GT, the BMW styling department team introduced

some of the styling language from the BMW GS off-road touring motorcycle. "The GS is not an overt sports bike, it's a cross-tourer, so we had the opportunity to provide a similar feeling on a scooter," explains Lotti. "The GT was a different proposition. We wanted to create a true GT focusing on fuel economy, comfort, riding position and all the attributes a true GT should have."

One concept introduced on the bigger scooter was a Ricardo idea: the patented Flexcase system, originally launched on the G650. The storage system can drop down to allow a full-face helmet to be locked away securely while the scooter is stationary and in the normal position, and can be used for general stowage when the scooter is being ridden. While the Flexcase system is not new to the market as a whole, the BMW machines are the only scooters available with anything like it.

The main target for the chassis design was to create an extremely rigid engine mounting and achieve the highest standards of handling feel. "One of the weak points of other scooter designs is that the engine is completely rubber-mounted, so the engine and rear wheel unit is not so rigid. This is to avoid noise and vibration from being transmitted to the rider and passenger, but it's not great for rideability," explains Lambertini.

At the front there is a 15-inch wheel to ease the shock of urban potholes, and telescopic forks aim to give the best ride possible. A small subframe, moulded in plastic, supports the instrument panel and front lights. The C400s incorporate some carry-over design features from other BMW bikes, such as the handlebar

**"It was a logical step to downsize our maxi scooters, so we can attract new and different target groups - there is a healthy market demand" Dr Joerg Reissing, BMW project manager**



switches, headlights and instrument cluster, to provide a strong link with the rest of BMW's two-wheeled family. The design goes one step further than competitors with the addition of a twin (rather than single) front disc brake set up with four-piston calipers to improve safety and give the rider a greater feeling of security.

### Engine and transmission design

A water-cooled, port-injected 350 cc single-cylinder four-valve engine with a single overhead camshaft and roller finger followers provides the power. Output is 34 PS at 7500 rev/min and torque is 35 Nm at 6000 rev/min; both the C400 X and C400 GT conform to the latest motorcycle EU4 emissions standards.

Engine design work started in 2013 with some initial information from BMW, and Ricardo was also involved in initial benchmarking and defining the specification. That involved reviewing existing products to establish the optimum engine capacity, and BMW's desire for some similarity with other Motorrad engines meant the bore size was initially set at 80 mm. "We hoped to use some carry-over parts like the valve train components and the piston but in the end the parts were all made in

China specifically for our project," says Ricardo's Nikola Fiket, who was in charge of powertrain design and development.

The engine incorporates a CVT transmission, with the front pulley mounted on the crankshaft. The second pulley is connected to the first by a rubber belt and drives a fixed-ratio secondary drive with a small centrifugal clutch. "These components account for more than half the weight of the swing arm," says Fiket. "We also had responsibility for the airbox and complete air intake, which is also assembled through the swing arm. The exhaust system is connected to the right-hand side of the swing arm."

### Balancer shaft: yes or no?

Some scooter engines have a balancer shaft for smoothness, while some others that do not still score well on vibration and refinement. "The big question was do we need one, and what would be the best position for it?" remembers Fiket. BMW looked at its two main competitors – one which had the most rapid performance and wasn't equipped with a balancer shaft, and the other, rated highest for refinement, which did. The objective was to achieve the best of both and become the new benchmark for others to follow, so the decision was taken to include the shaft.

"We chose the best position for the shaft to quell vibration and also take into account the swing arm pivot point we wanted. Intake gas flow was also the subject of considerable simulation work: as the cylinder lies almost horizontally so the air intake has to turn 180 degrees through the swing arm."

And although relatively conventional in its approach compared to others in the market, the detailed design of the BMW combustion system in terms of combustion stability, tumble ratio and airflow generally is at the cutting edge of what is technically possible.

### Production: technology transfer to China

The chassis and fairings for the familiar C650 series are manufactured in Europe, and were designed in collaboration with Italian scooter specialist EXNOVO (now part of Ricardo Motorcycle), while the C650's engine is produced by Taiwanese manufacturer KYMCO. In contrast, for the new C400 the manufacturing is carried out entirely in China, by LONCIN at its plant in Chongqing.

Quite apart from the design and engineering of the vehicle itself, the management of this remote manufacturing process was a demanding task and needed careful handling, as

## BMW C400 X product highlights





**“We took much more responsibility for the design and development as well as helping the new supplier base to deliver components meeting BMW’s stringent quality requirements” Paul Etheridge, Ricardo head of motorcycle strategy**

→

BMW’s Dr. Joerg Reissing explains: “One of the main challenges was to ensure fast and efficient communications between all the parties involved, including suppliers. Considerable effort went into establishing standard processes to ensure excellent levels of quality.”

The final result, a scooter which would be sold in Europe as well across global markets, had to be 100 percent BMW not just in quality, but in look and feel too. Overall, the engineering team had to work within the technical capabilities of the suppliers, and one of the issues was the fact that component volumes were being measured in the thousands rather than the millions that many Chinese suppliers are used to.

“This is a substantial step further than before,” explains Ricardo’s Paul Etheridge. “We took much more responsibility for the design and development as well as helping the new supplier base to deliver components meeting BMW’s stringent quality requirements. This alone represented an entire area of work, and of course it went without saying that the manufacture of the final vehicle also had to meet BMW requirements of quality and refinement.”

One of the ways this was managed was to perfect the various assembly techniques in Europe, then transfer and

demonstrate them in China. At that point the processes were adjusted to suit the Chinese workforce. All testing is carried out in China and the scooters are assembled on two production lines, the first for the powertrain and the second for the entire scooter, which at the end of the process is ready to ride away.

**Excellent outcome - and the media agree**

The end result was exactly as expected: a scooter that is well designed, well specified and with great handling. “Our focus was on typical BMW styling, market-leading innovations like connectivity with a large TFT display, and a riding experience that is closer to a motorcycle than a scooter to deliver our brand-core ‘Joy,’” says Reissing.

Like their bigger predecessors, the new BMW scooters have proved as popular with the world’s press as BMW hoped. “In town an excellent turning circle allows the C400 X to easily be U-turned in a road and its light feel and narrowness means you can zip through gaps, while the riding position means your feet are always close to the ground...” said *Motor Cycle News*. “The C400 X looks and feels a premium scooter...”

*Visor Down* agreed. “The C400 X was a delight to ride – it felt agile, and far lighter

than its 204 kg wet weight. The torque of 35 Nm peaks at 6000 rev/min, but there’s plenty of grunt throughout and the compact 400 easily hits the ton with a bit more to give.”

The leading website went on to say: “thanks to a ‘vibration-decoupled engine mount’ – rubber bushings damping the engine vibration – the bike is remarkably smooth, and there’s very little shake through the bars and mirrors. In fact, even at higher speeds you could still get a clear view of what’s behind you.”

*Mannheimer Morgen* was deeply impressed with the C400’s new navigation system, finding that the simple interface didn’t distract or mislead the rider, and in a three-hour test ride around Milan was “absolutely perfect.”

The competitively priced C400 scooters are now on sale, with features such as automatic stability control (ASC) and ABS as well as BMW Motorrad Connectivity which allows the rider to access phone, music and navigation via a multi-function controller on the handlebars.

A satisfied Reissing notes that “Ricardo made important contributions for the success of the project due to comprehensive knowledge of complete vehicles, the interactions between development and production and quick and flexible workflows.”

All in all, the new C400s are compelling new products of which both BMW and Ricardo are rightly proud, marking another milestone in what has proven to be a hugely successful relationship between the two companies. 





# Sailing on SOLAR

With the world waking up to the global climate emergency, major industries are looking towards zero carbon emissions by 2050 or earlier. Shipping, responsible for between 2 and 3 percent of global greenhouse gas emissions, has been one of the slowest to be regulated and hence, to embrace technical change. Yet according to a new Ricardo report there could be an answer, in the surprising shape of 'green' ammonia. **Tony Lewin** explains

The shipping industry, with its high investment costs and long replacement cycles for vessels and their engines, has traditionally been a slow mover when it comes to environmental initiatives. Recently, however, the International Maritime

Organization has agreed to halve the sector's greenhouse gas (GHG) emissions by 2050. The quantities are significant: if sea transport were a country, it would rank fifth in the world for GHG emissions, midway between Japan and Germany.

Decarbonized powertrains are at varying stages of development in almost every transport sector, with batteries, hydrogen and synthetic fuels all vying for advantage. But in shipping the route forward is less clear: battery power is currently inadequate

## Comparison of fuel characteristics

	Marine gas oil	Liquefied natural gas	Methanol	Green ammonia	Green hydrogen
Type	Fossil fuel, high carbon	Fossil fuel, high carbon	Low-carbon	Zero GHG emitting	Zero GHG emitting
Temperature for liquid storage	Ambient	-162°C	Ambient	-34°C [or pressurised]	-253°C
Tank volume for 1,000 nautical mile range of Handymax carrier	73m <sup>3</sup>	164m <sup>3</sup> [2.3 x MGO]	169m <sup>3</sup> [2.3 x MGO]	299m <sup>3</sup> [4.1 x MGO]	555m <sup>3</sup> [7.6 x MGO]
Suitable application	Short and long voyages	Short and long voyages	Short and long voyages	Short and long voyages	Short voyages

■ Best performing ■ Acceptable ■ Problematic

**Green ammonia scores well under every heading, its only minor drawback being lower energy density than other liquid fuels**

for any but the shortest of ferry routes, and hydrogen has challenges due to infrastructure issues. The liquefied natural gas fuel that has recently become more popular is helpful in avoiding the sulfur emissions of traditional heavy fuel oils and does slightly reduce CO<sub>2</sub> impact thanks to its lower carbon content; however, truly climate-neutral synthetic fuels are still too expensive for this acutely cost-conscious sector and are not currently available.

One possibility gaining traction is carbon-free 'green' ammonia, and its potential is highlighted in a study published by Ricardo Energy & Environment in spring 2019 on behalf of the Environmental Defense Fund, a leading international non-profit organization addressing environmental problems. The report, entitled *Sailing on Solar: Could green ammonia decarbonize international shipping?* builds a strong case for ammonia as a fuel which could not only decarbonize maritime transport but also help boost the economies of developing nations. The connection might appear obscure but, as we explain below, it could make perfect sense.

### Ammonia as a green fuel

On the face of it, using green ammonia as a marine fuel ticks a great many boxes. The lifecycle of green ammonia is climate neutral

if it is generated using carbon-free energy, and the fuel can be used in existing marine diesel engines with some modifications to the powerplant and fuel storage systems. There is a potential for the same fuel to be used later in fuel cell equipped vessels.

Ammonia is a known compound in industry. It is widely used in transport as a reductant, stored as AdBlue for use in the selective catalytic reduction (SCR) systems employed to reduce NO<sub>x</sub> from diesel exhausts. Despite its corrosiveness, ammonia is in general easier to store than hydrogen and does not require cryogenic freezing.

More compellingly still, if that ammonia is produced using renewable electricity, the whole fuel value chain becomes fully climate neutral. Abundant solar irradiation in many developing countries in the equatorial belt and southern hemisphere gives them the potential to set up green ammonia plants as part of extended solar farms. These could provide sustained demand for renewable energy and thus help the region or nation reach the critical mass required to increase the contribution from renewables in their energy mix. And that in its turn could help displace existing GHG-intensive sources of generation, further reducing aggregate global GHG emissions.

In the *Sailing on Solar* report, experts from Ricardo Energy & Environment have detailed some case studies of possible installations, each of them close to busy shipping routes so as to allow easy refuelling of vessels and loading of bulk ammonia carriers. Among the locations examined are Morocco, Greece and Chile.

### How is green ammonia produced?

Ammonia (NH<sub>3</sub>) is a compound of hydrogen and nitrogen, and in conventional industrial methods the hydrogen is 'reformed' from carbon-based feedstocks like natural gas, oil or coal. In the green ammonia process, renewable electricity powers electrolyzers that split water into its constituents of

hydrogen and oxygen; the hydrogen is then stored ready for the next process, which sees it combined with nitrogen harvested from the air using an air separation unit, again a familiar technology.

The electrolyser plants for green ammonia production are made up of multiple modular units that can operate at low loads and can be stopped or started easily, says the report. These characteristics give them high operational flexibility, which is well suited to renewable electricity with fluctuating output.

The Haber-Bosch process for turning the hydrogen and nitrogen into ammonia is also an established one. The technique involves an exothermic reaction [one that creates heat] that works best when it continues uninterrupted, explains the report, but it is possible to design a Haber-Bosch plant with the ability to operate more flexibly and to reduce the load at times of lower electricity output from intermittent renewable sources. In terms of energy demand [excluding the desalination plant that provides the pure water], the electrolyser absorbs some 92 percent of the total, with the Haber-Bosch synthesis accounting for just 6 percent.

Buffer storage tanks for both hydrogen and nitrogen allow the system to absorb surplus electricity supply, as well as enabling the process to continue even when renewable generation is low. In fact, says Nick Ash, one of the report's authors, the electricity supply could drop by more than 92 percent and the Haber-Bosch process could continue operation near full load.

### Green ammonia on board ship

The central advantage of using ammonia in any combustion application is that it contains no carbon atoms, so the fuel itself does not give rise to any carbon emissions. The harmful sulfur and heavy metal emissions associated with heavy oil bunker fuels are avoided too.

With large diesel engines running on heavy fuel oil being so dominant in the shipping sector, these engines would be the natural entry point for the new marine fuel. Yet the report identifies three further potential shipboard applications: firstly, indirect use as a hydrogen carrier for a hydrogen fuel cell system; secondly, to react chemically in a solid oxide fuel cell system; and finally, and perhaps least promisingly, for direct combustion in gas turbines – as used in some military ships.

As always, the substitution of the new fuel may not be quite as simple as plug and play. Because ammonia can be difficult to combust, especially at low loads and/or speeds, a support fuel [probably a fossil fuel or hydrogen] will likely be needed to ensure smooth operation. And given





the corrosive nature of ammonia, the main fuel storage and supply system would have to leak free and avoid certain materials such as copper, brass and zinc alloys, as well as rubber and some plastics.

The storage of ammonia is much less problematic than hydrogen, the only other current contender as a carbon-free fuel: ammonia can be kept under pressure at around 10 bar, or refrigerated to -33°C, though it is much less energy-dense than heavy fuel oil and occupies roughly four times the space of a fossil fuel tank giving the same range.

## Emissions profile

Combustion of ammonia either under stoichiometric or lean conditions can form NO<sub>x</sub>, notes Matthew Keenan, aftertreatment and chemistry technical specialist at Ricardo's Shoreham Technical Centre. "NO<sub>x</sub> emissions are formed in the combustion process under high temperatures, above approximately 2000 K," he explains. "This can be controlled, to an extent, by optimizing the engine operating conditions, and additional NO<sub>x</sub> control will be achieved through the application of an SCR-based aftertreatment system."

Spark-ignition stoichiometric NH<sub>3</sub> combustion will have higher NO<sub>x</sub> emissions compared to lean compression-ignition and lean spark-ignition NH<sub>3</sub> combustion owing to the higher peak combustion temperatures.

The aftertreatment is likely to be an SCR system, broadly similar to those already in use on many lean combustion engines. And no separate AdBlue supply will be needed as the reductant is contained in the principal fuel; even so, the aftertreatment and reductant supply may impact a vessel's payload and packaging.

As for particulate matter (PM), so long the bane of the diesel engine, the Ricardo engine performance development department cautions that PM emissions can still be expected from NH<sub>3</sub>-fuelled engines. However, NH<sub>3</sub> is expected to result in a much less visible emissions signature, with reduced black smoke. As with diesel engines, the lubricating oil will contribute to PM emissions, along with any hydrocarbon-based fuel used as a combustion enhancer.

Also, signal the specialists, the NH<sub>3</sub> fuel itself may form solid nitrates which will contribute to PM emissions. Appropriate aftertreatment filtration systems may be required to minimize particulate matter.

## Timescales

The urgency of the global climate crisis and the slow pace of upgrades and replacements in the marine sector mean that low-carbon

shipping needs to begin feeding into international fleets within the next five years, if not earlier. As ships have a typical lifespan of 20 to 30 years, it is important to act soon.

MAN, a leading manufacturer of marine engines, is planning to develop one of its engine models to run on ammonia, targeting brake thermal efficiency in the region of 50 percent, notes the report. Furthermore, MAN also indicated that up to 3000 existing engines could be retrofitted to run on ammonia. It is not clear from MAN's plans whether their approach is compression- or spark-ignited. The firm anticipates that a relatively short timeframe of two to three years would be required to develop and test its engine for ammonia combustion, which indicates that it is technically achievable to have new and retrofitted existing vessels with ammonia-operated engines in the next decade.

## Outlook

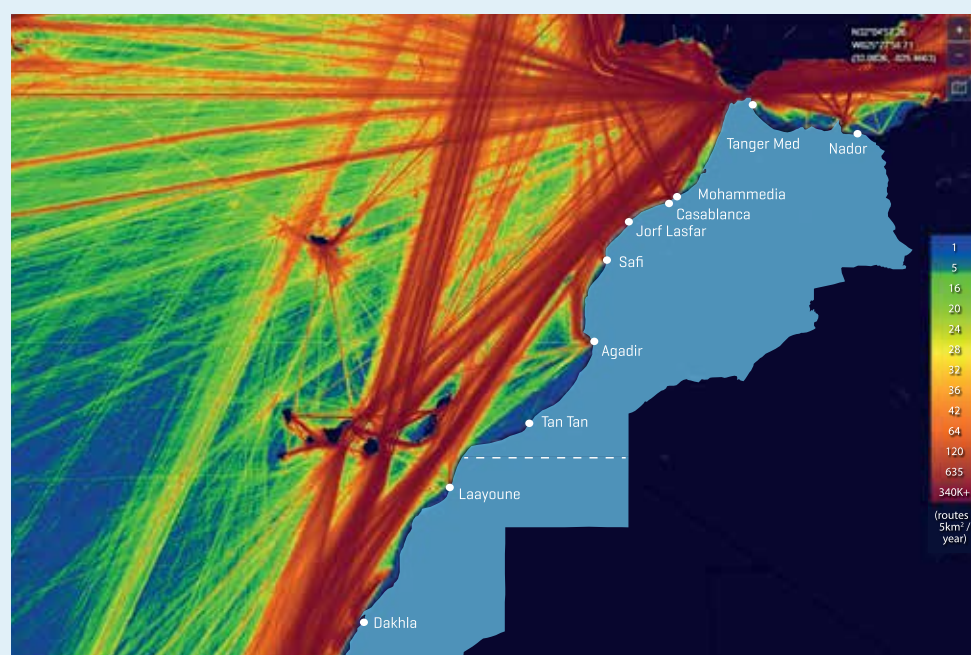
Green ammonia, concludes the report, is a technically feasible solution for decarbonizing international shipping, even though there are many development steps required prior to its introduction. It

is a fuel that can be combusted in engines and potentially used for fuel cells in the future. The pathway to its deployment can begin using technologies familiar to the maritime sector: diesel or dual-fuel engines in new and existing vessels.

But to make a success of this pathway, what is needed is certainty – both for the marine industry in building and retrofitting such vessels, as well for a green ammonia supply industry to manufacture at scale. This must be provided by strategic and policy measures adopted by the International Maritime Organization. This would encourage green ammonia and vessels that can accommodate it to be introduced within the timescales required to achieve the IMO's decarbonization targets.

What is more, demand from shipping could unlock investment in the green ammonia supply chain, including low-carbon industry and renewable electricity. This represents a unique opportunity for sustainable economic development and distribution of bunkering infrastructure around the world – especially for developing economies rich in renewable energy potential. [\[6\]](#)

**Case study shows Morocco as an excellent location for a carbon neutral ammonia plant, with abundant solar radiation, sea water and big volumes of shipping along its Atlantic coast**



## Ammonia in other engines

Thanks to its hydrogen content, ammonia can operate in a variety of different combustion engines and energy conversion devices. As well as conventional reciprocating piston engines, ammonia can also be burned in gas turbines. However, its lower energy density than conventional jet fuel rules it out for long- and even medium-haul aviation applications. For the same reason, it is not a suitable road fuel but, says Ricardo, NH<sub>3</sub> has the potential to be a viable fuel for stationary power.

Fuel cell applications are still under study, and initial indications are that ammonia could operate equally well in both PEM fuel cells, with their higher precious metal content, and in solid oxide fuel cells which run at high temperatures. In both cases, ammonia could offer advantages over hydrogen, which has to be stored under much higher pressure.

# RQ RICARDO NEWS

Latest developments from around the global Ricardo organization



## Rail digital resilience

International rolling stock manufacturer Bombardier Transportation has appointed Ricardo and Roke Manor Research to implement a new approach for managing digital risk in connected transport systems, focusing on the AVENTRA platform. This project expands on the unique digital resilience collaboration between Ricardo and Roke, a partnership built upon the twin foundations of Ricardo's position as a global leader in technology and innovation across the transportation and mobility sectors, and Roke's world-class experience in cyber security and communications.

The Ricardo-Roke team will work with Bombardier's in-house engineers to produce a full appraisal of the AVENTRA vehicle's digital security risk profile, starting from the perspective of the priorities of Bombardier customers. The AVENTRA is an electrical multiple unit train

that was introduced to the UK network in 2017. It will become increasingly familiar to the country's commuters over the next two years as it is added to fleets serving the south west, eastern and west midlands regions. Bombardier has requested an in-depth assessment of the AVENTRA's exposure to a range of possible threats – from espionage to remote hacking – and to evaluate the potential impact on its operation.

Doug Blanc, Ricardo Rail's head of digital railway, explains: "Unlike traditional enterprise security assessments, the Ricardo-Roke approach focuses squarely on the unique characteristics and priorities of day-to-day rail operations, such as the importance of maintaining a safe and open environment for passengers whilst ensuring minimum disruption to the network."

To deliver the findings, the team will benchmark the AVENTRA against current

industry standards and national legislation. This includes the Network and Information Systems Directive (NIS regulations), as well as well-defined practices from sources such as National Institute of Standards and Technology, Certified Information Systems Security Professional, and previous vulnerability and risk reviews conducted by Roke for the UK Ministry of Defence.

Once the investigations are concluded, the team will provide Bombardier with a detailed risk-based assessment of the AVENTRA platform, accompanied by recommendations that identify vulnerabilities and mitigate risk in an appropriate way, for incorporation into Bombardier's existing risk management practices. This assessment will provide Bombardier customers with a significant evidence base with which to demonstrate compliance with the NIS cyber assessment framework.

## Automotive cyber security consultation

The 5StarS consortium – which takes in Ricardo and Roke, together with HORIBA MIRA, Thatcham Research and Axillium Research – is aimed at addressing the increased cyber security threats associated with connected and autonomous vehicles. In support of this goal, the consortium has released a consultation paper to seek feedback on a new assurance framework to assess the cyber security of vehicles.

The 5StarS project, which is funded by Innovate UK, is seeking feedback from automotive manufacturers, government and insurers to ensure this revolutionary framework is readily adopted when finalized this summer. The 5StarS assurance framework outlined in the

consultation paper will enable manufacturers to gain assurance in their products, use cyber resilience as a market differentiator and establish meaningful ways of communicating cyber security risk to consumers.

The paper provides a roadmap to increasing assurance, which starts by meeting the requirements of the emerging regulations and standards such as ISO/SAE 21434, while introducing independent vehicle vulnerability assessments. This allows the framework to be adapted to cope with continually changing threats. The paper also proposes a consumer-facing risk rating system to reassure consumers about their choice of vehicle.



# VR helps global engineering collaboration

With complex automotive engineering programmes being carried out to unprecedentedly tight timescales and to ever higher levels of design optimization, the process of formal gateway-based design reviews is crucial to the achievement of performance targets and design for manufacture and assembly. Ultimately, market success can depend on the gateway structure, too.

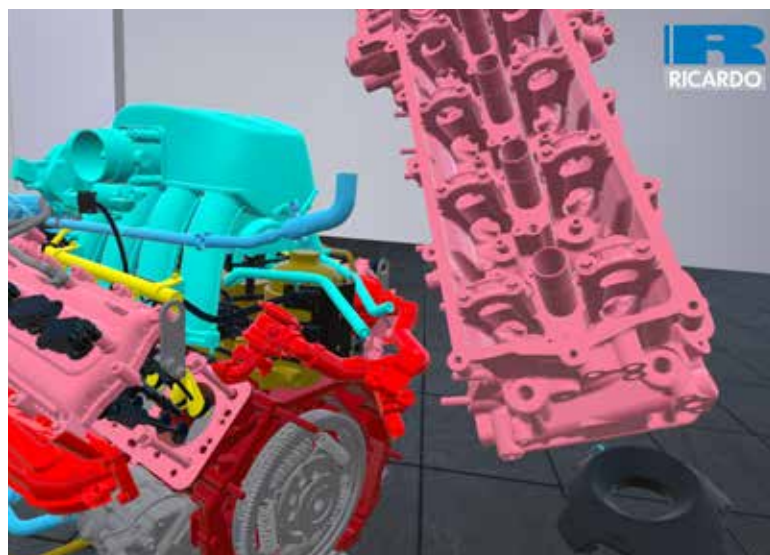
This challenge is further compounded by the almost universal requirement for the collaboration of different specialist teams on an international basis as automakers seek to develop platforms applicable to multiple markets; at the same time these teams must also draw on their own engineering resources from multiple locations.

Ricardo has invested in the development of advanced immersive Virtual Reality (VR) capabilities to promote effective and efficient design optimization by geographically dispersed teams. This technology, in the form of the Ricardo VR Engineering Design Review app [depicted

below], was showcased for the first time in May to delegates at the Vienna Motor Symposium. It enables users to investigate complex CAD designs, at full scale, in a shared immersive VR session, connecting interdisciplinary teams, customers and suppliers across the world in a 3D virtual environment.

The live demonstration in Vienna, in collaboration with engineers at Ricardo's UK headquarters, was based on an engine CAD model in which users were able to manipulate and examine individual components as well as show, hide and isolate sub-assemblies.

The app's dynamic cross-sectioning tool also allows users to visualize the innermost components – something that would not be possible even with physical prototypes – while also assessing the potential for component clashes, manufacturability and ease of assembly. In manipulating the model, users can also take measurements, add 3D annotations, and record screenshots and voice memos.



## ZEV vision for UK heavy goods transport

A new Ricardo study, commissioned by the Committee on Climate Change as part of research for its Net Zero report, outlines the costs and requirements of infrastructure to support a zero-emission heavy goods vehicle fleet in the UK by 2050, as required by the Government's proposed decarbonization targets.

Although electric and hydrogen vehicles are emerging as viable alternatives to diesel in the passenger car fleet, the most cost-effective route to decarbonizing the heavy-duty vehicle sector is not so straightforward. Policymakers need a full understanding of the entire ecosystem necessary to enable net-zero emission heavy goods vehicle transport to become a reality. The Ricardo study provides this much-needed infrastructure insight.

A range of infrastructure types was considered, including refuelling stations for hydrogen fuel cell electric vehicles; depot-based chargers and ultra-rapid charge points for battery electric vehicles; electric road system infrastructure – specifically overhead catenaries for battery-electric or battery-hybrid vehicles; and hybrid solutions combining elements of the above.

In addition to estimating the infrastructure costs for net-zero emission heavy goods vehicles, the project also considered issues around build rates and other infrastructure changes needed to deliver these scenarios. Identification of these challenges will help policymakers evaluate the broader implications of the deployment of various types of infrastructure, facilitating well-informed decision-making.

The study concludes that implementing an infrastructure to support zero emission heavy-duty vehicles is achievable, but there are key challenges including planning, co-ordination, supply chains, resources and materials, and the need for a skilled workforce and a strong government policy to enable the market to deliver.

## Advanced hybrid transmission for Geely

Geely Auto Group is one of China's leading automakers and is a name that commands international respect for its focus on new energy vehicles. To support its future product requirements, Geely has selected Ricardo to assist with the development, right through to production implementation, of a new advanced transmission for range-extended plug-in hybrid vehicles. Key requirements for the transmission are high efficiency and competitive cost for high volume A- and B-segment products.

The approach taken is highly collaborative and flexible, with co-located joint teams comprised of Geely and Ricardo engineers based in both the UK and in China. Not only does this support good internal communications

and optimal decision-making processes, it will also help in meeting challenging time-to-market targets. In addition to the core engineering team, support will be available from Ricardo's technical centres in other locations including the Czech Republic. Ricardo's involvement will encompass the mechanical design, control and calibration of the new transmission.

The collaboration with Geely builds on Ricardo's strong track record in assisting a wide range of customers in the development of advanced transmission technologies and successfully bringing them to production.



## Offshore wind energy expansion

In the face of increased demand for offshore wind energy, and in the light of the UK government's recently announced ambition to deliver 30 percent of the country's electricity from this renewable source by 2030, Ricardo is creating a dedicated team to service a significant growth in the parallel demand for consultancy expertise, including the provision of advanced technologies and innovations developed by the company.

The new team represents a significant expansion of Ricardo's activity in offshore wind consulting, and builds upon the company's investments in technology development specific to the unique demands of offshore wind energy. The marine environment brings significant opportunities as the prevailing winds are both strong and reliable and, freed from the constraints of land-based

transportation and installation, the size of turbines employed can be greater. At the same time, the challenges of maintaining and operating wind turbines in the marine environment are considerably greater than those on shore, meaning that operation and maintenance costs are much higher.

The key business driver for the success of any wind energy project is the cost per megawatt hour of electricity generated, and for this reason, technologies that can help deliver reliability and service life are extremely valuable. This has been the focus of significant effort by the Ricardo Innovations team in recent years – work which has resulted in the development of a range of proprietary wind energy innovations that the company can now exploit in the provision of high-value engineering and strategic consulting services.

## Australian rail acquisition

In May 2019 Ricardo plc announced a share purchase agreement to acquire the assets, operations and employees of Australia's Transport Engineering Pty Ltd business, with the acquisition expected to complete on or before 30 June 2019.

Transport Engineering has a strong technical advisory capability taking in the full lifecycle management of rolling stock and maintenance procurement programmes on behalf of its clients, as well as the provision of on-site inspectors and auditors in suppliers' premises. It also covers safety engineering, maintenance

engineering, project management, human factors, testing and commissioning and systems integration. It has delivered an impressive record of growth since it started trading in 2015 and employs circa 100 engineers and specialists across Australia and parts of Asia.

Ricardo's interest in the rail sector is underpinned by the increased global demand for urban and high-speed transport networks and the rapid integration of critical and complex rail technologies as governments respond to accelerating levels of urbanization. The addition

of Transport Engineering expands Ricardo's rail business to around 700 members of staff.

"Transport Engineering has built a first-class operation in Australia, with an impressive portfolio of projects and capabilities," commented Ricardo Rail MD Paul Seller. "By supporting the consultancy's desire to offer an increased range of technical disciplines to its clients, we can help it continue to grow within the Australian market and, by extension, support our mission to build a world-class rail services business."

## Ricardo receives Sir Henry Royce Memorial Foundation award



This special award was presented to Ricardo at a dinner of the Worshipful Company of Carmen, a Livery Company of the City of London founded

in 1517. The key modern charitable aim of this Livery Company is 'to promote fellowship among those engaged in the trade of transport'. The Sir Henry Royce Foundation Award has been presented each year since 1983, primarily to recognize endeavours in the sphere of transport, of national or international significance and involving skill, dedication or technical perfection of the highest order, in conformity with the untiring pursuit of excellence that was the philosophy of Sir Henry Royce, the engineering genius behind Rolls-Royce.

The award citation reflects Ricardo's

own long and proud history, being given "in recognition of over a century of this British company's world-leading technologies in automotive engineering and transportation, including the 1917 battle tank engine, the turbulent side-valve cylinder head of 1921 used almost universally until the 1940s, and the Comet diesel combustion chamber developed in 1931 – the design standard until the eighties. Post war, Ricardo developed the Harwell Air Pollution Model, 4WD viscous couplings for rally cars, the Bugatti Veyron transmission and V8 engines for McLaren road cars."





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A full-page background image showing a motorcyclist in a black and white racing suit and helmet riding a dark motorcycle on a road. The background is blurred with motion, showing trees and a bright sky. A blue semi-transparent box covers the bottom left portion of the image, containing the conference details.

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