What if all cars were ELECTRIC?

Would the grid cope? Could we generate enough renewable energy? Or should we focus on low-carbon liquid fuels? Ricardo’s groundbreaking study looks at the policy choices for 2050.

Interview
Michael Perschke, Pininfarina and Dr Pawan Goenka, Mahindra & Mahindra

Digital resilience
Ensuring cyber security in a complex interconnected world

California greening
Ricardo’s role in bringing sustainable hydrogen fuel to America’s golden state

Ricardo Rail
Tram and train programmes in the Netherlands and the UK
Define and optimize the next generation powertrain

Talk to us and find out how we can help you select and develop optimum powertrain technology, using Ricardo’s R-Intelect Integrated Model Based Development (IMBD) as a fast and flexible virtual environment.

Ricardo’s R-Intelect IMBD capability and virtual environment support technology selection and optimization, ensuring that increasingly complex powertrains achieve their maximum potential for fuel economy and emission control.

- Highly adaptable and customizable modelling capability
- Identify the critical trade-offs including hardware and control interaction
- Reduce hardware phase time and cost through virtual system optimization and pre-calibration
- Assess internal combustion engines, transmission and electrification options
- Study legislative cycles and real-world driving with varying driver profiles

Find out how Ricardo can help your product development.
Email: info@ricardo.com   Tel: (UK) +44 (0)1273 455611

www.ricardo.com
### CONTENTS

**Ricardo Quarterly Review • Q4 2018**

**NEWS**

- **Industry news** ...........................................04
  - Volvo’s carless show stand: California thinks hydrogen; wildfires intensify climate debate; electric bikes for the wealthy and electric cars for the masses; long haul on truck emissions; EV upswing forces VW production rethink

- **RQ viewpoint** ..........................07
  - Dr Richard Hodges
  - Industrial heat recovery can cut carbon emissions and production costs

- **Ricardo news** ..........................24
  - Energy support for European Investment Bank; Edinburgh Trams award; Climate Finance Accelerator enters next phase; digital and zero-emissions train expertise for Northern Rail

**FEATURES**

- **Mass EV rollout** ..........................10
  - What happens if everyone switches to EVs? Would a migration to more low-carbon liquid fuels be better? These are among the competing scenarios for 2050 tested by Ricardo in a ground-breaking new study. Tony Lewin reports

- **Digital resilience** ..................17
  - As the connectivity and complexity of modern vehicles increases, so too does the number of potential pathways for cybercrime. Ricardo and cyber security specialist Roke have published a white paper on enhancing digital resilience, as Anthony Smith reports

- **California greening** ..............20
  - As California looks to dramatically increase the use of hydrogen as a sustainable fuel, Jesse Crosse talks to the California Fuel Cell Partnership and the Ricardo engineers involved in the project

**Q & A**

- **Pininfarina** ..................08
  - Can Italy’s designer label succeed with its own luxury EV brand? Ian Adcock speaks to CEO Michael Perschke and Dr Pawan Goenka from parent company Mahindra & Mahindra

---

**Ricardo contacts and locations:**

- Head office:
  - Ricardo plc, Shoreham-by-Sea
  - West Sussex BN43 5FG
  - United Kingdom
  - Tel: +44 (0)1273 455611

- **RQ subscriptions:**
  - www.ricardo.com/rq

- **Sales enquiries:**
  - business.development@ricardo.com

- **Conceived and produced for Ricardo by:**
  - TwoTone Media Ltd

  - **Editor:** Tony Lewin
  - **Contributors:** Anthony Smith, Jesse Crosse

  - **TwoTone Media Ltd contacts:**
  - Anthony Smith: AVSmith@MediaTechnical.com
  - Tony Lewin: Tony@TonyLewin.com

---

**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.

---

**RQ viewpoint**

**Dr Richard Hodges**  
Industrial heat recovery can cut carbon emissions and production costs

---

**FEATURES**

**Mass EV rollout**

What happens if everyone switches to EVs? Would a migration to more low-carbon liquid fuels be better? These are among the competing scenarios for 2050 tested by Ricardo in a ground-breaking new study. Tony Lewin reports

---

**Digital resilience**

As the connectivity and complexity of modern vehicles increases, so too does the number of potential pathways for cybercrime. Ricardo and cyber security specialist Roke have published a white paper on enhancing digital resilience, as Anthony Smith reports

---

**California greening**

As California looks to dramatically increase the use of hydrogen as a sustainable fuel, Jesse Crosse talks to the California Fuel Cell Partnership and the Ricardo engineers involved in the project

---

**Q & A**

**Pininfarina**

Can Italy’s designer label succeed with its own luxury EV brand? Ian Adcock speaks to CEO Michael Perschke and Dr Pawan Goenka from parent company Mahindra & Mahindra

---
Volvo signals industry shift

The annual Los Angeles auto show is well accustomed to the tension between California’s green counterculture and the appetite of its wealthy citizens for extravagant and gas-guzzling luxury cars. But this year’s show, entitled Automobility LA, played host to a surprise which could well point to major disruption in the business model driving the industry into the next decade. By setting out a booth with no cars whatsoever on the opening press days, Volvo openly questioned the role of the event as a giant multi-brand showroom where consumers compare models to finalize their purchase. “Instead of bringing a concept car, we talk about the concept of a car,” said Mårten Levenstam, head of product strategy at Volvo Cars, referring to the company’s new role of “offering our customers access to a car, including new attractive services whenever and wherever they want it.”

“Our industry is changing,” added Håkan Samuelsson, CEO. “Rather than just building and selling cars, we will really provide our customers with the freedom to move in a personal, sustainable and safe way.”

Yet for every tantalizing display of sustainability on show, there was a counterbalancing debut of a fast and powerful new model. Audi’s striking all-electric e-tron GT contrasted with the VW Group’s eighth-generation Porsche 911, promising 450 hp and top speeds of over 300 km/h, while the same group’s sybaritic Bentley Continental GT Convertible went one better, topping out at a claimed 330 km/h.

Likewise, BMW’s Vision iNext concept, the battery-powered crossover that previews 2021’s production model, found itself paired with the giant X7 luxury SUV and the lavish 8-Series convertible. And against the background of news that GM was closing plants and axing the pioneering Volt, came new hybrids from Toyota and Subaru – plus a concerted attack on GM’s CEO from President Trump.

Hydrogen futures in the golden state

Two key fuel cell vehicles made their debut in California, the only region worldwide to have developed a hydrogen fuelling infrastructure. Hyundai’s 2019 Nexo is the follow-up to the Korean giant’s fuel cell Tucson SUV and boosts range on its three hydrogen tanks to over 600 km, with its five-minute refuelling time comparable to a gasoline vehicle’s. Mercedes-Benz’s GLC F-Cell is innovative, as the first fuel cell plug-in hybrid. Two tanks holding 4.4 kg of hydrogen give it a range of 430 km, with a further 51 km available from traction battery. Four driving modes include hybrid, where sudden power demands are handled by battery boost, and charge, where the fuel cell tops up the battery. In parallel, Volkswagen is working with scientists at Stanford University on atomic layer deposition techniques which promise to dramatically reduce the amount of costly platinum needed in fuel cell stacks, paving the way for lower priced hydrogen power.
**Wildfires sound climate alarm**

A matter of days after wildfires swept through two areas of California, killing more than 85 people and destroying 14,000 homes, the US Congress forced the publication – against the wishes of the President – of the Fourth National Climate Assessment. Drawn up by 13 high-level federal agencies and academic institutions, the assessment links heatwaves, fires, hurricanes, droughts, floods, infrastructure damage and crop failures to the effects of climate change, blaming the phenomenon as an accelerator in the California tragedies, the second largest in the state’s history.

The Congressional report is one of several recent studies urging immediate action to mitigate climate change. In the wake of its Living Planet Report 2018 showing a 60 percent decline in animal numbers since 1970, the WWF is calling for a collective rethink on the way we feed and fuel our societies, while the American Geophysical Union warns of increasing extreme heat events as well as decreases in cold spells.

In the UK the new Climate Projections 2018 predicts summer temperature highs increasing by up to 5.4 Celsius by 2070, with the risk of a 1.15 m sea-level rise by 2100; summer rainfall is set to drop by up to 47 percent but winter precipitation to rise by 35 percent.

---

**e-bikes aim high**

Electric two-wheelers will be elite sports machines as well as efficient commuters if the new releases at Milan’s motorcycle show are anything to go by. Harley Davidson announced that it would sell its Livewire e-machine from next year, but declined to provide pricing or specifications, while the Arc Vector (pictured) from a UK startup aims at the very top. Priced at over €100,000, this limited-edition bike hits 100 km/h in around 3 seconds and has a 300 km range. Weighing just 220 kg thanks to its carbon frame and swingarms, it comes with a special interactive safety suit and helmet.

---

**EU rules will harm us, say firms**

Automakers are accelerating their plans for greener models as more nations and cities announce plans to ban the sale of combustion-engined cars and vans. The latest to join the list is Denmark, which will outlaw the sale of new diesel and gasoline models from 2030 and stop hybrid sales from 2035. Denmark joins Norway, France, the Netherlands, the UK and several European cities in planning the phase-out of combustion vehicles.

On a closer timescale, the EU’s proposal for a 35 percent reduction in automakers’ fleet average CO2 emissions by 2030 is causing alarm in some industry quarters, with Volkswagen Group CEO Herbert Diess saying that a quarter of the firm’s jobs would be threatened by the new limit, itself a compromise from the 40 percent reduction proposed by the European Parliament. BMW, for its part, still expects 85 percent of its vehicles to be combustion engined by 2030.

---

**NEWS IN BRIEF**

**Sail away Renaults**

Groupe Renault has partnered with French shipping firm Neoline to build two wind-powered cargo ships to operate between France and the US eastern seaboard. The industrial-scale use of wind power in the ships promises to reduce CO2 emissions by up to 90 percent and the initiative comes as part of Renault’s commitment to reduce its carbon footprint by 25 percent by 2022.

**Fuel cell car cleans London’s air**

Some 800 kg of London’s most polluted air was cleaned and purified as a Hyundai Nexo fuel cell crossover was driven around the city’s dirtiest routes as part of Clean Driving Month earlier this year. Covering more than 550 km and spanning 31 days, the Nexo is claimed to filter 99.9 percent of airborne NOx, SOx and ultrafine particulate matter in its three-stage filtration system.

**Toyota first with industrial hydrogen burner**

The forging line at Toyota’s Honsha plant in Japan has a special claim to fame: it is the first in the world to incorporate a general purpose hydrogen burner for industrial use, says the automaker. Conventional combustion of hydrogen and oxygen is too violent, giving off NOx emissions. Toyota’s solution is to pre-combust small volumes of the two gases and lower the oxygen concentration for the main combustion inside the furnace, resulting in lower-flame temperatures.

---

**Sales results shakeup**

Fiat Chrysler outsold Ford in the US in September to claim second place behind GM, thanks to combination of fleet orders, a strong showing from Jeep and Ram, and sharp falls in sales of passenger cars relative to light trucks. The same month yielded freak results in Europe, too, as PSA Groupe unexpectedly topped the sales charts. Twenty-three of 27 markets posted double-digit falls as major players stalled on the supply of WLTP-homologated models. All automakers were hit, especially Volkswagen and Audi, each suffering 50-plus percent reversals to allow PSA Groupe through to take market leadership. Even the redoubtable VW Golf, down a precipitous 71 percent, momentarily lost its habitual top spot – to Opel-Vauxhall’s Corsa.

---

**Mazda rotary engine returns**

Car enthusiasts have been overjoyed to hear that Mazda is to bring back its charismatic Wankel rotary engine. What may not go down so well is that the rotary’s renaissance is only as a smooth, silent range extender unit in an upcoming electric vehicle, due in 2020.

---

**VW to “digitize” car sales**

Volkswagen promises to revolutionize car sales in Europe with a digitization programme beginning in 2020. Customers will each have their own unique Volkswagen ID number, giving them access to online ordering, round-the-clock individual support and over-the-air software updates.
The Volkswagen Group is the first major automaker to announce a rethink of its manufacturing operations to enable million-scale production of EVs. It is also expected to launch an entry-level EV priced from €18,000 – much lower than commentators had been expecting.

Under the first phase of the electric strategy, the Zwickau plant, which was once home to the Trabant, will switch over completely to production of the new ID electric range, the first of which is set to be introduced next year. With an eventual annual output of 330,000 units it will form the nucleus of the VW brand’s electric offensive.

From 2022, Emden, which currently builds the Passat, will transition to a new electric model, expected to be the lower-cost in the line-up; the Hannover truck plant will begin building the ID Buzz range of battery-powered light commercials, alongside conventionally engined vans. VW expects to be selling 150,000 EVs by 2020 and a million by 2025. All will be based on the MEB electric platform and use the Group’s new VW.OS operating system, E3 electronic architecture and batteries built in Braunschweig. The batteries will be modular and scalable so that customers can choose ranges between 320 and 550 km.

“With our electric cars we want to make a substantial contribution to climate protection,” said VW board member for E-mobility Thomas Ulbrich. “The decisive factor is that electric cars will be both built and used sustainably. The ID will be a model for sustainable mobility.”

Veckswagen tools up for mass EVs

Solid-state batteries still 10 years away

Solid-state batteries might be convincing in the laboratory but, says leading manufacturer Panasonic, it is a long way from lab to road. Volkswagen, for one, is not expecting to fit them to production vehicles before 2025, though Henrik Fisker, with finance from Caterpillar, has signalled an introduction in his EVs from 2020. A Chinese news agency reports that Qing Tao Energy Development Company of Kunshan has started production of solid-state batteries, but it is not clear whether these are of the scale required for automotive use.

In the meantime, many other technologies are vying for attention, and investment. Munich-based LION Smart has developed a 100 kWh lithium ion system to replace the 33 kWh unit in BMW’s i3, giving a 700 km range, and the Fraunhofer Institute has come up with a battery insulated from the environment in a sandwich casing containing a phase-change material. This material absorbs heat during recharging and returns it to precondition the battery, improving vehicle range in low ambient temperatures.

NantEnergy’s Air Breathing Rechargeable Storage uses electricity to convert zinc oxide to zinc and oxygen. The battery takes in air, which oxidizes the zinc, generating electrons, while Swiss-German startup Innolith has an inorganic non-flammable chemistry which allows exceptional durability of some 50,000 cycles, equivalent to an iPhone lasting 100 years.

Startups want part of the electric action

Little more than a decade ago, Tesla was no more than a visionary startup. Now, with EVs moving decisively into the mainstream, a rush of startups have appeared, some of them opportunistic, others still idealistic.

One that is causing quite a stir is Michigan-based Rivian, which impressed LA showgoers with its big R1T double-cab pickup (pictured) and the associated R1S SUV. The design is notable for its cleverness, as well as for the power of its four wheel motors and the size of its top-specification 180 kWh battery and the 650-km range it promises.

Bollinger and Workhorse also have stakes in the electric pickup game, and Byton showed both its K-Byte luxury sedan and an M-Byte SUV concept spinoff. Both will be produced in China and are scheduled to launch in 2019-20. British vacuum cleaner magnate James Dyson will build his EV in Singapore, but little of its design or configuration has yet been revealed.

Dyson’s design is likely to be as innovative as his household products. So too are those of two other European hopefuls: crowd-funded Sono Motors in Germany already has almost 9000 reservations for its simple, solar cell-clad hatchback, while in Denmark, with the backing of a Hong Kong finance group, premium bicycle maker Biomega has taken a Renault Twizy-like approach for its cool urban minimalist four-seater.
Emboldened by the IPCC’s special report on 1.5 Celsius warming, Euro MPs have voted to strengthen their draft legislation on truck emissions, proposing a 20 percent CO2 reduction for 2025 and 35 percent by 2030. This is the first time truck emissions have been regulated in Europe, but while commercial vehicle makers have raised objections, some are already supplying low-emission models to the market.

Daimler’s Mercedes eActros delivery truck is on trial placement with several operators in Germany prior to launch in 2021. It has a 10-tonne payload and a range of 100 km in an urban duty cycle. With Europe in mind, US truck startup Nikola has developed a forward-control version of its hydrogen-powered tractor unit (pictured above) and is expecting to manufacture it in Europe from 2022, in tandem with establishing a network of hydrogen fuelling stations. Hyundai has already announced plans for fuel cell heavy trucks in Europe, and Toyota is to supply its fuel cell system to Portuguese bus maker CaetanoBus.

In the US, FedEx has ordered 1000 electric large delivery vans, sourced from China: the Chanje V8100 has a range of 240 km and a payload of 2720 kg. However, where electric power has made the biggest steps is in urban buses, with one in ten new buses sold in Europe now battery powered. The environment committee of the European Parliament is backing a sales target requiring bus makers to sell 50 percent zero emission urban buses by 2025, and 75 percent by 2030.

European air quality in crisis

With the European Environment Agency reporting that 98 percent of the continent’s urban population is exposed to harmful air, legislators and industries are locked in discussions. In the face of this very real air quality crisis, it is city authorities that have begun to take action.

At the heart of the crisis are older diesel vehicles, and city authorities in Brussels have begun implementing fines of €130 for drivers of the very oldest models. In Germany the long list of cities breaching European air quality limits are implementing bans on diesel vehicles of Euro 4 or earlier standards. Next year, even Berlin will be affected, with ten or more major thoroughfares barred to older diesels. More than 8 million Euro 4 and Euro 5 diesel models still circulate on Germany’s roads, and manufacturers are seeking a solution involving a combination of retrofit actions and vehicle replacement incentives.

Londoners were scandalized by the revelation that schoolchildren in particularly polluted areas are being compelled to wear facemasks and are not allowed to play outside; from April next year the City of London financial district will ban all but the least polluting vehicles from several streets.

Industrial heat recovery can cut carbon emissions – and costs

Dr Richard Hodges – principal consultant, infrastructure & utilities, Ricardo Energy & Environment

Around the world, industrial processes release vast amounts of heat as waste to the atmosphere. Where this heat can be recovered and this does not happen, a significant opportunity to improve process efficiency, reduce costs and even generate new revenue streams is missed. It also needlessly adds to the stock of national emissions. The challenge and opportunity of industrial waste heat recovery is well recognized internationally, and this is an area in which Ricardo is keen to help customers.

In the UK, the Department for Business, Energy and Industrial Strategy (BEIS) announced in October the launch of the Industrial Heat Recovery Support (IHRS) programme. This is a grant funding programme open to manufacturing sites and data centres that would like support to scope out and implement projects to recover and utilize surplus heat.

There is a widespread belief that industrial operators are not tapping into the potential to recover and reuse heat and are therefore not enjoying the financial benefits. This could be because of a lack of knowledge and information about the potential to do this at their sites, or because of the relatively long payback periods when specific projects are identified. The IHRS programme has been developed to address these barriers by providing grant funding for feasibility studies and for the actual implementation of projects to recover and reuse heat.

The programme is open to manufacturing sites located in England and Wales where activities fall under Standard Industrial Classification codes 10-33. It is also open to data centres in respect of heating, ventilation and air conditioning, and ancillary systems. All activities in the lifecycle of a heat recovery project are eligible for grant funding. This means that grant funding is available against the costs incurred when carrying out feasibility studies, preliminary engineering, detailed design, and capital project delivery.

In all, there is £18 million of grant funding available. £42 million is available for feasibility studies and preliminary engineering, and £13.8 million for detailed design and capital delivery. Applicants may receive up to 50 percent of grant funding against the costs of feasibility studies, preliminary engineering and detailed design. Up to 30 percent is available for capital project delivery.

There is a continuously open application window running until the end of September 2019. Applications received are not assessed continuously but during assessment windows, each of two months’ duration. Crucially, this means that all applicants wishing to access this grant funding must make their applications by the end of September 2019 at the latest. Moreover, BEIS is front-loading the availability of grant funding towards the earlier assessment windows.

I would urge qualifying industrial and data centre companies to embrace this programme. For those requiring assistance, we are here to help. Ricardo worked closely with BEIS in defining the scope, eligibility and assessment criteria of the programme, so we understand what a successful project would look like. Our CHP (combined heat and power) and heat recovery experts have a comprehensive range of skills and experience key to scoping out and implementing heat recovery opportunities. These include knowledge of industrial processes and heat recovery technologies, generation and audit of mass and energy balances, due diligence of technical proposals, and project financial appraisal. These skills are key for identifying and progressing technically sound projects which can be implemented efficiently and generate long term cost and carbon savings.

Most of all, we are impartial. We are not a technology supplier, so our advice is technology neutral and based solely on each solution’s technical and economic merits. Moreover, our technical competencies and impartiality can be applied to industrial heat recovery projects globally.
Your background is with Audi, most recently as part of the e-tron project. What attracted you to Pininfarina?

I've known Mahindra Group chairman Anand Mahindra, and managing director Dr Pawan Goenka, since I headed Audi’s Indian operation from 2010 to 2013. So when they called in 2017 with the idea of making Pininfarina a brand in its own right, I was immediately interested. From an Audi perspective I was watching what was happening in electric vehicle (EV) development and was involved with the e-tron project – so I was already an EV convert, but it was intriguing to do something from scratch with a brand of Pininfarina’s magnitude. If we could find the right technology this was definitely lower risk than some of the Chinese-funded new kids on the block.

Pininfarina is one of the most respected design houses in the world. Is your biggest challenge to convert it into an automotive brand in its own right?

Yes and no. We presented our first car at Pebble Beach – the PF0 hypercar – and the brand recall was pretty high. Its positive heritage and legacy mean you don’t have to convince people – in contrast to some of the new startups, which don’t have any of that. It’s comparable to when McLaren launched its road car programme: they were known because of their F1 success, so there was already a certain degree of trust and credit. It won’t be easy, but we can de-risk it to an extent with the strength of our design capability and a high level of recognition in certain target groups.

Specifications for your first car, the PF0, seem wildly over the top. Is it the ultimate Top Trumps card?

You could say that: 1400 kW, 2300 Nm, 0-100 km/h in under two seconds, a V-max approaching 480 km/h – that’s if the tyres hold out. The range is circa 500 km, the price tag is €2 million and we’re only going to build 150 – but this is our halo car that will get us noticed when it’s revealed at the [2019] Geneva Salon. That car will be built to order, not stock: it has already been shown at private events in both the USA and Europe, and we have received enough orders to make it profitable from the off.

Pininfarina CEO
Michael Perschke

Michael Perschke joined Pininfarina in 2018 after 14 years with Audi and the Volkswagen Group in a wide range of roles, prior to which he worked for Mitsubishi and Mercedes-Benz.

So a collectors’ hypercar makes a strong business case?

You’re absolutely right. We have an eight- to ten-year business strategy, our ‘Milestone Plan’, fully funded by the shareholders, that will see us launch a new product every 12 to 15 months starting with the PF0 next March. If you look at luxury brands selling around 10,000 a year, the Bentleys, Aston Martins, Lamborghini of this world, they all have three core products, more or less, in their line-ups. If you want to play in that league you need to have a similar number of models, so there’s a luxury crossover and two further models in the pipeline. We’re targeting customers of luxury brands which don’t yet have EVs as well as those from premium brands that want to upgrade, plus Tesla owners who want something more European. I think we have a recipe that can do justice to all three audiences.

Who has joined the organization to engineer the cars?

The technical team is in place, headquartered in Munich: the ex-Porsche Mission E engineering project lead, Christian Jung, has joined as chief technical officer; Paolo Dellachia (who...
brought the Maserati Levante to fruition) and former Bugatti regional director Marcus Korbach, also in the team. We’re working with two or three big collaborators and have feasibility studies underway with potential partners. Between Munich, Stuttgart and Pininfarina’s Italian base in Turin - what I like to call the ‘Magic Triangle’ - we are close to leading German Tier Ones, like Bosch, ZF and Schaeffler, as well as to Silicon Valley entrepreneurs like Amazon.

Where will you build the cars?
The PF0 will be hand-built by Pininfarina in Italy at the rate of one car a week; Pininfarina has two other assembly facilities in Italy, so the second product could be built there, while we are also considering a third manufacturing plant which could be in Europe or North America, depending on how our sales strategy develops. We definitively won’t be building the cars in either India or China as the quality isn’t good enough at this level. Initially, we don’t see China as a market for us: it’s not suited to hypercars, whereas our second model will be more attractive to that market. Globally, we’re looking at 25-30 percent of sales in the USA, a similar percentage in Europe and the balance split between the Middle East, Hong Kong and Japan. By the end of this year we will have more than 25 luxury partners in place who know and understand our target audience.

In 2015 we bought Pininfarina, and that with the knowledge we gained from Formula E and it gave us the chance to create Automobili Pininfarina. We also recognised that we couldn’t do all this ourselves, which is where the Rimac partnership came in.

What was the rationale behind this extreme performance car?
There are multiple objectives. We believe that in the automotive sector brand is very important and we’re licensing the [Pininfarina] brand separately: Pininfarina is always associated with luxury, performance, design. So the PF0 helps us to launch the brand: once we have done that, we get into higher volumes and lower prices.

Your product roll-out is quite aggressive. Will it require large investment in facilities, equipment and people?
We have a phased investment programme: right now we have invested in PF0 and have already done quite a lot of work on the next project. We envisage that as the business grows we will have other investors joining us; we’re not trying to do everything ourselves and today there is more manufacturing capacity than the world needs, so there is no need for us to break ground. We can work with a contractor or on a licensing basis with a third party. We will use technology that’s already available and then develop our own brand and product DNA.

“At first sight a multi-million Euro hypercar, Pininfarina and Mahindra & Mahindra don’t seem like natural bedfellows... It goes back eight years to when Mahindra bought the Indian Electric Car Company, as we thought that EVs were the future. We are the biggest seller of EVs in India, but they are low-end - 40 hp, 140 km range, $12,000. Then five years ago we entered Formula E, which introduced us to high-end EVs: this started us thinking that upmarket EVs were the future, but the Mahindra brand couldn’t be stretched that far. In 2015 we bought Pininfarina, and that gave us access to the high-end market with the untapped potential of a globally recognised and respected brand. Combine that with the knowledge we gained from Formula E and it gave us the chance to create Automobili Pininfarina. We also recognised that we couldn’t do all this ourselves, which is where the Rimac partnership came in.”

Dr Pawan Goenka, managing director of Mahindra & Mahindra and chairman of the supervisory board of Automobili Pininfarina
Pawan Goenka joined Mahindra & Mahindra in 1998 as R&D manager, after 10 years with GM in Detroit. He became CEO of Mahindra autos in 2005 and MD of the complete business in 2015.
Are EVs really the solution to Europe’s environmental problems? And if so, what happens if everybody rushes to adopt them? Could the electricity grid and materials supplies possibly cope? Or would a migration to more low-carbon liquid fuels be a better answer? These are among the competing scenarios for 2050 tested by Ricardo in a ground-breaking new study that has set commentators talking. Tony Lewin reports for RQ
With September’s IPCC report on climate change as a timely wake-up call, Europe’s policymakers face weighty decisions on how the continent’s road transport should best drive into the low-carbon future enshrined in EU legislation. Will that future be electric? What about hydrogen power? Or could super-clean designer fuels be part of the solution, if not the complete answer?

Whilst battery power is seen as working well in light-duty passenger cars and vans, it is significantly less suited to use in larger and heavier vehicles. What is more, unless charging demand is carefully managed, a mass rollout of electric vehicles would place huge stresses on the electricity supply infrastructure, requiring significant investment.

Better and speedier, argue some, would be to accelerate the shift to low-carbon liquid fuels. These offer the hugely tempting advantage of retaining large parts of the existing fuel supply infrastructure, and they can potentially go directly into the gasoline and diesel vehicles we are already using today.

Each of these scenarios is fraught with unknowns. How much and how fast will battery technology improve? How easily can electricity supply networks be expanded? Is there enough lithium for the billions of extra battery cells that will be required? Will the liquid fuels industry be able to scale up its currently lab-based processes many thousand-fold to supply enough low-carbon fuels to power our conventional cars into a clean future?

**Scenario planning**

In the face of so many wild-card variables, detailed policymaking might appear nigh-on impossible. But Ricardo’s state-of-the-art scenario planning process provides a very useful strategic tool to explore the likely outcomes and possible consequences of a variety of proposed future scenarios. And this is precisely the type of exercise Ricardo has recently undertaken in collaboration with Concawe, the environmental science organization for the European fuels industry.

Challenged to examine potential pathways to achieving a major reduction in European automotive GHG emissions by 2050 compared with business-as-usual (BAU) projections, the study developed two deliberately very contrasting scenarios. The first assumed a near-universal uptake of electric vehicles in the light-duty sectors, while the second relied more on combustion-engined vehicles and the phased replacement of today’s gasoline and diesel with their low-carbon biofuel or eFuel equivalents, combined with a lower (46 percent) share of plug-in vehicles. Both scenarios were scoped to deliver tank-to-
The Low Carbon Fuels scenario

2050 objective: Total light-vehicle parc lifecycle GHG emissions below 13% of 2015 values
Strategy: Decarbonization of liquid fuels
Principal assumptions: Availability of biomass supply chain and renewable electricity; reduction or elimination of first-generation biofuels; WTT GHG emissions for all LCFs halve by 2050; all diesel and 78% of gasoline substituted by 2050; 46% of vehicle parc is plug-in
Not included: Trucks, buses, heavy vehicles; hydrogen fuels
Advantages: Easy to implement; ‘drop-in’ fuel for existing ICE vehicles; faster improvement of ICE powertrains; 96% reduction in oil-based liquid fuel use; less impact on electricity infrastructure than HEV scenario
Risks: uncertainties about scaling up of biofuel supply chain and processes; inefficiencies in combustion engines and fuel production; requires electrical energy and extensive use of unproven CCS processes; overall energy use cut by only 49%; uncertainty concerning the availability of imported eFuels
Verdict: Longer term emissions savings are slightly greater under this scenario than HEV, but using more low-carbon fuels within HEV would reverse the position.

Low-carbon fuels: the runners and riders

Biofuels, first generation: these already form 5–6% of European pump fuel but are on their way out because of indirect land use change (ILUC) concerns and sustainability issues
Biofuels, advanced: these bypass ILUC concerns by using food-industry waste oils and lower-quality biomass materials as well as certain specific energy crops with high yields
Algal biofuels: these are showing promising results in an Exxon-Mobil study in the US, with a pilot programme aiming to scale up to 10,000 barrels per day by 2025

Pyrolysis, gasification, Fischer-Tropsch: these processes can produce jet fuel and diesel-like fuels from gas feedstocks, waste plastics or some of the next big biomass sources such as forestry waste
eFuels: power-to-liquid ‘designer’ fuels drawing carbon atoms from the atmosphere or waste streams and combining them with low carbon footprint hydrogen to produce tailor-made substitutes for gasoline, diesel and jet fuel
John Cooper, director general, Fuels Europe

**Fuels Europe, representing the EU refining industry, aims to promote economically and environmentally sustainable refining and use of petroleum products**

Why is the percentage of low-carbon fuels sold in Europe still so low?
Currently, 5 to 6 percent are biofuels, either first or second-generation, meeting the sustainability standard defined by the European Commission. Typically, from an investor’s standpoint it takes a couple of years of operation to get to breakeven on your investment. Advanced biofuels and eFuels are much more capital intensive, and the reasons the quantities are so low is that the investors have never seen the regulations as being stable enough, or as having a long enough duration to be able to plan for stable demand for those products for the 10 or 15 years that you would probably need to remunerate your investment.

**Could the fuels industry ramp up production of low-carbon fuels enough to replace all diesel and 80 percent of gasoline by 2050?**

The report describes the volumes achievable for road transport and is based on substantial third party work. Beyond that, for international transport including aviation and marine, it will be much more complex. It will be much more expensive.

**Could you give an example?**

A refinery producing advanced biofuels would need low-quality biomass such as wheat straw or forestry waste: it would require many thousands of tonnes every day, day in, day out. So you would need to find locations to aggregate that and transport it to the refineries. It will take time to build out the value chains. It’s not going to be done overnight: the quantities of fuel are huge.

**Will low-carbon fuels feed into existing distribution networks?**

In the electricity supply sector there has never been a separate grid for renewables, but the carbon intensity of the supply has simply evolved [as more renewable capacity has come on stream]. It will be the same with the distribution of liquid fuels. We have networks of pipelines that go across the UK, across Europe and across the US, and these supply huge volumes. The infrastructure exists from the gate of the refinery through to the side of the aircraft, the truck, or the car in every case. It is very efficient, but what we envisage is that the carbon intensity of these fuels can be reduced by the gradual introduction of these [new] technologies.

**Will low-carbon fuels cost more?**

We need to recognize that all of these technologies will produce a fuel that is more expensive than fossil fuels. The new processes take something that is not oily at all, like the tops of trees and wood bark: it’s a long series of processes to get from there to a nice clear zero-sulfur jet fuel or high-cetane diesel. Not surprisingly, it’s more expensive.

**How much extra grid electricity will be needed to produce these biofuels and eFuels?**

Typically, biofuel plants will be self-powering and will take a portion of the biomass to power the plant. In the same way, eFuels are likely to require the production of dedicated power generation. But when you consider what might be necessary for the production of renewables for the entire consumption in Europe, including the decarbonization of industry, it is clear that we will have to have much more electricity than we have today. Some work that we are doing with the European Commission suggests that that by 2050 requirement could be three times what we have today. And that would all be expected to be renewable.

**How much of your existing refinery and processing network will you have to replace?**

Some processes are so good that you’d simply be blending [their output]: what we are seeing is some processes evolving in the refinery and others being superseded by others outside – which might be next door. Refineries may grow to accommodate more complementary technologies with suppliers around them. They will use some of the same infrastructure, starting with the port, the storage, the power stations, the connections for power, gas and liquids. The units themselves will evolve, be replaced or be switched off over time.

applied to each one of the contributory influences. As such, the scenarios represent opposite extremes that are unlikely to occur: clearly, the outcome will be somewhere in between, but analysis of the scenarios can be very helpful in providing planners with insights into the potential implications of a move towards either extreme. A halfway-house Alternative Scenario has been modelled, too.

**What if fuels were all low carbon?**

This presents itself as a highly attractive solution, something that would allow us to utilize more of our existing manufacturing skills and assets, our existing liquid fuels distribution network, and large parts of today’s refinery inventory. It would not require significant behaviour change in how consumers refuel their vehicles, and the principal disruption would be the investments required by the fuels industry. As with the rival HiEV scenario, LCF [see panels on page 12] will deliver the target 85 percent reduction in total lifecycle GHG emissions by 2050, even allowing for the near-50 percent rise in annual light-vehicle registrations projected in the European Commission’s Reference Scenario by that year.

So the obvious question presents itself. Why, if LCFs are such a simple and obvious solution, have they not yet gained a foothold? The answer, says John Cooper, director general of Fuels Europe, is an equally straightforward one: the oil companies do not see any profit in it.

“Typically, from an investor’s standpoint it takes a couple of years of operation to get to breakeven on your investment,” reveals Cooper. “Advanced biofuels and eFuels are much more capital intensive, and the reasons the quantities are [currently] so low is that the investors have never seen the regulations as being stable enough or having a long enough duration to be able to plan for stable demand for those products for the ten or 15 years that you would probably need to recoup your investment.” Even the most recent findings of the IPCC and the European Commission’s...
Cooper also observes that he “finds it strange” that LCFs do not contribute to the EU’s car CO2-reduction targets as only the TTW element of the fuel’s lifecycle is taken into account. The Ricardo study considered the GHG contribution from sources including fuel or electricity production, vehicle production and disposal, as well as vehicle use. The production of fuels in particular requires large amounts of electricity, so for the well-to-tank (WTT) phase of the energy chain to be truly low carbon the electricity employed must itself be renewable or very low in GHG emissions. In the LCF scenario, carbon capture and storage (CCS) is assumed to play an important role in the fuels’ overall carbon performance.

The broader picture

“What matters most,” argues Ricardo’s chief technology officer Professor Neville Jackson, “is the total environmental impact. You need to be sure of this before making any decision.”

The processes involved in producing LCFs are lengthier and more numerous the further away you get from basic petroleum, explains Cooper, and the yields are lower as only certain parts of the existing refinery systems can be used. The quantities of fuel involved are huge: today’s aggregate consumption across light vehicles in the EU is 236 billion litres per year, and business- as-usual scenarios show only a 3 percent reduction in this by 2050.

The LCF scenario for 2050 assumes the full substitution of all diesel fuels by low-carbon biofuel or fuel equivalents, and around 80 percent of gasoline volumes becoming low carbon. What is less certain is whether the fuels industry is capable of making such a dramatic turnaround to ramp up to the vast volumes required. As Cooper points out, “we can’t expect a transition like this to take place over ten years, considering how the industry has been built over 100 years.”

Neville Jackson, too, is wary of extreme either/or scenarios: “this is all about reaching a sensible ecological and economically-viable balance, not 100 percent of one or 100 percent of the other,” he says. Cooper, for his part, draws a parallel with the electricity industry, where wind and solar power are only now beginning to be deployed at scale, some 50 years after the first panels appeared.

What if all cars were electric?

For the HEV scenario the 2050 outcome is clear: fully 100 percent of new light-vehicle registrations would be battery-electric models, the gradual phasing out of internal combustion engined (ICE) vehicles over the years leaving just a 10 percent ICE contingent in the overall vehicle parc.

The air quality and efficiency benefits of such a scenario are well understood. But what about the implications for the electricity infrastructure of having so many vehicles to charge? And what further resources might become stretched in the process?

For electric vehicles to deliver their full carbon-saving potential, one clear requisite is a low or zero carbon intensity for the generating grid, and Europe already has policies in place to accelerate progress towards this. In the simplistic HEV scenario, where vehicle charging is unregulated, the expanded fleet of electric passenger cars

The High EV scenario

2050 objective: Total light-vehicle parc lifecycle GHG emissions below 13 percent of 2015 values

Strategy: By 2040 battery power is the only light-vehicle option permitted for new vehicles

Principal assumptions: Battery pack costs reduce and energy density improves significantly by 2050; GHG intensity of European electricity improves by 2050; electricity prices level off after 2025

Not included: Hydrogen powertrains; battery technologies other than lithium ion; home energy storage; use of vehicle-to-grid connectivity; trucks and heavy vehicles

Advantages: 74% reduction in overall energy consumption; 97% reduction in liquid fuel use; frees up LCF supplies for other applications where electricity is less suitable; greater reductions in other air quality pollutant emissions; greater energy security

Risks: Requires major incremental investment in electricity grid and battery production; higher on-cost over reference vehicle; high sensitivity to raw materials pricing; uncertainties over lithium and cobalt supply

Verdict: Provides lowest total cost of ownership for end users and for society

“In a managed home charging HiEV scenario approximately 60 percent of energy is expected to come from charging overnight in residential areas”

Nik Hill, Ricardo Energy & Environment

Net present value of total cost of ownership under the High EV scenario

<table>
<thead>
<tr>
<th></th>
<th>Capital Cost</th>
<th>Fuel / Electricity Cost</th>
<th>Operating &amp; Maintenance Cost</th>
<th>EV Infrastructure Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline ICE</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Diesel ICE</td>
<td>56,922</td>
<td>2,480</td>
<td>427</td>
<td>925</td>
<td>63,952</td>
</tr>
<tr>
<td>Gasoline HEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Gasoline PHEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>BEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Average</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>2030</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline ICE</td>
<td>54,020</td>
<td>2,967</td>
<td>407</td>
<td>1,020</td>
<td>58,414</td>
</tr>
<tr>
<td>Diesel ICE</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Gasoline HEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Gasoline PHEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>BEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Average</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline ICE</td>
<td>53,487</td>
<td>3,067</td>
<td>411</td>
<td>1,081</td>
<td>58,136</td>
</tr>
<tr>
<td>Diesel ICE</td>
<td>53,487</td>
<td>3,067</td>
<td>411</td>
<td>1,081</td>
<td>58,136</td>
</tr>
<tr>
<td>Gasoline HEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Gasoline PHEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>BEV</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
<tr>
<td>Average</td>
<td>52,963</td>
<td>2,634</td>
<td>375</td>
<td>856</td>
<td>56,622</td>
</tr>
</tbody>
</table>

Source: Ricardo analysis. EV infrastructure costs include only costs end-users are assumed to directly pay for, i.e. provision of on-/off-street charging units.
and vans would require massive investment in the electricity grid and distribution networks. As a worst-case illustration, unmanaged charging coinciding with the evening spike in domestic electricity use could impose such high demand peaks that the equivalent of 120 traditional 2 GW power stations would have to be added to the network’s generation assets, along with significant reinforcement of both high and low-voltage resources.

Few, however, believe that EV charging will remain unmanaged, and even relatively simple controlling of plugging-in schedules can halve the overall peak power requirement: the study calculates that the generation capacity uplift required will then be around 15 percent. This compares with the 6 percent likely to be needed in the low-carbon fuels scenario.

“We think the majority of people are likely to home charge,” says Ricardo Strategic Consulting’s Nick Powell, one of the authors of the study. “The main issue here comes in urban city environments, where access to charge points – and parking – is more of a challenge.” Both Powell and co-author from Ricardo Energy & Environment, Nik Hill, agree that the ‘refuelling’ model, where EV drivers mainly top up their batteries in large commercial recharging stations, will not be the main method of charging. In a managed home charging HEV scenario approximately 60 percent of energy is expected to come from charging overnight in residential areas.

“On the costs side, managed charging roughly halves the cumulative outlay to 2050,” says Hill, who is knowledge leader for transport technology and fuels. “Managed charging stops you having to do so many network interventions and capacity extensions. Unmanaged charging would be an unusual situation to end up in, as lots of these things are already being worked on.” Nevertheless, there are still important risks to take account of, as the results of the modelling show. The most headline-grabbing of these are on the battery raw materials side, notably the possibility of a massive hike in the demand for virgin lithium: with a conservative view of battery evolution, and no allowance made for the effects of new chemistries, peak demand for the metal could amount to six times current production. And despite improving technologies, similar insecurities surround cobalt, another key battery constituent.

What about goods vehicles?

In order to keep the scope of the report within manageable limits, heavy vehicles were not included within the study. Hydrogen and battery-powered trucks are now beginning to appear, but changes within this sector are slow to take effect as the vehicles...
have a high capital cost, fleet renewal is slow and the predominant focus is on total cost of ownership over a short period.

“Low-carbon fuels do make a lot of sense for long distance heavy duty vehicles,” says Powell, “as well as for other difficult forms of transportation such as aircraft.” The assumption within the LCF scenario, he explains, was that the quantities available to light-duty vehicles would allow for similar substitution levels in other forms of road transport. In 2015 diesel accounted for over 70 percent of overall EU fuel consumption.

“Heavy vehicles represent a much better use of LCFs’ than passenger cars and vans,” agrees Hill. “And other sectors such as shipping and aviation have a lot more problems finding ways to decarbonize other than by adopting low-carbon fuels. HDVs and other modes stand to benefit even more greatly from the introduction of low-carbon fuels and further reinforce the case for investment in this area.”

**User costs and society costs**

The study includes a multi-layered analysis of the costs of transitioning to each of these proposed scenarios, assessing the influences of everything from raw materials prices to taxation. The issue is sufficiently complex that it requires an article all of its own, so for reasons of space those aspects of the comparison are not discussed here; suffice to say that all three scenarios – HEV, LCF, and the halfway house position – result in lower costs than the reference business-as-usual scenario. The costs, to the end user, are similar for each scenario, when adjusted to maintain net fiscal revenue.

**Conclusions**

In conducting this study Ricardo and its partners did not aim to establish the rights and wrongs of any particular technology, nor to provide predictions for how light-duty transport might evolve over the next 30 years. Instead, the work revolved around exploring two deliberately contrasting scenarios which pushed competing trends to extremes – to help understand the pressure points within each scenario.

But major policy choices such as this are rarely binary, and the rational approach is to make the best and most balanced use of the resources that will be at Europe’s disposal by the mid-point of the century. At the same time the study’s findings provide a valuable planning tool to judge the implications of any chosen position on the spectrum between those extremes. One conclusion shines through very clearly, as even fuels industry representatives concede. In most situations, passenger cars and light vans will be most efficient with batteries directly charged with electricity. But most heavy-duty vehicles are less well suited to battery technologies and certainly for the next few decades low-carbon liquid fuels would be best directed at trucks and aircraft. Much depends on the future availability of renewable electricity.

Given that the supply of renewable electricity is likely to be limited, the crux question becomes this: what is the best use of that electricity? On this, the engineers are unanimous: “On a fundamental level it is more efficient to use this renewable electricity directly in the vehicle rather than by turning it into an eFuel,” notes Nick Powell.

Though there could be a convincing case for e Fuels as a means of storing energy and transporting it from remote locations inaccessible to grid connections, on a windfarm-to-wheels basis light electric vehicles are several times more efficient than those using combustion engines. Many analyses put the efficiency of the eFuel production process at under 50 percent which, when combined with the combustion engine’s energy losses of some 70 percent, gives a factor of five or six in favour of the EV.

Overall, says Nik Hill, it amounts to “a massive difference” in the primary energy needed to power a vehicle with eFuel versus a pure electric. “That’s why,” he concludes, “if you had to choose, you’d definitely put that energy into an electric vehicle.”

Of course, electricity infrastructure costs are significant, and there are resource uncertainties surrounding battery production, but all of the pathways to very low carbon have their challenges. So to minimise the risk in achieving our future targets we should consider a broad range of solutions, making the best use of existing energy supply infrastructures.

---

“On a fundamental level it is more efficient to use this renewable electricity directly in the vehicle rather than turning it into an eFuel”

Nick Powell, Ricardo Strategic Consulting

---

**Lithium, cobalt and nickel resource requirements under both projected scenarios**

Under the Low Carbon Fuels scenario the annual requirement for lithium will be less than half that in the High EV scenario: the HEV would be more than six times today’s production level.
The modern car has come a long way in terms of connectivity compared to previous generations of vehicles. Just a few years ago, cars were essentially a mechanical system with discrete electronic modules that remained disconnected from the world outside. The physical ‘system boundary’ of the vehicle was thus extremely clear – the skin panels, the glassware, and the rubber of the tyres on the road. The commercial interface with the consumer was similarly simple. After purchasing the vehicle from a dealer, the customer would be responsible for maintenance (other than that covered by a modest warranty period) and the purchase of the consumables – fuel, replacements parts, insurance – required for operation throughout the product’s useful life.

This situation is, however, changing rapidly. The growing sophistication and connected nature of modern vehicles – and the trend towards servitization of automotive supply, from vehicle leasing to ride hailing and ‘mobility as a service’ solutions – means that both the physical/electronic system boundary of the vehicle and the commercial boundary with the customer are increasingly complex. Changing ownership models in particular are fundamentally affecting the economics of transport and of vehicle insurance, transferring risk and liability from the driver and their insurer to the vehicle manufacturer and automotive supply chain.

With the advent of ever cheaper and more powerful processors and associated communication technologies, as well as the numerous application innovations based upon these, almost all new vehicles today are connected in a multiplicity of ways. Even in what might be considered a basic conventional vehicle architecture, dealer maintenance and emergency assistance systems such as eCall are likely to be linked via cellular networks; infotainment systems may include DAB radio, Bluetooth, and WiFi connections; navigation systems will connect with one or more global navigational satellite systems such as GPS; and web-enabled infotainment system apps may use a range of these and other media.

To these interfaces, many users may also add insurance driving assessment and pay-as-you-drive monitoring and road toll collection systems, and beyond...
the over-the-air connections there are many further wired data interfaces to the vehicle, ranging from the OBD port, the infotainment system USB sockets and, for plug-in vehicles, the recharging cable port.

With each of the increasing number of external electronic connections comes a potential attack vector for hackers to exploit. In addition to the obvious motivation of motor vehicle theft, personal and vehicle data may be targeted for identity theft or financial fraud. More serious still is the risk that a compromised vehicle could represent an immediate risk to its occupants or to pedestrians and other road users, if safety-critical systems such as steering, braking and powertrain control are undermined.

Implicit vulnerability

With the greater number of potential points of attack for hackers, the modern vehicle also presents inherent vulnerabilities associated with its architecture, as Nick Tebbutt, Ricardo business manager for cyber security explains: “The automotive industry has an exceptional capacity for innovation that delivers functionality at an affordable price to the consumer. Many electronic systems are designed using off-the-shelf components and open-source software. Each will have its own electronic control unit (ECU) which is linked to the industry-standard controller area network (CAN) bus and receives all of the messages passed on this network.”

“As such,” he warns, “a hacker gaining access to just one ECU – for example the climate control, infotainment or a seat positioning system – can then pass messages to any other ECU including those associated with safety-critical functions.”

In some cases, automakers are starting to retrofit security mechanisms into CAN bus systems, or are replacing them with automotive Ethernet, which has its own established security protocols. However, neither approach is foolproof as they both remain hackable.

As further advanced driver assistance systems and automation is added to new vehicles, the potential vulnerability to hacking can only increase as yet more interfaces are added. This could take place through vehicle-to-vehicle and vehicle-to-infrastructure communications that are incorporated for self-driving applications.

Ricardo-Roke – a new focus on digital resilience

In 2017, Ricardo and Roke launched a collaboration to provide a ‘one stop shop’ for the design of cyber-resilient systems and infrastructure for the automotive sector. “This collaboration builds upon the twin foundations of Ricardo’s position as a global leader in technology and innovation throughout the transportation and mobility sectors, combined with Roke’s 60-plus years of experience in cyber security for government and commercial clients,” explains Tebbutt. “It is unique within both the digital security and automotive industries in the way it combines an advanced skill set that cuts across both domains.”

The collaboration aims to work with automakers in order to manage digital risk throughout the vehicle lifecycle. The approach taken recognizes the increasing complexity of onboard systems and the fact that the system boundary of modern vehicles exists within the cloud rather than the physical world. The approach developed by Roke-Ricardo to meet this challenge is termed ‘digital resilience.’

The Roke-Ricardo collaboration has already led to the creation of a new Digital Resilience Lab to help automotive manufacturers design and produce the next generation of secure vehicles and realize the vision of future transport systems. The lab is located at the Ricardo Shoreham Technical Centre and contains a combination of specialist and off-the-shelf technologies to enable the assessment of digital resilience against a wide range of wired and remote attacks. Made up of both Ricardo and Roke engineers, the team will be able to conduct ‘test and fix’ exercises on behalf of automotive customers based on an assessment of acceptable risk. The lab will also provide validation of
new systems, applying the principles of ‘designed-in’ digital resilience. The facility allows the potential for attack through a wide range of wireless and other media to be assessed, including OBD II ports and USB.

**From cyber security to digital resilience**

In addition to launching the new Digital Resilience Lab, Ricardo and Roke have also jointly published a white paper, Digital Resilience - A new approach to cyber security for vehicles without boundaries, which argues that a fundamental change in approach is required throughout the automotive and transportation industry to maintain consumer trust. Future connected vehicles will have no readily identifiable digital boundary, so the industry’s approach must evolve from one of cyber security to one of digital resilience.

In principle, this requires the convergence of the two formerly discrete functions of information technology (IT) and operational technology (OT). To date, cyber security has tended to function on IT systems, whereas, the paper argues, a new approach is required that accepts that both IT and OT need to work in conjunction to successfully monitor, control and operate the physical systems of the vehicle. “In essence, this is about hardening and securing connected systems against attack,” explains Mark West, Roke’s head of cyber engineering, “not only making it as hard as possible for hackers to get through, but also mitigating the potential impact when a breach occurs.”

The paper concludes that, to provide the levels of digital resilience that customers will rightfully demand in the future, experts will be required to collaborate across traditional commercial and industrial sector boundaries. This approach will realize the vision of future transport systems that will be resilient: hard to penetrate and continuing to work safely when attacked.

**Critical national infrastructure**

Beyond the automotive sector, the Ricardo and Roke approach to digital resilience is particularly applicable to organizations responsible for delivery of critical national infrastructure and services. Earlier in 2018 the EU adopted the Network and Information Services (NIS) Directive for infrastructure providers to defend against and report attacks; the directive was also passed into UK law as the NIS regulations. The regulations will help make sure that operators in electricity, transport, water, energy, transport, health and digital infrastructure are sufficiently prepared for dealing with the increasing numbers of cyber threats. The regulations also cover other threats affecting IT, such as power failures, hardware failures and environmental hazards.

“In many respects the major utilities, such as the power distribution network operators, the water companies and the railway industry, have a more developed understanding of the need to provide true digital resilience rather than just cyber security,” contends Nick Tebbutt. “Our initial aim in the collaboration between Ricardo and Roke was to provide services to the automotive sector in the face of rising demand due to increasing connectivity and the emergence of automated self-driving technology. What we are now finding, however, is that the demand for the combined Roke-Ricardo service is equally great across the customer base of Ricardo Rail and Ricardo Energy & Environment.”

Across multiple sectors from automotive to the railways and utilities, the Ricardo-Roke philosophy of developing systems according to the principles of digital resilience is finding a very receptive audience. While those industries subject to NIS and similar regulations may already be aware of the need to move in this direction, the automotive industry is arguably at an earlier point on the learning curve. “In many respects the focus has been more on the very significant challenge of developing radically new functional capability, for example for SAE level-4 vehicle automation,” adds Tebbutt. “What we are demonstrating is that these efforts to innovate in automation functionality must be balanced by similar efforts to ensure digital resilience. Without this, there is a genuine risk that public acceptance of automated vehicle technologies may not be forthcoming.”

Roke’s Mark West agrees: “The collaboration between Roke and Ricardo and the concept of digital resilience is extremely timely, recognizing the sheer complexity of connected autonomous vehicles, fixing vulnerabilities in today’s vehicles, while ensuring future models are secure by design.”
Hydrogen is already being produced from sustainable energy sources today and instead of finding ways to restrict the amount of renewable electrical energy to meet prevailing grid demand, that energy can be stored in the form of hydrogen for indefinite periods. In something of a virtuous circle, the production of hydrogen by electrolysis can be used to expand the total output of renewable electricity eventually delivered, which helps improve grid stability and efficiency across the entire generation system.

Reaching critical mass

The state of California gained a reputation for being a leader in the drive for zero emissions in the 1960s, setting standards that the rest of the world would follow. The current vision of one million fuel cell vehicles by 2030 is one shared not just by the CaFCP but also by more than 40 partners, including vehicle manufacturers, energy companies, fuel cell producers, and many others.

As California looks to dramatically increase the use of hydrogen as a sustainable fuel, Jesse Crosse talks to Ricardo’s Marc Wiseman and Bill Elrick of the California Fuel Cell Partnership to find out more.

The question of which will be the most sustainable method of powering vehicles in the long term is still an open debate. Although the global focus is currently on battery electric vehicles, work is also progressing in California on bringing large numbers of hydrogen fuel cell electric vehicles to the market over the next decade. Ricardo is at the forefront of this initiative, working on a project with the California Fuel Cell Partnership (CaFCP) aimed at ramping up the number of fuel cell electric vehicles (FCEVs) on California’s roads to 1 million by 2030, along with an infrastructure of 1000 hydrogen filling stations to support them.

“Ricardo is active in assessing the potential methods for deploying the hydrogen infrastructure, the likely cost of hydrogen to the consumer, and the vehicle cost of ownership,” explains Dr Marc Wiseman, president, global mobility programmes at Ricardo Strategic Consulting. “When the proposed numbers are reached, the environmental benefits will be substantial.”

The CaFCP estimates a reduction in gasoline consumption of over 693 million US gallons, with NOx emissions reduced by 3.9 million tonnes. Based on today’s energy mix of 33 percent renewable hydrogen, it also predicts a reduction in greenhouse gas emissions of 2.7 million tonnes. These numbers can be significantly boosted by increasing the proportion of decarbonized hydrogen.

The development of the hydrogen fuel cell vehicle was seen as the next big thing at the turn of the 21st century, and manufacturers and organizations ploughed huge resources into making them work. “The CaFCP has been in operation for 20 years and during that time it hasn’t wavered in its mission to establish hydrogen as a primary fuel for powering vehicles,” says Bill Elrick, executive director, California Fuel Cell Partnership.

Hydrogen is already being produced from sustainable energy sources today and instead of finding ways to restrict the amount of renewable electrical energy to meet prevailing grid demand, that energy can be stored in the form of hydrogen for indefinite periods. In something of a virtuous circle, the production of hydrogen by electrolysis can be used to expand the total output of renewable electricity eventually delivered, which helps improve grid stability and efficiency across the entire generation system.

Reach critical mass

The state of California gained a reputation for being a leader in the drive for zero emissions in the 1960s, setting standards that the rest of the world would follow. The current vision of one million fuel cell vehicles by 2030 is one shared not just by the CaFCP but also by more than 40 partners, including vehicle manufacturers, energy companies, fuel cell producers,
government agencies, non-government organizations and universities.

The CaFCP has high expectations for FCEVs, even though today’s hydrogen fuel cell cars cost more than conventional cars, fuel costs are higher and the network coverage for hydrogen falls way behind that of gasoline. However, performance is on a par, as is range. “Once the point of critical mass is reached with a state-wide network of hydrogen filling stations and large numbers of FCEVs in production, we expect that vehicle cost, range and network coverage will match that of gasoline, while performance will be superior and, crucially, fuel costs will be lower too,” explains Elrick.

In January 2018, California Governor Jerry Brown called for a dramatic increase in zero-emission vehicles and a subsequent Executive Order directed state entities and the private sector to collaborate in putting 5 million zero-emission vehicles on the state’s roads by 2030, as well as supporting the installation of 200 hydrogen stations by 2025.

“To make that happen, the CaFCP has developed a three-point strategy,” says Elrick. The first step is to develop a market-driven framework to attract investment, increase the availability of hydrogen, and reduce costs. The ultimate goal is to create a self-sustaining commercial market. The second step is to establish the market by building consumer demand for cars by offering better value for money and broadening the customer base beyond early adopters to mainstream consumers.

“The third step,” continues Elrick, “is to expand the market by promoting the use of fuel cell technology and helping to accelerate the growth of the electrification in the transport sector. Increasing demand for hydrogen will encourage further investment in hydrogen production, distribution and dispensing. At the same time, linking renewable electricity generation with hydrogen will increase the robustness of the grid and help to drive down emissions.”

**Economies of scale**

Significant economies of scale are crucial to the development of large-scale hydrogen production and could deliver a 50 percent reduction in capital costs for hydrogen infrastructure by 2020. This would depend on hydrogen stations being constructed at the rate of 30 to 50 per year. The CaFCP has produced ‘A California Roadmap’ identifying major cluster areas and an initial network of 35 stations is serving those areas today. “We expect that increasing the area covered by the network will build consumer confidence and promote sales of FCEVs,” says Elrick. A California Air Resources Board (CARB) model demonstrates that one million FCEVs could be supported state-wide by 1000 strategically placed hydrogen stations.

Existing methods for incentivising buyers to choose FCEVs in preference to conventional gasoline cars include the CARB Clean Vehicle Rebate Project and High-Occupancy Vehicle (HOV) lane access. A hydrogen network of the size proposed in the CaFCP 2030 Vision will provide a level of access to hydrogen equivalent to that enjoyed by drivers of gasoline cars, who are currently served by 8000 filling stations. Existing gasoline stations have been used as a template for forecasting the future deployment of hydrogen stations. "The involvement of communities in planning the deployment of stations will be important to ensure they meet customer demands at a local level,” adds Elrick.

The CaFCP believes that long-term success will require the number of stations to stay half a step ahead of the number of cars, a ratio which the partnership believes will give peace of mind to prospective customers. This in turn will
Earlier this year Toyota announced the next great leap towards the future of zero-emission trucking when it unveiled the second version of its Project Portal hydrogen fuel cell electric Class 8 truck. The new ‘Beta’ truck significantly exceeds the capabilities of the ‘Alpha’ demonstrator revealed in 2017, with a 50 percent greater range of over 300 miles per fill. The truck has enhanced versatility and manoeuvrability with the addition of a sleeper cab and a unique fuel cabinet combination that further increases cab space without increasing the wheelbase.

Ricardo assisted Toyota with a wide range of engineering functions on both this vehicle and the previous Alpha demonstrator. These included systems integration and packaging, including the fuel cells, power electronics, hydrogen tanks, cooling systems, batteries, electric motors and transmission. Many of the ancillary systems that are traditionally driven by the engine were also electrified, including the air compressor, power steering and HVAC system, the controls of which required integration into the vehicle’s J1939 CAN BUS. Both the Alpha and Beta vehicles were developed by Ricardo at the workshops of its Detroit Technology Campus located at Belleville, Michigan.

Ricardo and the Toyota fuel cell electric truck

need to be balanced against the number of FCEVs in the market to support the stations and make them profitable. As the infrastructure grows, existing legislation adopted as far back as 2006 requires that a third of the hydrogen sold comes from renewable sources, currently the most aggressive clean fuel requirement in California. Hydrogen infrastructure developers are aiming higher than that, hoping to make hydrogen the best choice of alternative fuel and thus strengthening its commercial appeal. “A combination of robust government policy and this kind of commitment from the industry will drive down the cost and also accelerate a transition to 100 percent decarbonized hydrogen in the future,” says Elrick.

Diversity and scalability

One advantage of fuel cells over battery-only technology is their potential for diversity and scalability. Battery size, weight, cost and range effectively restrict the size of an electric vehicle and, in the case of a truck, its payload; there are no such restrictions with fuel cell systems. Fuel cell buses have been operated in California by SunLine Transit and AC Transit since 2000. These companies have developed the largest fuelling infrastructure and revenue operation for fuel cell buses in America. Fuel cell systems and the underlying technology are modular, too. The same stack could be used in more than one vehicle and more than one stack integrated into a truck or other applications. This scalability, modularity and flexibility will contribute to delivering economies of scale in fuel cell system development and production. Long-haul trucks carry freight state-wide and across borders to neighbouring states, while short-haul trucks operate in towns and cities. Both provide a perfect opportunity for expanding the hydrogen filling station network, creating consistent heavy-duty fuelling demand along freight corridors in regions such as Central Valley. As such, California’s highways have the potential to prompt rapid growth in hydrogen demand. Hydrogen filling stations for dedicated truck use will be complimented by multi-use stations servicing both light- and heavy-duty vehicles.

The relationship between trucks and fuel cells will also help accelerate improvements in air quality. Today, regions with the worst air quality often overlap with areas of heavy freight activity. Medium- and heavy-duty vehicles are known to be among the fastest growing sources of energy consumption and emissions. The CaFCP’s strategic plan for both light- and heavy-duty filling stations puts the nearest station within a 15-minute drive for 94 percent of the entire population of California and 97 percent of so-called ‘disadvantaged communities’ (those which suffer most from a combination of economic, environmental and health problems). It also means fuel cell technology can be expanded to a range of municipal vehicles such as school buses, garbage trucks and street sweepers, further improving local air quality.

Linking hydrogen and electricity production will help smooth out the peaks and troughs of renewable electricity production. Renewable energy can be generated from such sources as solar, wind, biogas or biomass – but the rate of supply can be intermittent. During periods when renewable resources are high and there is an excess of electricity available to the grid, using this surplus to generate hydrogen means the excess energy can be stored indefinitely. “CaFCP’s government and stakeholders intend to work with the California Public Utilities Commission, the California Independent System Operator and utilities to further develop this important link,” says Elrick.

Ricardo crunches the numbers

The key to achieving the CaFCP’s 2030 Vision is not just the availability of hydrogen but its cost, and also the cost of owning and running a FCEV. Ricardo has supplied its hydrogen refuelling cost and total cost of ownership (TCO) models to the CaFCP and its members. “We will be working with the CaFCP to understand how the 2030 Vision could have a positive impact on hydrogen fuel costs and significantly stimulate the hydrogen economy,” explains Marc Wiseman.

During the last few years, Ricardo has undertaken a number of studies aimed at better understanding how the demand for hydrogen use for energy storage and as a passenger car and commercial vehicle fuel will evolve. The research has investigated barriers to using hydrogen as a transport fuel. It also includes the production of detailed economic models for the hydrogen generation, storage, delivery and the dispensing as H35 (350 bar pressure) and H70 (700 bar pressure) hydrogen fuel. “The scope of the work also included calculating total cost of ownership models for FCEVs and a quantitative adoption rate model for use in assessing opportunities that lie in the commercial vehicle sector,” adds Wiseman.

The 35 hydrogen stations already installed in California are serving just over
5000 fuel cell vehicles. This equates to an average demand on those stations of around 80 kg per day. With an average station capacity of around 190 kg per day, utilization would be running at only 40 percent, although the range varies significantly across the state, with stations in core markets operating at near maximum utilization and those in remote or connector areas having low utilization.

Today, the price of hydrogen varies between $12 and $16 per kg, according to the CaFCP. California’s Low Carbon Fuel Standard policy offers credits to hydrogen suppliers which, if taken advantage of, could reduce the price by $4 per kg to a minimum of $8 per kg at today’s level of supply. Today, the main delivery method to the stations is by gaseous hydrogen in tube trailers.

**Fuel cost reduction is key**

Ricardo has also analysed hydrogen station capital and operating expenditure and identified the main factors influencing the price of hydrogen fuel. Low utilization of a station not operating at anywhere near full capacity is inefficient and more expensive. The price of hydrogen supply today is relatively high, with 30 percent of the retail hydrogen price dictated by the cost of processing and supply hydrogen to the stations. The operational costs associated with the hydrogen stations account for around a further 30 percent.

“As demand grows, hydrogen processing, supply and the operating efficiency of stations will rise, and prices will fall as a result,” explains Wiseman. The capital expenditure of filling stations is high today due to the low utilization of the equipment and contributes to about another 30 percent of the hydrogen cost. Fixed operational costs, such as site rental, insurance and maintenance, are estimated at 18 percent of the retail hydrogen price.

Those financial drawbacks today are encouraging in the sense that they give plenty of scope for improvement through scale of economy, as Ricardo’s analysis also shows. The CaFCP’s 2030 Vision of one million FCEVs served by 1000 filling stations again relates to 5 kg per week per vehicle, based on current average usage. That suggests a total daily demand of 714,000 kg per day of hydrogen so each of the 1000 stations would be consuming 714 kg per day. A station capable of dispensing 800 kg per day would therefore be operating efficiently at 90 percent capacity.

**Aligning supply and demand**

The impact of the improved operating efficiency and closely aligning supply with demand is that the retail price of hydrogen fuel could then fall towards $3 per kg. The reduction can be broken down into its component parts. Firstly, 90 percent utilization of filling stations, increased demand, and processing specifically for transportation could reduce the price to the station to 95-6 per kg. Further delivery and processing efficiencies and capital cost reductions would create the final reduction to $3 per kg.

“The impact this would have on sustainable transport would be significant, with high efficiency fuel cell systems produced in volume at a lower cost than today.”

**Dr Marc Wiseman, president, global mobility programmes at Ricardo Strategic Consulting**
An international consortium led by Ricardo has been awarded a four-year framework agreement to provide consultancy services to the European Investment Bank (EIB), supporting investment projects in the energy sector around the world. The appointment extends Ricardo’s relationship with the EIB, which already includes an ongoing project to provide institutional support and capacity building to the Power Division of the Ministry of Power, Energy and Mineral Resources in Bangladesh.

The Ricardo consortium will support the Projects Directorate of the EIB with a range of activities for its countries of operations, both within and outside the European Union. These will include performing technical, economic, financial, procurement, environmental and social appraisal and monitoring of energy projects. Assistance will also be provided in project preparation, implementation and institutional support for promoters, including undertaking major technical assistance programmes. Finally, expertise will be provided in engineering and economics for essential studies and research projects.

Led by Ricardo, the consortium includes BERNARD Ingenieure ZT GmbH of Austria, the National Renewable Energy Centre (CENER) of Spain, Danish Energy Management, and Sweco and WSP, both of the UK. Ricardo was chosen on the strength of the expertise and experience it offers in renewable and conventional power generation, energy efficiency, storage and networks, and pipelines. The consortium’s team of energy specialists has supported projects across Europe, the Mediterranean region, sub-Saharan Africa, Asia, South America, the Caribbean, and Pacific nations and territories.

**Solid-state EV battery research**

Ricardo is collaborating on the 30-month PowerDrive Line project, which started in October, in conjunction with project leader Ilika, the Centre for Process Innovation and University College London. The project aims to develop a lithium-based solid-state battery for EVs and PHEVs, and to establish a pre-pilot line for this solid-state battery cell technology, building upon Ilika’s Stereax® manufacturing experience.

The innovative solid-state battery technology will result in cells that are safer and have greater energy and power density, permitting ultra-fast charging such that PHEV or EV drivers can charge their car in as little as 15 to 25 minutes. Ricardo will design and construct a prototype battery module to demonstrate its potential in-vehicle performance.

The company will also apply its industry-leading expertise in EV Battery Management Systems (BMS) technology. Thanks to its high processing power and model-based control capability, Ricardo’s BMS approach is ideally suited to the evaluation of new and innovative cell chemistries: the careful monitoring and close control of every aspect of battery cell and pack performance is essential for effective development and evaluation. Ricardo will additionally develop the BMS to enable a capability for super- and ultra-fast charging at ratings of 50 to 350 kW, in a manner that can be demonstrated in the prototype battery module.
Edinburgh Trams award

Edinburgh Trams, the operator of the light rail system in the Scottish capital, was ‘Highly Commended’ at the Global Light Rail awards in the Environmental Sustainability Initiative category. The commendation was for the successful introduction of the SmartDrive system, a co-development between the University of Birmingham Centre for Rail Research and Education (BCRRE) and Ricardo Rail. SmartDrive applies a mix of train trajectory optimization analysis and on-site driver training to reduce energy costs on light rail, metro and self-contained heavy rail routes. The system is capable of delivering a reduction of up to 25 percent in traction energy costs.

The SmartDrive process begins with the modelling of individual routes to find the most appropriate train movement sequences under different scenarios, such as bad weather. This analysis becomes the basis for identifying where certain driving techniques – such as coasting and braking – can reduce energy use along the route. Once tested under true operational conditions, the evidence is compiled into a bespoke driver training programme specific to each route. With no in-cab display – and thus compatible with systems that use line-of-sight driving – the focus of SmartDrive is less on instructing drivers and more on empowering them to apply efficient behaviours as they see fit and when conditions allow.

For a typical 1.2 km tram journey on a section of segregated track, for example, SmartDrive has previously revealed how up to 500 metres can be travelled by coasting. Furthermore, the early pilot schemes have shown how drivers were often surprised by the coasting distance that can be achieved.

With more efficient transitions between acceleration, coasting and braking, passengers also benefit from smoother rides, whilst less frequent braking reduces wear and tear and thus requires less maintenance.

Simulation testing on the Edinburgh Tram network, as well as light rail systems in China, has demonstrated a potential reduction in traction power use of between 10 and 25 percent, offering the potential of significant energy cost savings.

Performance transmissions upgrades

Ricardo has announced upgrades to its transmission test and manufacturing facilities at the Midlands Technical Centre. The modifications to the centre’s test beds – which will be completed early in 2019 – will ensure that the company’s test capabilities are ideally suited to the demands of vehicle electrification, including for premium electric motorsport classes. The upgraded transmission test beds will be capable of simulating input speeds in line with the next generation of high-performance e-machines. While suitable for a broad range of transmission development applications, the first clients to benefit from the use of these upgraded test rigs will be a number of top-tier Formula E customers who have selected Ricardo transmissions from Season 5 onwards.

At the same site, Ricardo has also committed a further £1.5m to provide state-of-the-art spiral bevel grinding capability from Klingelnberg, building on the investment in leading-edge gear manufacturing machine tools announced earlier in the year. This latest round of investment also includes a number of additional machines to enhance capacity, as well as new design and quality assurance capabilities through the latest software upgrades including the KIMOS (Klingelnberg Integrated Manufacturing of Spiral Bevel Gears) package from Oerlikon.

Together, these investments in manufacturing technology and software will improve Ricardo’s capability to design, analyse, manufacture and inspect bevel gears within a closed-loop system, delivering optimized customer solutions with outstanding precision and quality. The benefits of this new technology will positively impact on nearly every aspect of Ricardo’s manufacturing work for motorsport clients from WRC through to LMP and GT, resulting in even higher standards of product quality and shorter lead times.
Ricardo has secured an order to assist Volvo Cars with the provision of a large-scale test programme to assess the lifecycle characteristics of a range of new lithium-ion cells to determine their suitability for various future production electrified vehicle applications.

This work builds upon Ricardo’s extensive experience and reputation in all aspects of electrified vehicle powertrains, serving a wide range of leading global customers. In terms of battery systems this experience ranges from partnering in research projects exploring the application of new cell types and chemistries, through to the execution of multiple design, development, testing and niche production manufacturing projects in the area of advanced electric vehicle battery packs and their control systems.

Ricardo Rail has been assisting UK regional rail operator Northern with an upgrade programme to its Class 158 trains, equipping them with on-board digital enhancements such as at-seat USB charging sockets and wi-fi. The first refurbished Class 158 entered into full service in September between Leeds and Lincoln and will soon be followed by more than 240 refurbished trains from across Northern’s fleet, including Class 150, 155 and 319 sets.

Ricardo has supported Northern’s rolling stock refurbishment programme since 2016, providing system integration services from the concept design stage through to detailed design and installation. To deliver the full scope of works Ricardo brought together a multi-disciplinary team – including rolling stock engineers, human factors specialists and EMC experts – to compile and produce the necessary technical designs and reports. These included initial installation concepts, design risk assessments, electrical schematics and wiring diagrams, as well as final drawings and documentation such as Modification Procedures and Maintenance Bulletins. Ricardo also carried out the approvals process, validating the systems and the design integration.

This Ricardo assistance helped ensure the new onboard digital systems – including CCTV, wi-fi, Passenger Counting, Passenger Media Information, Forward Facing Cameras and provision for a Driver Advisory System – were integrated into a single ethernet-based onboard network. This was to help minimize the number of antennae, communications hardware and sub-components, and enable a single sign-on to activate the systems.

Battery power for regional Dutch trains

In the Netherlands Ricardo has been collaborating with local design and consulting firm Arcadis on a feasibility study, commissioned by the northern provinces of Friesland and Groningen, to explore zero-emissions rail propulsion. The study concludes that by enabling batteries to recharge during standstill at turning points, and adopting one of two potential range-extension solutions, rail vehicles in the region could be operating entirely on battery power by the year 2025.

Focusing on this so-called ‘opportunity charging’ and complemented by a range-extender solution, the study shows that vehicles could operate a full timetable each day without the need to carry a large number of batteries. The study proposes two viable range-extender options: firstly, partial catenaries, which would be installed along stretches of the longer routes so that the trains can charge during operation as well as during station stops; and secondly, the use of hydrogen fuel cells to charge the batteries and/or directly provide the vehicle with power.

The study concluded that zero-emission trains are feasible in the region within the projected timescale. Both the provinces and the regional 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 required technical modifications.
Subscribe
to benefit from:

Industry news – the latest in technology, innovation and sustainability from across the world

RQ viewpoints – industry opinions from Ricardo experts in every sector from automotive and defence, to environment and rail

Interviews with leading technology developers, senior executives and industry thought leaders

In-depth features revealing the industry-leading projects in the Ricardo portfolio

Ricardo news – latest developments from across Ricardo’s global organization

Visit: www.ricardo.com/RQsubscribe
Testing for Euro 6 and Beyond

Ricardo’s new world-class Vehicle Emissions Research Centre (VERC) enables the development of the next generation of clean, low-carbon vehicles

- First UK facility to be accredited to the WLTP standard
- Bespoke testing service for certification testing to all levels including WLTP
- Extensive experience in testing for RDE robustness including custom cycles
- Vehicle benchmarking to all emissions levels
- Climate-controlled vehicle tests, with humidity regulation and configured for 4WD powertrains of up to 300 kW
- Advanced testing technology for hybrid electric vehicles
- Fully compliant with current global regulations, including Euro 6 and Tier 3, and incorporating additional capabilities in anticipation of regulations to 2020 and beyond
- State-of-the-art gas analysers for real-time measurement of CO, HC, O₂ and NOₓ plus both EGR and exhaust CO₂
- Fully integrated measurement capability for NOₓ speciation (FTIR) and detailed particle properties (mass, number, size)
- Supporting analytical capabilities compliant with next-stage European legislation (Full WLTP), including carbonyls, alcohols and greenhouse gases

Find out how Ricardo can help your product development.
Email: info@ricardo.com  Tel: (UK) +44 (0)1273 455611

automotive.ricardo.com/testing