Ricardo Quarterly Review **Q2** 2020

RQ

A focus on the latest in technology, innovation and sustainability

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Mercedes-Benz head of battery R&D on the world beyond lithium

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Prepare for the unexpected by exploring alternative scenarios

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Sustainable agriculture

How intelligent land management can keep quality up and emissions down

Creating a world
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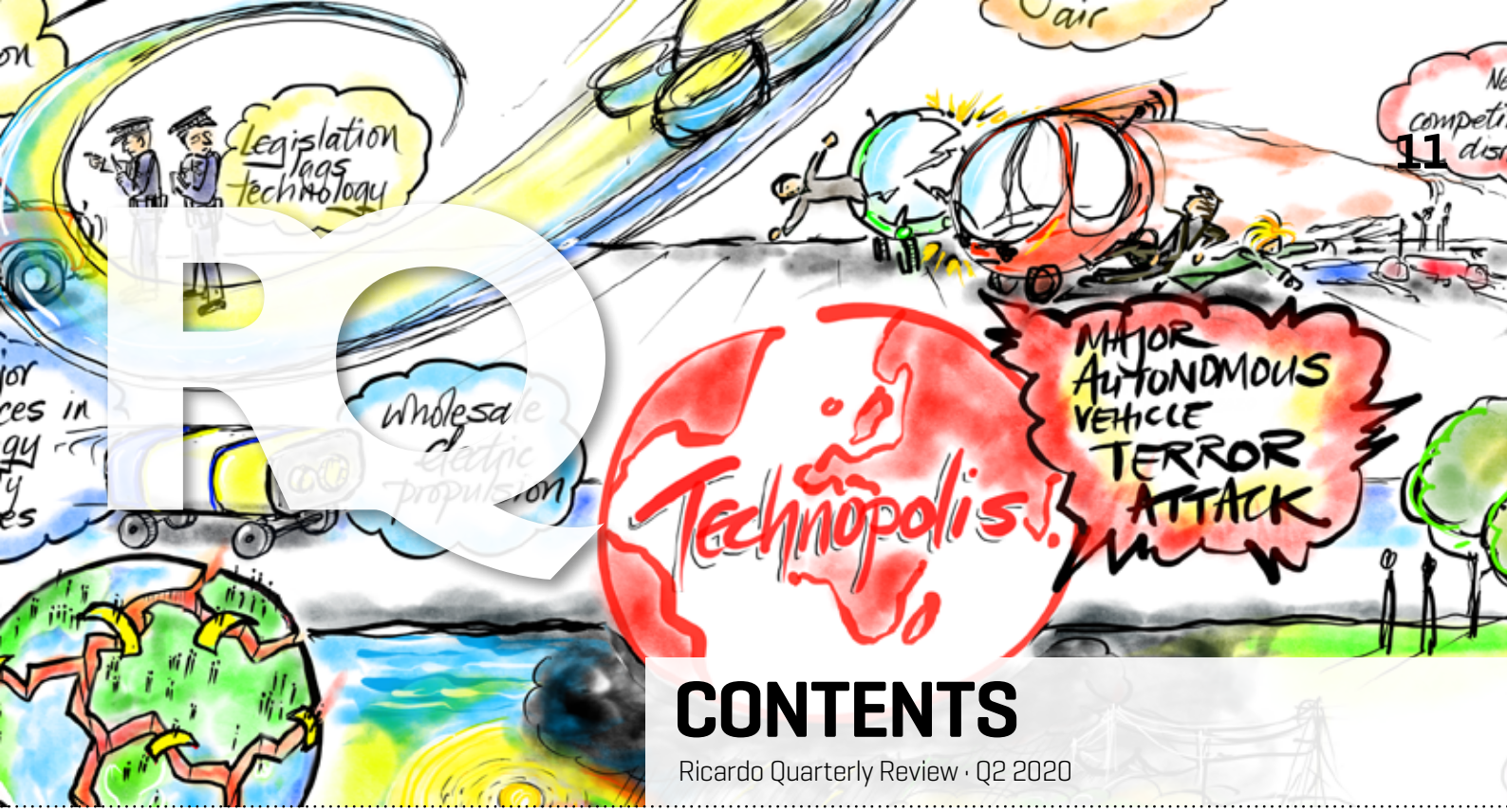

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RQ The task of RQ is to highlight the latest thinking in global engineering and technology in the transportation and clean energy sectors and related industries. We aim to achieve this by presenting an up-to-date mix of news, profiles and interviews with top business leaders, as well as in-depth features on programmes – both from within Ricardo and other leading companies.

Client confidentiality is of the utmost importance to Ricardo, which means that we can only report on a small fraction of the work carried out by the company. So we are especially grateful to those Ricardo customers who have kindly agreed to co-operate with RQ and allow their programmes to be highlighted in print: without such help from customers it would not be possible to present such a fascinating insight into the development of new products, technologies and innovations.

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RQ INDUSTRY NEWS

The latest in technology, innovation and sustainability across world industries

Covid-19: chance for blue-sky reset

An unexpected consequence of the near-complete shutdown of industries, workplaces and travel prompted by the Covid-19 pandemic has been a glimpse into a possible future world where harmful emissions are dramatically reduced.

In April, for instance, daily global emissions of greenhouse gases were 17 percent lower than in 2019, while in the locked-down EU the figure showed a fall of 60 percent. The European Environmental Bureau (EEB) reported a near-halving of NO_2 concentrations in several cities, and air quality across Asian pollution hotspots such as China and India improved markedly.

However, a report in Nature Climate Change also includes the stark warning that emissions risk rebounding beyond their pre-crisis levels if business as usual is restored, pointing to the sharp spike in pollution recorded in China after its lockdown was lifted in April.

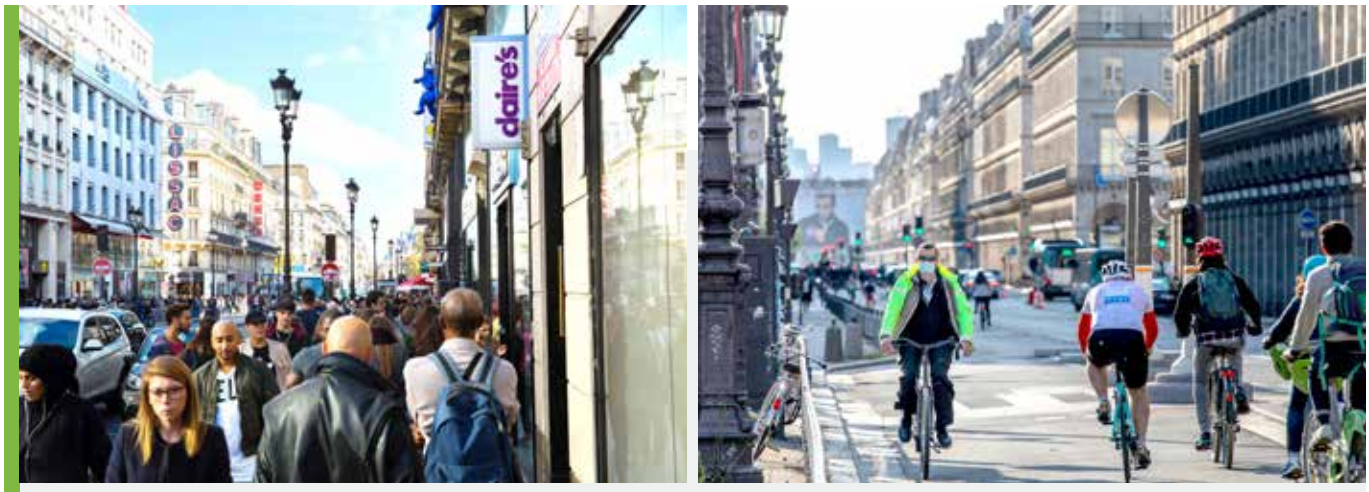
For this reason, European politicians and campaign groups are calling for any post-Covid recovery incentives to be linked to measures to improve the climate in parallel, and in late May the European Commission president Ursula von der Leyen proposed an ambitious €750 billion 'next-generation EU' green recovery plan.

The improved air quality under lockdown has led many people to think twice about returning to business as usual

Even at the time of writing, after just three months of lockdown, the primary and secondary impacts of the crisis are already off the scale of anyone's experience, and well outside the envelope of any existing economic modelling: oil prices, already on a downward spiral, briefly panicking into negative territory; millions of workers isolating themselves at home on furlough; bars and restaurants shuttered; aircraft grounded; and once-busy cities now eerily silent ghost towns.

Yet, amid all the uncertainty and the sorrow over the six-figure global death toll, one positive observation has been widely shared: the air has been fresher, the skies have been clearer, and city-dwellers have been able to breathe more easily. And it is this window of environmental clarity, though narrow and costly in today's terms, that is being seen as an unmissable opportunity to reset what is regarded as 'normal' and to emerge from the crisis greener and cleaner.

"This is an historic chance to rebuild Europe, creating secure, new jobs and building more resilience to future crises," said EEB secretary general Jeremy Wates. "How we respond to the corona crisis will decide whether we build a healthier, greener future or continue a dangerous descent into climate breakdown, further loss of biodiversity and more harmful pollution. The future of Europe is at stake."



Before and after: the exclusive Rue de Rivoli in the centre of Paris, streets jammed with traffic and sidewalks crammed with people prior to lockdown *(left)* **and with easy-going cyclists and pedestrians after vehicles were excluded under Covid-19 regulations** *(right)*

Crisis boosts case for renewables

The share of energy investment going into renewables could be set for a major boost if governments promote a green post-Covid recovery strategy rather simply allowing industries and businesses to return to business as usual.

Describing the crisis as "a historic shock to the entire energy world", IEA head Fatih Birol said that it was still too early to determine the longer-term impacts but that "the energy industry that emerges from this crisis will be significantly different from the one that came before".

In addition to wind and solar power, said the IEA, key stand-out technologies for decarbonization will be hydrogen-producing electrolysers and battery storage systems.

Germany is expected to remove some of its obstacles to expanding wind power, and the UK government will once again allow onshore windfarm construction.

Denmark's new climate package aims to cut the country's GHG emissions by 70 percent in the next decade. Its centrepiece is an ambitious scheme for so-called energy islands in the Baltic and the North Sea: each would generate more than 2 GW to triple Denmark's offshore capacity, and the North Sea site could be expanded to 10 GW and incorporate hydrogen conversion facilities too.

Big oil, big splits

With the price of crude in free fall, the oil industry was already on the ropes before the lockdown and before BP broke ranks in February to commit to a 2050 net-zero carbon target. BP has since been joined by France's Total and Royal Dutch Shell, though the latter shocked the establishment by cutting its dividend to shareholders for the first time in three-quarters of a century.

Conoco Phillips, a major US producer, announced a cut in output of one-third; top-five producer ExxonMobil, meanwhile, is under pressure from its own shareholders to reform its governance structures and to take greater note of environmental concerns.

What comes next?

In a traditional economic model, those businesses that survive a downturn usually seek to pick up where they left off, restarting factories, refilling supply chains and re-hiring staff. But the coronavirus crisis is different: not only has it been more abrupt and much deeper than the 2007-8 financial crisis, it is also a crisis overlaid on one that is bigger still – the climate emergency.

McKinseys summed up the situation in a recent report: "It now appears that recovery from the Covid-19 economic crisis will require stimulus programmes lasting for months or even years. Those coming months and years will also be a decisive time for efforts to keep global warming within 1.5°C to 2°C. Low-carbon stimulus measures can help policy makers fulfil both needs at once – but the clock is ticking."

The unprecedented €750 billion recovery plan proposed by the European Commission is a potentially big step in this direction, even though there will have to be compromises on how much of this cash will actually be geared to pro-climate objectives; in France, president Macron is clear that his €8 billion stimulus to the auto industry is contingent on boosting electrification and repatriation of high-value production into the country.

Back in the real world of June 2020, broad streets in the centre of Milan and Paris that were once jammed with traffic are now peaceful bike and pedestrian precincts, and the world has learned to appreciate remote working and videoconferencing, so many people will be reluctant to return to their pre-crisis commute. In fact, so many things have already changed that a rethink of the status quo is more feasible than ever before.

NEWS **IN BRIEF**

Highlighting the latest thinking in automotive engineering and technology worldwide

EuroNCAP raises bar for crash safety

Automakers will be faced with a tougher set of vehicle safety targets under EuroNCAP's new 2020 protocols. The biggest change will be the replacement of the familiar partial overlap deformable barrier test with a new crash test involving a moving barrier impacting the moving subject car. The procedure is designed to improve vehicle-to-vehicle compatibility by showing how a car's frontal structures contribute to injuries in the collision partner vehicle.

All Volvos to be speed restricted

In 2019 Swedish automaker Volvo promised that in the interests of safety it would implement a blanket speed restriction across its whole model portfolio. All models are now capped at 180 km/h [112 mph], and in addition the cars come with a so-called Care Key which allows owners to further restrict top speed if the vehicle is being used by younger or inexperienced drivers. Volvo did not say whether the speed restriction would apply to its eco-focused Polestar performance sub-brand.

Best-seller surprises

What was 2019's top-selling sports car? Not, as many might expect, the neat and agile Mazda MX-5 or the popular Audi TT. Instead, it was Detroit's Ford Mustang that took worldwide honours, with over 100,000 finding buyers. And Volkswagen's biggest hit? For once it was not the Golf, but the Tiguan compact SUV, which shifted over 900,000 units.

Europe's big bet on batteries

European companies and governments committed more than €60 billion on batteries and electric cars in 2019. This figure, says Transport & Environment, is more than three times the investment undertaken in China, and will be reinforced by Tesla's new venture near Berlin. T&E's report highlights alliances such as those between Volkswagen and Northvolt, and SAFT within the European Battery Alliance initiative. Northvolt and Norsk Hydro subsequently announced that they would team up in a battery recycling plant – a key element in reducing the lifecycle carbon footprint of automotive batteries.

Rail freight is clean freight

Newly independent after having separated from the main SNCF organization earlier this year, France's Fret SNCF has appealed for a "Marshall Plan" to encourage a shift of goods transport from road to rail. It has called for revised timetables and a revision of the national rail infrastructure.

Lock-in for Tesla carjacker

Germany's *auto, motor und sport* website reports how a Californian Tesla Model 3 owner had the last laugh after a carjacker forced him out of his vehicle and drove off in it. Reaching for the Tesla app on his smartphone, the owner selected the Shutdown function to remotely cut the motor and lock the doors. He then called the police, who arrested the drug-influenced thief – who had not realized that, for safety reasons, the doors could still be unlocked from the inside.

Climate crisis: no let-up

Locked-in global heating may mean polar ice keeps on melting even if GHG emissions are stemmed

The North Pole will be ice-free in summer before 2050, according to a new study - but the extent and frequency of the melting will depend on the trajectory of future GHG emissions. The McGill University paper, prepared in collaboration with 21 other research institutes, analysed 40 different climate models and made the point that some simulations even showed summer sea ice disappearing with a falling GHG path.

At the opposite end of the temperature spectrum, Texas A&M University specialists focusing on south-east Asia predict that extreme heat events will increase in frequency by 75 percent by 2050 to 78 days a year; even more worryingly, incidents which combine extreme heat and extreme levels of particulate matter will go up by 175 percent.

Additionally, a team at Virginia Institute of Marine Science has concluded from a study of the Ganges and Brahmaputra in India that rising global temperatures will lead to a wetter climate, which in turn will enhance soil respiration and decrease stocks of carbon in the soil, releasing CO_2 and giving a further twist to the global warming spiral.

On a more hopeful note, Princeton scientist Meiyun Lin claims to have cracked the mystery of why Europe's concentrations of harmful ground-level ozone remain persistently high, despite legislation designed to cure the problem. Her team concluded that higher temperatures and dry weather were stressing the region's plants, hampering their ability to extract ozone from the air.

Mixed messages on fuel cells

The tide appears to be flowing both ways when it comes to the suitability of hydrogen fuel cell powertrains for passenger cars and trucks. Earlier this year, Volkswagen briefed strongly against the application in cars, claiming much superior overall efficiency for pure battery systems. And, more recently, Daimler announced that it was abandoning development of fuel cell systems for its Mercedes-Benz passenger cars, though the company has also announced tie-ups for heavy vehicle fuel cell development.

Yet BMW, which has partnered with Toyota, continues to promote its hydrogen car programme, with the X5-based i-Hydrogen NEXT technology demonstrator and the promise of production versions around 2022. "Hydrogen fuel cell technology could quite feasibly become the fourth pillar of BMW's powertrain portfolio in the long term", said research chief Klaus Fröhlich: "The upper-end models in our extremely popular X family would make particularly suitable candidates here."

Hyundai is another strong believer in light-vehicle hydrogen power, as are Toyota and Honda. In the heavy duty arena Toyota and Hino are developing a fuel cell medium truck, based on the 25-tonne Hino Profia *(pictured)* and with a range of 600 km, while two of the truck world's biggest hitters – Volvo Group and Daimler Truck AG – have founded a joint venture aiming to develop, build and market heavy duty hydrogen commercial vehicles "in the second half of this decade".

Shortly after that announcement, Daimler Truck AG made public a further tie-up – with aero engine and power systems supplier Rolls-Royce plc – for the development and sale of fuel cell systems for stationary power generators.

All at sea on marine power

The clean ships of tomorrow will be powered by e-fuels – or hydrogen, or batteries, or the sun, or sails and the wind. Even ammonia is under consideration.

Now, with the maritime industry responsible for up to 3 percent of global carbon emissions and committed to a 50 percent reduction by 2050, new technologies are getting more attention and stakeholders such as Lloyds List are seeking to accelerate the change.

Norwegian operators are some of the leaders in the field. Battery-hybrid ferries are already in service on some short routes; the Yara Birkeland coastal container ship project is trialling both battery power and autonomous control; and the ocean-going Eidesvik Viking supply vessel, due to launch in 2024, will run on ammonia-fed fuel cells.

One of the highest-level deals so far is that between ABB and Hydrogène de France for a "megawatt-scale" hydrogen fuel cell powerplant *(pictured below)*. Based on Ballard stationary power technology, it will be manufactured in France.

While San Francisco's promised fuel cell powered ferry has yet to enter service, Japan-based Eco Marine Power is advancing trials of its marine renewable energy solutions, including the EnergySail. This employs large arrays of solar cells on multiple rigid deck-mounted sails that are computer controlled to extract the maximum possible energy from the sun and the wind.

Eco ideas to save CO_2

For proof that legislation can spur innovation, look no further than the latest wave of technologies to feature on European models as automakers race to bring down their fleet average CO_2 emissions and avoid punitive fines from the EU authorities.

Among the most recent examples are Hyundai hybrid models' deletion of the heavy conventional accessory battery in favour of a 'partition' within the main traction battery, and sister brand Kia's industry-first adoption of a by-wire e-clutch on manual versions of its new Rio 48V mild hybrid. Claimed CO_2 reductions are between 8 and 11 percent.

BMW's extensive raft of revisions for the 2021 model year will see CO_2-saving 48V technology applied to a further 37 models; 14 models, including the new 5- and 3-Series, already have the system. The company has developed a new six-cylinder diesel engine, also teamed with 48V hybrid technology: the twin-turbo unit now features 2700-bar injection pressures and two-stage SCR NOx reduction.

VIEWPOINT

Why virtual certification may be the new normal beyond Covid-19

Richard Murphy, director of test operations, Ricardo Automotive & Industrial

If necessity is the mother of invention, there can be no better proof than the development and implementation by Ricardo of its virtual certification testing capability.

Throughout the early part of 2020 the world has been faced with a wave of national and regional lockdowns on commercial and industrial activity. First this affected the major cities and regions of China in January, but by late March and early April lockdowns were in place across Europe and much of the rest of the world. These forced the temporary closure at short notice of a large proportion of the testing and certification capacity of the world's automotive industries. Like many testing providers, we at Ricardo faced the prospect of a complete shutdown of operations – or, as an alternative, we could seek a new way of continuing to provide a testing serving in a safe and socially distanced manner.

A major obstacle to achieving this for vehicle and equipment certification testing – an essential element of the automotive type approval process – is that the work typically requires operatives from three organizations to be present. In addition to the Ricardo team executing the tests, representatives both from the official witnessing body and the automaker will typically be on site. In the first week of the UK lockdown in late March, however, we were able to use Ricardo's digital-first IT infrastructure to create and rapidly implement a virtual vehicle certification service.

Our approach enables both customers and independent witnessing bodies to observe tests remotely and to validate quality checks that replicate processes (such as checking tyre pressures) which would usually be done in person. This enables the witnessing body and the client representatives to participate fully in the test and certification via a secure connection, thus removing the need to travel. The client merely needs to arrange shipping of the vehicle to the Ricardo test facility: all other interactions throughout the test and certification process are conducted remotely.

The first virtual certification tests were carried out in March 2020 at our Shoreham Technical Centre on behalf of a UK automaker, and were independently witnessed by a European agency. This service has now been expanded to take in testing carried out at the Midlands Technical Centre too, and also to include the regulatory testing of electrified powertrains and their power electronics systems.

"As well as helping customers maintain a flow of crucial vehicle certification work during the Covid-19 lockdown, the new process has significant advantages that are likely to endure beyond the current restrictions"

In addition to providing a means for customers to maintain a flow of crucial vehicle test and certification work during the Covid-19 lockdown, the new process has significant advantages that are likely to endure beyond the current restrictions. As a result of completing the review of the facility, it has been possible to identify significant elements that can be completed remotely and in advance of testing.

Even after the Covid-19 crisis is over, this new approach may be attractive both to customers and to witnessing authorities, particularly where the additional flexibility might be of value due to time restrictions, schedule congestion, or a requirement to collaborate across different time zones.

In my view, the benefits of virtual vehicle and powertrain system certification will remain just as attractive to clients long after Covid-19 and the requirements of workplace social distancing become a thankfully distant memory.

RQ INTERVIEW

The world beyond lithium

Battery technology will be key to every automaker's survival and prosperity over the coming decades – and few companies are doing more R&D on this than Daimler's Mercedes-Benz division. In a recent interview **Professor Andreas Hintennach**, head of battery cell research, explains how manganese, silicon, sulfur, air and even organic cells could be part of tomorrow's batteries

You are working on the research and development of batteries. How is Mercedes-Benz tackling this topic?
Battery technology is a key element of electric mobility: it isn't an off-the-shelf product but an integral part of the vehicle architecture. Therefore we cover all stages from fundamental research to production maturity. Our activities include the continuous optimization of the current generation of lithium-ion battery systems, the further development of cells available on the world market, and research of next-generation battery systems. We are also working on the battery management system, which is a complex computer that you can always improve on. Thermal management is an important topic as well. It is responsible for the life and also the performance of the battery pack. You have to really understand the mechanism of technologies in order to be able to make the right decisions.

What is your current focus?
While our all-new EQC model is being introduced to the markets, we are preparing the way for next generations of powerful battery-electric vehicles. Lithium-ion batteries are the most common type used in electronics and electric vehicles today. In the years ahead, this technology will continue to set the pace – but there is more to come. Regarding research and development, we follow several specific guiding principles. We are consistently working on innovation and alternatives beyond lithium-ion – not least regarding energy density and charging time, but also sustainability. For example, we have agreed on a sustainability partnership with Farasis Energy to take a holistic approach along the entire value chain.

So it is more than just about increasing the kWh per battery pack?
Energy capacity is important, of course. But there is more to it: safety is a very decisive factor for us. Material-related changes could make it possible to obtain a higher capacity – but with compromises in terms of safety. For us, this is definitely out of the question. A Mercedes-Benz has to be the benchmark when it comes to safety, and this also goes for its battery pack. One of

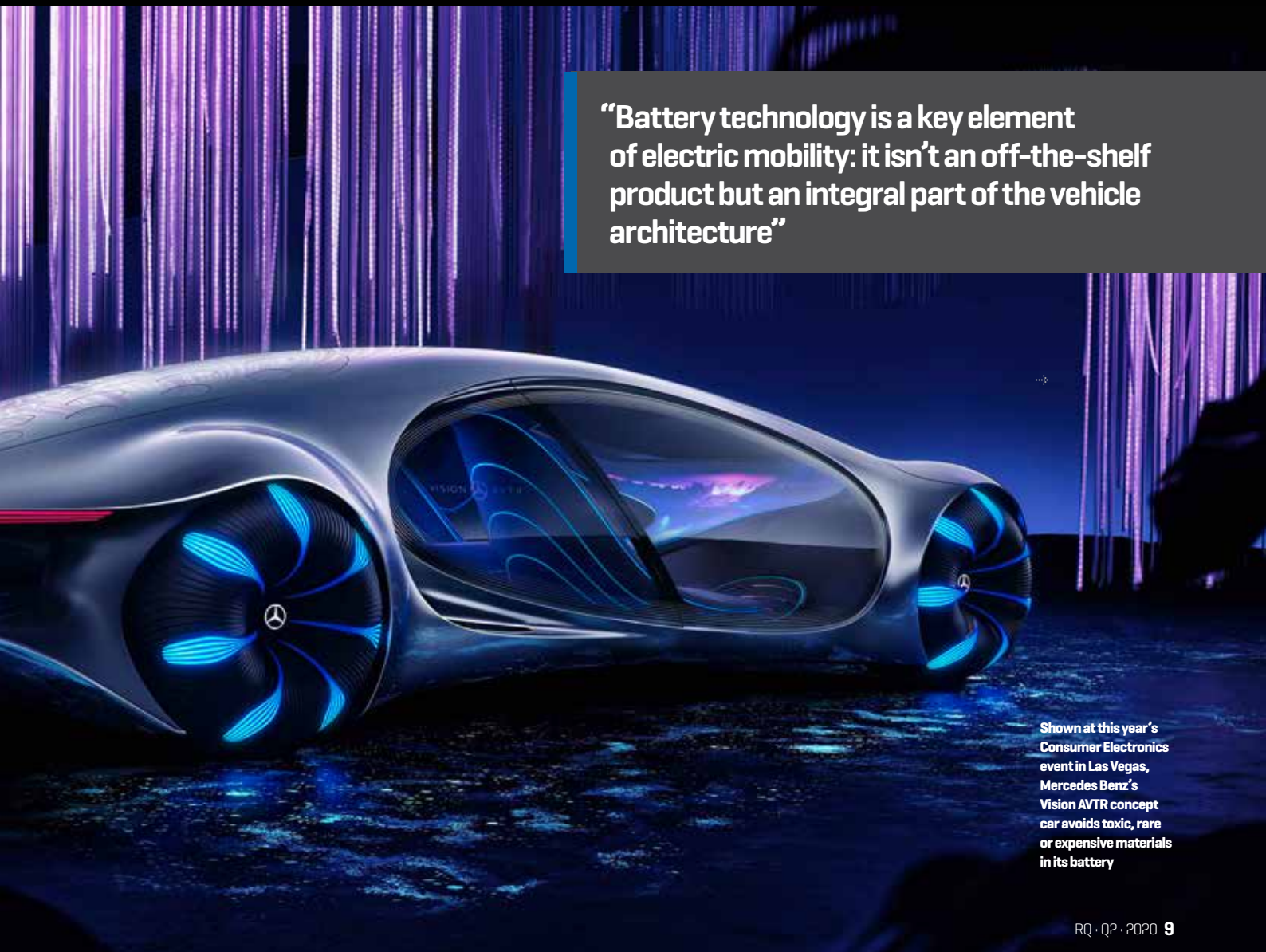
our guiding principles of development is also flexibility: at Daimler, there are a lot of use-cases for battery packs, from the smart to Mercedes-Benz cars and vans, to buses and heavy trucks, and finally from 48-volt mild hybrids to plug-in hybrids and purely electrical cars. And of course, the solutions we come up with must be sustainable.

How important is sustainability in development?
Sustainability has become the overarching principle for any development activity at Daimler. Since the manufacture of vehicles naturally requires a high amount of raw materials, one of our development focuses is on minimizing the need for natural resources, but also to increase transparency. During development, we create a concept for each vehicle model in which all components and materials are analyzed for their suitability in the context of a circular economy. Concerning batteries, this concept is already used for fundamental research in which rare materials can be substituted, minimized or used more efficiently. What's more, recyclability is already taken into account from the beginning. So battery production becomes a part of a holistic approach – a closed loop, a so-called circular economy.

Electric propulsion has a bigger impact than combustion engines when it comes to production. What is the environmental impact of electric vehicles?
The production of the internal combustion engine (ICE) has been steadily improved over the past 133 years. The battery and the fuel cell, on the other hand, currently start life with more emissions due to the increased energy requirement. However, in terms of operation they are both much more efficient than ICEs. And that pays off in the long run. Even if we do not charge them using CO_2-neutral electricity, battery-powered vehicles generate around 40 percent fewer emissions over their lifecycle than vehicles with gasoline engines, and 30 percent less than diesel-powered vehicles. And in this calculation, our target CO_2 reductions for production by 2039 and the recycling of raw materials that will be incorporated into the production cycle in the future are not even taken into consideration. Both will further improve the sustainability of our vehicles holistically, and in so doing contribute to our "Ambition2039". Today, our vehicles are already 95 percent recyclable.

What materials are used in the battery?
With lithium-ion technology the cell structure is always similar, regardless of whether it is a cell phone or an EV battery. There are always two metal sheets, such as copper and aluminum. Between the metal sheets are the two poles with the cathode and anode, between which the electric reaction takes place. For the reaction, a reactive metal such as lithium is required. The biggest cost factor is the composition of the cathode, meaning the positive pole of the battery. It consists of a mixture of nickel, manganese and cobalt. The anode is made from graphite powder, lithium, electrolytes and a separator.

"Battery technology is a key element of electric mobility: it isn't an off-the-shelf product but an integral part of the vehicle architecture"



Shown at this year's Consumer Electronics event in Las Vegas, Mercedes Benz's Vision AVTR concept car avoids toxic, rare or expensive materials in its battery

And where does the silicon you mentioned come into play?
Silicon will largely replace graphite powder in the future. This will enable us to increase the energy density of batteries up to about 20 to 25 percent. Silicon allows us to use materials on the cathode side that are not compatible with the graphite that is currently used.

What will replace cobalt and other materials like lithium?
They are materials that are mainly based on manganese - a raw material that is less troublesome from an ecological perspective and easier to work with. Excellent recycling facilities are already in place for manganese because it has been used for decades in non-rechargeable alkali batteries. The task for researchers is to make this type of battery chargeable. We expect the technology to be ready for market by the second half of the 2020s. Another alternative is the lithium/sulfur battery. Sulfur is an industrial waste product with almost zero cost that is very pure and can easily be recycled. It poses significant challenges with respect to energy density, but also has an unbeatable eco balance. However, it may take years until this technology is available for passenger cars.

Lithium is also the subject of criticism. Can this raw material also be replaced?
It can. The magnesium-sulfur battery, for example, contains no lithium. We are familiar with magnesium from our everyday lives in the form of chalk. The big advantage is that it is freely available; however, our research is currently at a laboratory stage.

So there are no alternatives to the lithium-ion battery at present?
There are, in some applications. There are even technologies that are superior to the lithium-ion battery. These include the solid-state battery, which we will be using in our Mercedes-Benz eCitaro urban bus within the second half of the 2020s. The technology has a very long lifecycle, and also does not include any cobalt, nickel or manganese. However, its energy density is lower, which makes it relatively large and slow to charge. That is why it is good for commercial vehicles but not for passenger cars. The lithium-ion battery will be with us for years to come.

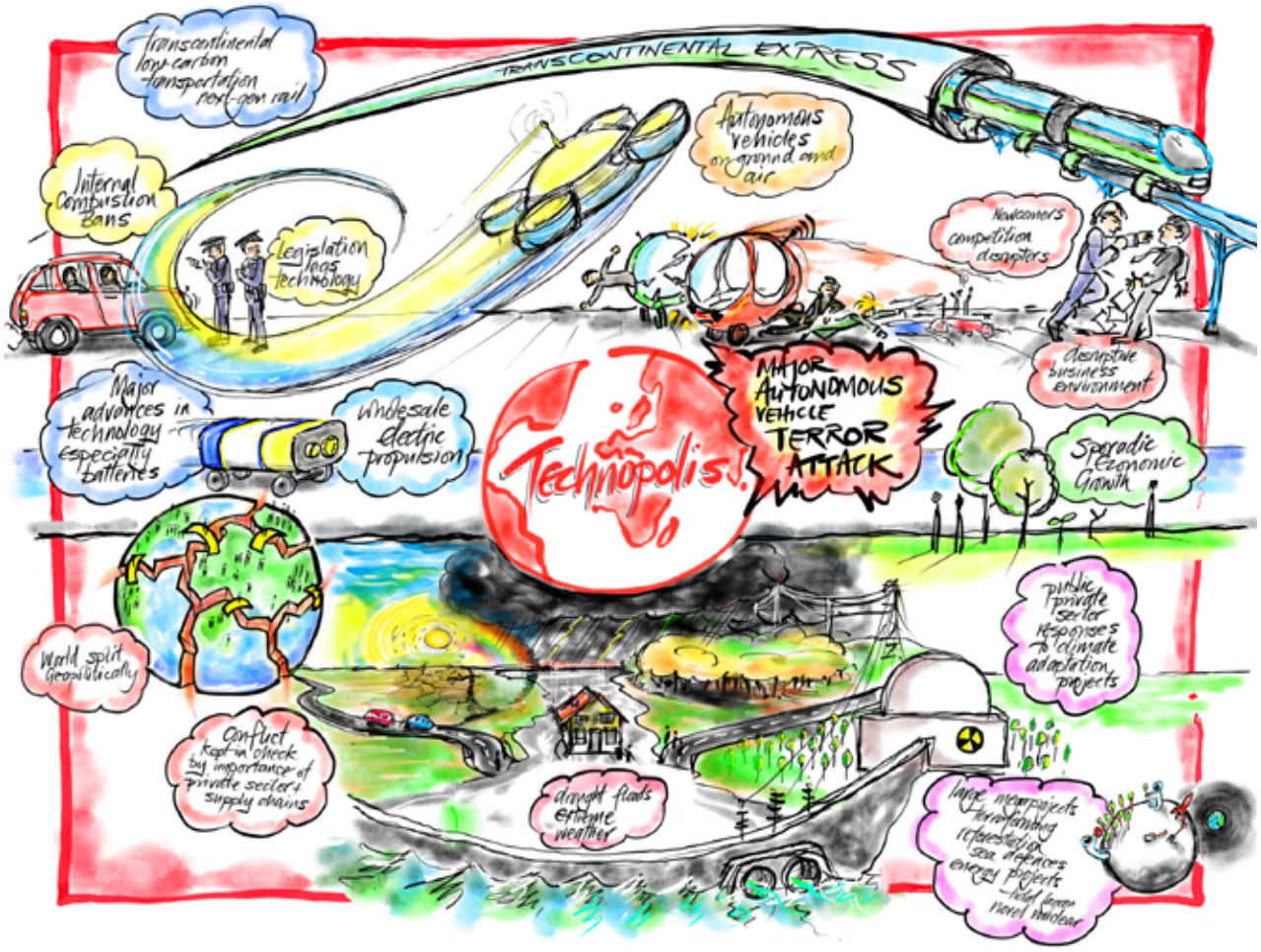
A future zero-emissions urban scene, as envisaged by Daimler and featuring electric bikes, city cars, SUVs, buses and trains

What will be the next holy grail? Are solid-state batteries the future?
There is not one single post-lithium-ion technology. Be it cells with solid-state electrolytes, lithium metal anodes, or lithium sulfur systems, all technologies differ in their specific material requirements, their applications and not least their level of maturity. Each technology has its specific pros and cons. The good news is that there are multiple paths which lower the risk of a potential dead-end road in development. Not quite around the corner – but also not very far down the road – are batteries in which the graphite coating of the anode can be replaced with novel materials such as lithium-metal foil or silicon powder. Both increase energy density significantly. This leads to higher range and could even support fast charging. All solid-state batteries have great advantages when it comes to safety, but we are still working on fast charging and a longer lifespan before we can say "this is the technology we should bring to the road now" regarding our passenger cars.

And what will happen further down the road?
Lithium-sulfur is one possible alternative. Replacing the nickel and cobalt of today's batteries with sulfur would significantly increase sustainability. The energy density also has a lot of potential, but the lifespan is not yet long enough and it will take a while until there is a breakthrough in this area. In lithium-air batteries, there is really only lithium. The rest – the oxygen – simply comes from the air. Chemically, it's a concept similar to what you have in a fuel cell, where we are using hydrogen. The energy density would be outstanding – but this technology is still quite a long way away.

With your research car VISION AVTR you went one step further, far beyond tomorrow. Is organic battery technology really an option?
With the VISION AVTR, Mercedes-Benz is presenting a sustainable vision of emission-free mobility – also when it comes to drive technology. For the first time, its revolutionary battery technology consists of organic-cell chemistry based on graphene and thus does not use any rare, toxic or expensive materials such as metals. This makes e-mobility independent of fossil resources. An absolute revolution is the 100 percent recyclability through composting due to the materiality - a prime example of a future circular economy in the raw materials sector. In addition to an exponentially high energy density, the technology also impresses with its exceptional quick charging capability. Organic batteries are currently part of our fundamental research. It will still take several years until it can be established in Mercedes-Benz vehicles - but the potential is there.

Prof. Dr. med. Andreas Hintennach, senior manager of battery research at Mercedes-Benz AG
A chemist and medical doctor with multiple PhDs, Hintennach studied at ETH Zurich, the Paul Scherrer Institute, the University of Bern and Ludwig-Maximilians-Universität in Munich; and he completed an MBA and PhD in Economics and Business Administration from the HSG University of St. Gallen and the University of Zurich. After a postdoc stay at MIT in the field of lithium-air and catalysis in 2010-11 he joined the research department of Mercedes-Benz AG. In 2013 he was appointed assistant professor and in 2014 full professor in medicine. His present focus in the field of electrochemistry is fundamental research on next-generation electrical energy storage and conversion materials and systems.



Prepare for the UNEXPECTED

Coronavirus lockdown; crumbling international trade; oil prices plunging below zero: huge blows that have caught the business establishment off guard. But in this new world of spiralling uncertainty, help is at hand in the shape of a collaborative process which future-proofs organizations to prepare for the unexpected – whatever that might prove to be. **Tony Lewin** reports

Shocks to the system don't come much bigger than Covid-19. It has taken most countries and most organizations completely by surprise: few, if any, had any inkling that such a calamity might be just around the corner.

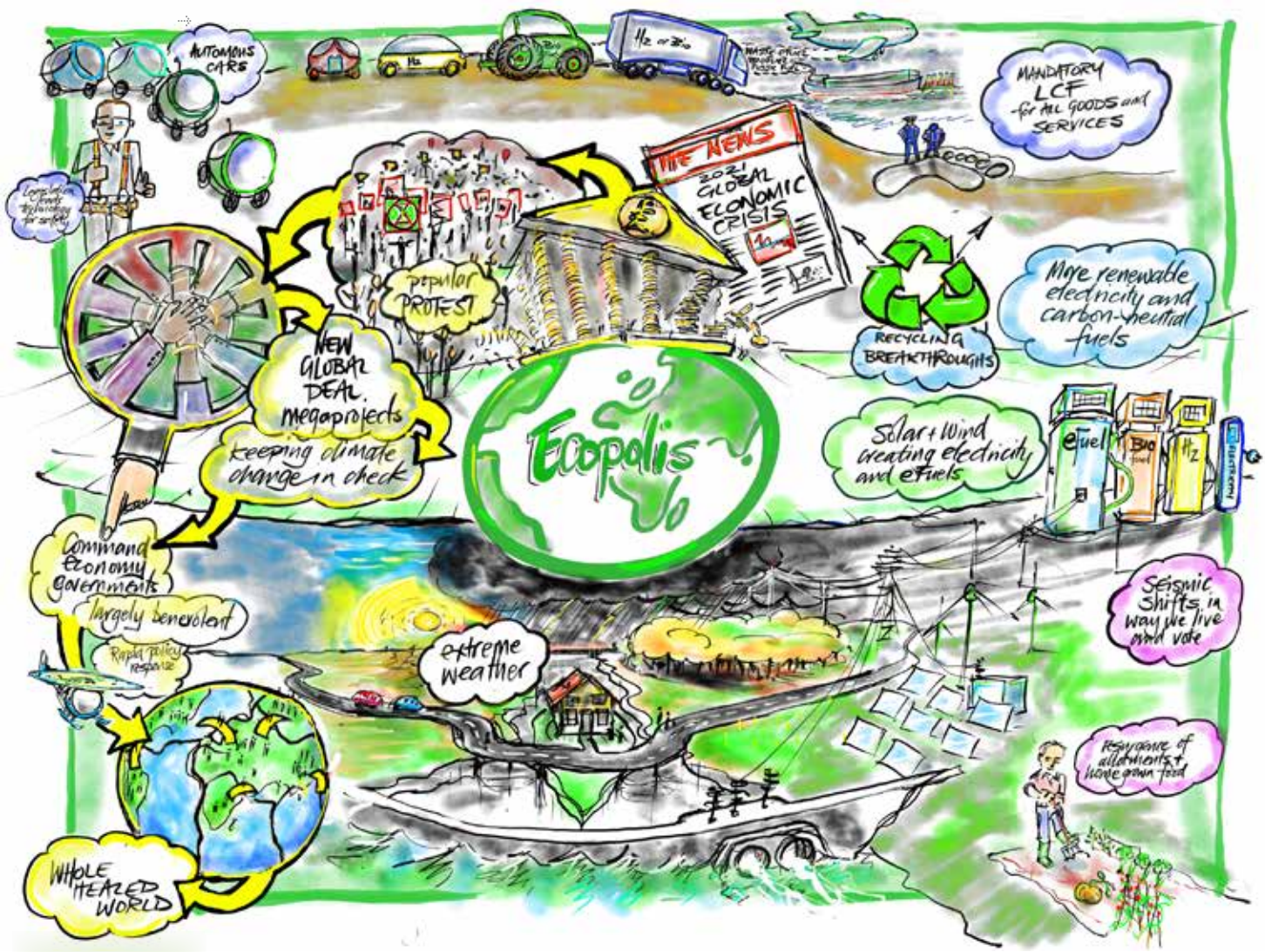
Yet even though nobody had prior warning of the outbreak, that doesn't mean that no one was prepared for it. While some countries spent several weeks locked in indecision before settling on a course of action, others – Germany and South Korea are prime examples – were able to respond swiftly and decisively. The temptation is to conclude that while some were flying blind, the fortunate few had a ready-made plan.

History may one day reveal who did and who did not have a plan, but one thing is for certain: while no one can ever tell precisely what is going to be around the next corner, modern management techniques such as scenario planning can do a tremendous amount to enable organizations to anticipate cataclysmic events and to be prepared for them when they do occur.

Likewise, some companies are better prepared than others: Ricardo, for instance, has had pandemic flu high on its risk register for several years.

"You cannot predict the future," says Carl Telford of Ricardo Strategic Consulting, "but you can plan for it." What scenario planning can do, he explains, is help organizations explore how they might respond in the face of a range of different hypothetical future shocks or upheavals – anything from the collapse of the global internet infrastructure to a major crisis in food supply or, like now, a major health crisis.

The far-reaching consequences of the coronavirus crisis have shocked the whole world and are prompting many more organizations to look closely at how they plan for the future. Gone, says futures research lead Telford, are



The hypothetical Ecopolis scenario for 2035 envisions a largely harmonious society following a decade of environmental consensus and the greater personal security of a universal basic income. Earlier splits and divisions are healed, and mandatory lifecycle footprint accounting has come to dominate decision making at all levels. Voters took a collective mindset to elect pro-climate governments, and the Amazon and residual Arctic and Antarctic are protected as global parks. Under the imagined Technopolis scenario *(previous page)* **technology advances run riot, benefiting private companies and privileged individuals but also diminishing the role of governments and bypassing the less well off - who are hit hardest when a New World plague strikes the Americas.**

the days of simple one-track linear projections: interest in the much more agile strategies unlocked by Ricardo's scenario planning process is ramping up and the RSC team is deploying scenario planning in more and more projects.

Ways of looking ahead

Traditional ways of planning for the years ahead tend to be linear and tightly focused in their view, relying on mathematical extrapolation from earlier performance and perhaps a best-guess estimate of how a particular market might evolve.

More sophisticated market forecast and roadmapping techniques, as practised across wide swathes of industry, are largely technical in nature and juxtapose upcoming legislative steps with engineering developments known to be in the pipeline. But again, as Telford points out, roadmaps can fall into the trap of regarding each sector as a closed system and cannot easily take account of external impacts and wildcard influences.

Many organizations employ external agencies to look at emerging trends and developments, hoping to get early warning of shifts in the market or consumer tastes over a horizon of perhaps five to ten years. Yet, critically, none of these approaches are capable of generating useful signals of a growing trend that might escalate into a full-blooded crisis: more critically still, none can provide messages clear enough to jolt companies into preparing themselves for an upcoming impact. Only through deeper and more interactive processes such as scenario planning can organizations do the groundwork to ensure they are resilient in the face of any major shocks that might come their way.

"Only through deeper and more interactive processes such as scenario planning can organizations do the groundwork to ensure they are resilient in the face of any major shocks that might come their way"

Dealing with shocks

What if the oil industry implodes because of collapsing prices? Or hackers hold the international banking system to ransom, disabling it permanently? Each would trigger a significant crisis among governments and businesses, and taking the necessary difficult decisions in haste in the midst of that crisis might not result in the optimum outcome.

In an acute energy crisis, for instance, an oil company would be likely to suggest a solution involving fossil fuels; renewables engineers would be equally likely to promote their own technologies, and chemicals specialists would see laboratory-derived e-fuels as the answer.

The need-to-know of scenario planning

Seven simple steps to shockproof your company

1. **Interactive workshops decide future corporate goals and scope, and list factors which may impact the company**
2. **Further interactive sessions determine how likely and how impactful each factor might be**
3. **Factors are placed on an 'an axes of uncertainty' grid to generate a wide range of possible future scenarios**
4. **The most extreme and challenging of these scenarios are selected for further exploration**
5. **Chosen scenarios are vividly illustrated and described in narrative stories**
6. **Each scenario is matched against proposed corporate strategies to gauge their fitness for future conditions; responses to scenarios are rehearsed and potential product opportunities identified**
7. **Real-world events are monitored to gauge which of the hypothetical scenarios is looking the most likely**

Unconscious bias towards their own speciality may lead different experts to give conflicting answers, and if the crisis is of such a magnitude that it threatens the survival of a whole industry or sector, those working within that sector may stubbornly deny the inconvenient truth that their organization's days might be numbered.

For automotive companies, for instance, the prospect of a widespread take-up of autonomous urban mobility systems might be seen as an existential threat to their business model, further polarizing the internal debate.

Within an organization, says RSC senior consultant David Abdulmasih, scenario planning can enable an opening up of the internal dialogue under less urgent non-crisis conditions: "Rather than actually directing the planning itself, scenario work can stretch people's thinking and catalyze new solutions that take a higher level approach that can command much greater consensus," he says.

And though, as we will see below, the nature of each hypothetical crisis explored in the scenario process might be quite different, there can be strong similarities across all acute events in terms of the response mechanisms that might be required. This in turn further strengthens the case for overall preparedness.

Scenarios in decision making

Scenario planning has a long history, though much of that history is shrouded in secrecy as the technique was first developed by the semi-clandestine US Rand Corporation during the Cold War. In the 1960s Shell made extensive use of scenarios, as did some other organizations, including the Pentagon and the US government through its five-yearly Global Trends reports developed by the National Intelligence Council.

Today, the use of scenario processes has spread more widely across industries, NGOs and government bodies. BMW is known as a high-profile user and in May this year even headlined a media announcement "BMW Group plans for various scenarios and can react swiftly to new developments". It explained: "The Group is well prepared to react swiftly and decisively at all times to new developments during the corona pandemic by systematically identifying potential scenarios... The BMW Group is developing strategies for various scenarios and is prepared to take additional measures to safeguard its financial position and use its underlying strength to steer itself through this challenging phase."

"In no way does the pandemic call our business model into question," said Oliver Zipse, chairman of the company's board of management. "Driven by technology and innovation, our business model will remain future-proof after the current crisis has ended... we are monitoring developments extremely closely to be able to respond with maximum flexibility."

This relatively confident voice contrasts with the much more cautious tone adopted by many automakers in their announcements, with most declining to give any guidance on future business performance.

How scenario planning works

The BMW announcement referred to above encapsulates all the key outcomes of a scenario planning process. Even today, at a time of great industrial instability, the company has the reassurance of knowing it has explored a wide range of worst-case events and situations, and that it has prepared strategies to cope. Its "monitoring [of] developments extremely closely" shows that it is watching very carefully to see how the situation evolves and which of its imagined scenarios is most closely reflected in what actually transpires – another essential tenet of the technique. And while the claim to be "future-proof" may smack of corporate PR bravado, it does contain more than a germ of truth as most eventualities have likely been considered, and responses prepared for each one.

But how does the process operate within an individual organization? Firstly, it is an interactive process throughout, with free information sharing between participants and external advisers such as Ricardo, if they have been brought in.

The customer initially decides the decision focus, effectively framing what kind of things need to be decided and how broad a scope the vision should have. Next, a series of workshops at different levels brainstorm all the upcoming forces and factors that could influence the company's business; further interactive sessions will look at each of these forces to establish which are the most likely and which will have the biggest impact on the company's operations. Factors taken into consideration can be anything from technical developments, regulations, politics and economics, to natural disasters, climate events and societal changes. As with most of the scenario processes, the discussion around factors and probabilities is shaped by the individual intuitive logic of the participants rather than volumes of data or computer projections.

Many of the more certain forces – such as climate change or digitization – will be common to the six or eight potential themes that emerge from this interactive process. The differences, often dramatic and startling, result from the lower-likelihood, but nevertheless high impact, factors that are drawn into the frame; the Covid-19 outbreak could be considered just such a wildcard factor, albeit one that many larger companies will have war-gamed in terms of their possible response to a pandemic 'flu outbreak. Again in full discussion with the client, the forces within each identified theme are ranked graphically along two axes according to their certainty or uncertainty and the likely severity of their impact.

From these themes the three or four

Under the **Digitopolis** scenario for 2035 society is highly automated and electronic resources take precedence over physical ones, with online life becoming more important than face-to-face interactions. Most travel, work and socialising is virtual, dramatically reducing the demand for transport and consigning the personal car to the history books. Extensive monitoring of climate helps anticipate extreme weather events to protect more vulnerable communities. The grimly-named **Creative Scavengers** scenario, not shown, imagines a fractured and anarchic 2035 world where resources are scarce and everyone has to mend, reuse, and grab what they can in order to survive.

"At Ricardo, our clients ask us many questions about future technologies, products and services. Some clients also want our opinion of their future strategy; we are developing tools that enable us to test the robustness of their strategy against a set of future scenarios"
Carl Telford, Ricardo

most pertinent to the client company's future will be selected to be developed into full-blown scenarios. Often these will be the most extreme of the future pictures: these push the company further and faster in its thinking and, as Telford explains, lend themselves best to the creation of the type of vivid visual and storytelling narrative that helps build engagement with staff and management at all levels of the company.

Deep listening and intuitive logic

It was one of the scenario planning proponents within Shell who characterized the internal process as one of deep listening – the ability to hear what others are saying, to take in a broad spectrum of perhaps contrary views, and to emerge from your individual silo to see the bigger picture.

"It's a collaborative process building scenarios and exploring implications," explains David Abdulmasih. "Everyone can have an opinion, and you come to a collective judgement. This removes the bias, and all clients see the value in it. Yes, some people are siloed in their thinking, but you'd be surprised how the scenarios get them out of those silos."

One of the keys to making sure that top- and mid-level executives buy in to the scenario process is to ensure that the scenarios being contemplated are plausible, not necessarily probable. This makes them more vivid and more involving, and provokes a much stronger response to one of the most important prompts in the whole process: "Imagine you were in this scenario at our chosen future time point. How would you feel? What would you do?"

Imaging, not modelling

In approaching scenario planning, Telford underlines the importance of moving beyond the number bias that many science and engineering communities are accustomed to: "We are talking about the future, here: it has not been created yet, there are no right and wrong answers, and there is no data."

Breaking down that no-data barrier can be difficult with some clients, he concedes. "Yes, you can do projections and model things. But the more complex the system and the more the variables, the more difficult it is; you have to make too many assumptions. Yet some people are obsessed by numbers: they demand a figure or a projection."

The solution, he says, is to shift from the quantitative to the qualitative, and to begin unlocking the imagination as to how things might be in that future. Breadth rather than depth is what is needed. Taking in the worlds of geopolitics, economics, social forces and other influences that are so often alien to precise metrics, the technique is to reflect these but not to go into needless detail. "It can be tricky to deal with," adds RSC technology strategy consultant Marvin Tchamiller, "but once you've got people involved in making the scenarios the imagination is sparked, and because there is an underlying structure to the process, it becomes a delight for the client. Building scenarios and exploring their implications is a very collaborative process. Everyone can have an opinion."

Working with the results

With the three or four contrasting scenarios written up in an engaging narrative and illustrated in a vivid graphic style, clients are presented with a powerful collaboratively constructed picture of where the world might be in the target year.

For some, that alone may be enough, but for others who crave the certainty of spreadsheets and correlations the Ricardo scenario process can provide an enhanced analysis of the forces within each scenario. Breaking the scenario down into manageable chunks and using a complex 20x20 matrix to assess each feature and its interaction with the others, this results in a strongly graphical 'heat map' that enables the client company to see the strengths and weaknesses of its strategies against each set of future scenarios.

As an obvious example, an OEM closely focused on combustion engine technology would flash up a strong negative correlation with any scenario in which fossil fuels were phased out for road vehicles.

"We've found this quite powerful,"

says Tchamiller. "We can use the heat map and the associated scores to show a client that their strategy perhaps looks well suited to scenario A but would be problematic in D and disastrous in B and C. Our Japanese clients particularly like this – there's a visual pattern, something which shows a clear preference."

Watching the signs

Watching every aspect of the world around for signs of change – be they economic, political, social, or cultural – the monitoring process searches for clues large and small as to the way the world is heading, much as an astronomical radio telescope scans the universe to pick up faint signals. Which, if any, of the scenarios is it coming to resemble?

Covid-19 is the clearest signpost yet seen, argues Telford. "In fact it is a composite of many different signs. It is pointing towards more teleworking and more command economies, for instance, and those are some of the things our scenarios say we should be looking out for."

The task of the monitors, whoever they may be, is to keep a constant lookout on all fronts for emerging trends and clues as to the direction of travel. The scenarios are not mutually exclusive: indeed, it is likely that forces from all of them will feature in some form in the years to come.

Powerful management tool – and safety net

We have seen how the imagining and the exploring of different future scenarios can be a powerful catalyst for companies to stretch their thinking, to discover new opportunities and to prepare for the uncertainties that lie ahead. Responses developed in scenario exercises can be rolled out for real as the basis for agile action plans when a crisis event does occur, and the strengths and weaknesses of company strategies can be held up to the light of each scenario in turn.

To stay relevant, those scenarios need to be regularly updated to reflect real-life events and technology developments. A watchful organization will learn to sense the overall direction in which the world is moving; it will be aware of the shocks and disruptions that could lie ahead, and it will be secure in the knowledge that it has rehearsed for these eventualities and is agile enough to cope with them when they finally occur.

"I don't try to describe the future," wrote science fiction author Ray Bradbury in the 1990s. "I try to prevent it." We'll never know whether Bradbury intended his mission to be such an oxymoron, for unpredictable events will by definition continue to happen. It is fortunate, then, that sophisticated management techniques such as scenario planning are on hand to help organizations to look into that future, to anticipate the shocks it might deliver, and to be ready for the unexpected when it does arrive.

Scenario planning in high places

One high-profile user of scenario techniques is the US Government, which produces five-yearly Global Trends reports through the National Intelligence Council. The reports are timed to be on the desk of an incoming President as he or she takes office.

Entitled *The Paradox of Progress*, the 2017 report takes 2035 as its horizon and postulates three principal future scenarios:

- ***Islands*, in which global players become isolated, globalization unravels and countries turn inwards to address political instability;**
- ***Orbits*, where tensions arise between competing major powers seeking their own spheres of influence, set against a of rising tide of nationalism and emerging disruptive technologies;**
- ***Communities* portrays a future in which national governments fail to meet growing public expectations, opening the way for local and private operators to deliver services and, in effect, undermine the democratic role of central government.**

Ricardo under its own microscope

"You wake up on January 1st, 2036. What does the world look like?"

That was the question put to Ricardo managers and staff as the Group embarked on its own ambitious scenario planning process late last year. But this was no idle exercise: with Ricardo's corporate maxim of "Creating a world fit for the future" firmly in mind, the task was to take a forensic look at the Group's activities, strategies and aspirations and test their suitability for whatever the next 15 years might bring.

Carl Telford *(left)*, **who led the four-strong team co-ordinating the process, was taken aback by how eagerly Ricardo's extremely busy top managers took to the process. "The response right across Ricardo has been brilliant," he reveals. "It shows you that we've got some real intellectual heavyweights, and the reactions of some of the most senior people were very interesting. The scenarios, after all, are a product of Ricardo, not my team."**

Working with intuitive logic rather than formal modelling, the wide-ranging groups of experts homed in on four contrasting and highly challenging hypothetical – but still highly plausible - scenarios for that January 2036 target date.

Those scenarios are illustrated and described on pages 12 to 14. Though there are common technical elements such as the need to address climate change and key materials shortages, marked differences emerge in the way each situation treats social, economic and political forces.

Following extensive debate around the scenarios, Ricardo experts were able to pinpoint possible strategic responses and identify potential business opportunities, too. Most of these responses must remain confidential as this scenario exercise forms part of a much broader body of work that will shape the whole future of the Group.

Nevertheless, it was concluded that Ricardo's existing suite of activities has many positive synergies with those future scenarios: critical themes across the scenarios included energy, mobility, and resources. One recommendation was that Ricardo should reduce its dependency on selected legacy business activities to focus on high-value domains and technology; the analysis also highlighted "potential capability gaps" in areas of the Ricardo business that are likely to be critical for future success, but also showed how the needs of sectors could benefit from Ricardo's capabilities. In addition, some areas of high capability within Ricardo were found to be particularly sensitive to those scenarios; they are therefore likely to be sensitive to real-world trajectories.

SUSTAINABLE AGRICULTURE:
land-use change and forestry

The way that land is managed can have a significant impact upon both the immediate greenhouse gas balance of agricultural systems, and on longer-term environmental sustainability. **Anthony Smith** speaks to the Ricardo Energy & Environment agriculture team about the latest thinking for the future of the farmed and wild landscape

Agriculture is much like any other industry when it comes to the evaluation of its greenhouse (GHG) emissions. The carbon footprint of agricultural business operations and the value chain of food products from farm to fork can be calculated using a broadly similar approach to that used for any other commercial activity or industry: each process, from tilling the soil ready for planting, through to harvest, together with the downstream supply chain of storage, processing, distribution and marketing, will be associated with a range of inputs and outputs and, in GHG terms, emissions to the atmosphere and removals from the atmosphere. The cycle of livestock husbandry can be treated in much the same manner.

In the same way that a new car, a smartphone or a transatlantic air trip can be measured in terms of the net equivalent quantity of carbon dioxide (CO_2e) emitted to

the atmosphere as a result of its manufacture as a product or delivery as a service, so too can a loaf of bread, a litre of milk, a joint of beef or any other agricultural product.

Balance of emissions and removals

Yet along with the similarities of approach there are also some fundamental differences in the way GHG emissions arising from agriculture are assessed compared with those from other products and services.

Firstly, whereas most products and services will typically involve only emissions, agricultural processes can also give rise to 'removals' of carbon from the atmosphere that is then stored in a stable and non-gaseous form. Perhaps the best known of these processes is photosynthesis, through which plants and trees absorb carbon dioxide to create the starches, sugars and structural materials that they need to grow. The carbon removals associated with such plant-based growth are mostly temporary and are emitted to the atmosphere when plant material is digested or otherwise decomposed. Some of the removed carbon, however, finds its way into long-term storage such as in soil or in wood products, and will at least partially offset the emissions involved in cultivation and downstream processing.

The second big difference between the assessment of industrial GHG emissions and those from agriculture is that, for most farming operations, carbon dioxide is a comparatively minor emission.

Jeremy Wiltshire, principal consultant and knowledge leader for Ricardo Energy & Environment's agriculture team, explains: "Agricultural GHG emissions are dominated by methane and nitrous oxide, which in the UK represent averages of 62 percent and 35 percent respectively, of agricultural emissions expressed as carbon dioxide equivalent. Carbon dioxide forms most of the remaining balance of just 3 percent. These comparisons take account of the greater global warming potential of methane and nitrous oxide, compared with carbon dioxide."

According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, the global warming potential of nitrous oxide and methane are multiples of 264 and 84 times respectively that of CO_2 as measured over a 20-year timeframe. However, as methane tends to decay gradually in the atmosphere through oxidation into carbon dioxide and hydrogen, its global warming potential reduces to 28 times that of CO_2 if assessed over a 100-year timeframe. Conversely, as nitrous oxide is chemically very stable within the atmosphere, it remains broadly as harmful over 100 years as it does over 20 years.

"Methane emissions from farming can be hard to control," notes Wiltshire. "While some methane arises from the decay of manures, the bulk is generated from enteric fermentation by ruminant livestock such as sheep, goats and cattle. This is a fundamental effect of their digestive system which enables them to feed on grass and digest cellulose. While there are certain dietary supplements that can marginally reduce the emissions per animal, they remain significant: a dairy cow can produce up to 650 litres of methane per day. It is hard to mitigate this form of methane emission at farm scale without simply reducing the headcount of livestock."

Emissions of nitrous oxide arise in smaller quantities than methane but are highly damaging in their global warming impact, though they are amenable to a broader range of mitigation options. While

Global warming potential (GWP) of agricultural greenhouse gas (GHG) emissions

Gas	Chemical formula	GWP (20-year)	GWP (100-year)
Carbon dioxide	CO_2	1	1
Methane	CH_4	84	28
Nitrous oxide	N_2O	264	265

Source: Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report

some quantities are emitted through the decay of manure, the bulk of nitrous oxide emissions in agriculture arise from the soil after nitrogen-based fertilizers have been applied. The level of inputs of such fertilizers is important in optimizing yields, but excess application increases the GHG emissions with no additional yield benefit.

Terrestrial carbon stores

While the dominance of gases other than carbon dioxide represent a difference between the GHG emissions of industry and agriculture, perhaps the most fundamental contrast relates to the effects of land use on carbon storage.

"Despite the history of carbon dioxide emissions built up over the 260 years since the start of the industrial revolution," explains Jeremy Wiltshire, "soils still contain approximately twice as much carbon as is present in the atmosphere. So, in addition to ensuring that agriculture is as efficient as possible in its day-to-day GHG emissions, the effective stewardship of these terrestrial stores is of crucial importance."

The net flux of carbon between terrestrial carbon stocks and the atmosphere is thus a key metric and can flow in either direction. For example, in annual arable cropland there is likely to be a net emission as carbon is lost from the soil by oxidation, and little of the crops' root systems will remain within the soil in the long-term. Conversely in grassland, there is likely to be a net removal of carbon from the atmosphere as the plants are perennial and there is little or no soil cultivation. In commercial forestry the carbon removal into wood may remain locked up long after the tree is felled if, for example, the timber is used in building materials. But if the felled wood is used to create biomass pellets for combustion, net removed carbon is emitted back to the atmosphere.

Land-use change from a production system that is removing atmospheric carbon, or from forest, to a system that is emitting stored carbon, can result in large and rapid GHG emissions that dwarf the usual annual emissions of methane and nitrous oxide associated with agricultural production. Conversely, land-use change from a system that is emitting stored carbon to a system that is removing atmospheric carbon has the opposite effect, but the removals build slowly over many years.

"In GHG inventory terms, the distinction between annual emissions and removals associated with agricultural activities and the carbon stock within soil, woodland and other forms of biomass can be likened to that between a profit and loss account and a capital account of a business," explains Wiltshire.

"For dairy unit operation or for annual wheat or rapeseed cultivation, the emissions and removals are considered in agriculture rather in the same manner as financial profit and loss. But changes of land use or, for example, the development of field margins or hedgerows for the purposes of increasing biodiversity, are considered as 'land-use change' emissions and are analogous to capital investments or disposals."

GHG emissions from farming can be significant, with a typical cow producing up to 650 litres of methane per day

Importance of a holistic approach

Estimating the overall net GHG emissions and removals from farms and farmland, and taking account of carbon stock change in and on land, is a particular specialism of Wiltshire and the Ricardo agriculture team.

Often the requirement to investigate will come from a large food manufacturer that wishes to ascribe a carbon footprint to its products as they reach the consumer. For larger brands this might involve groups of farms which need to be assessed in terms of multiple inputs and outputs, including crops and their rotations, as well as details of livestock enterprises. Strategic advice is also often required in terms of farmland management, including the assessment of non-productive areas of land such as hedgerows, field margins and unmanaged farm woodlands.

In addition to the agricultural incentives that are available to farmers for particular initiatives – for example, to improve biodiversity and availability of natural pollinators – this form of analysis is important in helping farms move towards net-zero emissions, and by extension to improve the carbon footprint of food products manufactured from their produce and livestock.

This holistic approach to the farmed and managed environment extends to other major non-farming landowners or to non-agricultural businesses conducted by farms. For example, water and energy companies are businesses that are tasked with transitioning their operations towards a net-zero future; at the same time they are also responsible for the management of significant land holdings. Similarly, many

Many farming operations such as this this Missouri-based installation *(below left)* **producing maize-derived bioethanol, use anaerobic digestion of farm wastes** *(below right)* **to produce renewable energy from biomethane in order to substitute for grid-based power supplies**

"Despite the history of carbon dioxide emissions built up over the 260 years since the start of the industrial revolution, soils contain approximately twice as much carbon as is present in the atmosphere"

Jeremy Wiltshire, Ricardo Energy & Environment

farm-based businesses are finding direct incentives from favourable electrical feed-in tariffs to pursue micro-generation enterprises such as the production of renewable power from biomethane-derived anaerobic digestion. For consulting engagements such as these, the Ricardo agriculture team will collaborate with colleagues serving the utilities and power sectors, to ensure that an informed and holistic approach can be considered.

Managing natural carbon repositories

In terms of the wild landscape, while much attention is rightly focused internationally upon the protection, maintenance and expansion of forests, those forests are – perhaps surprisingly – not top of the list of the world's most significant terrestrial repositories of carbon.

According to the UN environment programme (as reported in Nature, February 2020) peatlands store more than twice as much carbon as that held by the world's forests. Despite accounting for just 3 percent of the Earth's land area, peatlands host more than one-quarter of all soil-based carbon. So, not surprisingly, when these significant repositories of carbon become damaged or drained, the process goes into reverse and they can become very significant carbon sources. Emissions of at least 2 billion tonnes of carbon dioxide annually result from fires and the oxidation of exposed peat.

To put this into perspective, emissions from damaged peatlands are estimated to equate to around 5 percent of anthropogenic GHG emissions. Like forests, peat bogs can be very different in their makeup in different parts of the world. Tropical peatlands are typically formed in forested areas, whereas those in northern Europe are formed of mosses and require very different approaches to protection and, where necessary, rehabilitation following damage.

"While not directly a part of the commercial agricultural system, the maintenance of terrestrial carbon stocks such as peat is important," explains Wiltshire. "And when damage occurs, either through previous generations of poor stewardship, peat harvesting or drainage, or as a result of emergencies such as wildfires, our team is able to make rapid estimates of the carbon loss to the atmosphere."

One such example of this area of work for the Ricardo agriculture team was in the investigation of the May 2019 peat fire in the Flow Country of Sutherland in the highlands of Scotland (see panel below).

Future sustainability

Whether it is for the protection of natural carbon repositories or for the optimization of farming operations for maximum efficiency and minimum environmental impact, Wiltshire believes that a holistic approach is the only way of moving towards true sustainability.

"Farmers and other land managers are currently not well rewarded for the stewardship of their land and maintenance of the natural carbon stocks that it holds," he notes. "Until recently, the usual focus for the environmental assessment of the carbon footprint of food products has been the analysis of the field from which the crop is grown and the net emissions of the annual production activities.

"Increasingly, governments, food manufacturers, supermarkets and farmers are beginning to recognize that we need to look more holistically at GHG emissions across the farm, and reward the protection of carbon stocks including grasslands, woods, wetlands and peat," he continues.

"There are many synergies to be had from such an approach. One of these is increasing biodiversity, which can also have benefits in terms of carbon removals from the atmosphere. Ultimately, it will be increasingly crucial to all of us to improve the environmental footprint of agriculture at the same time as maintaining our precious terrestrial carbon stocks."

Estimating the carbon loss and economic impacts of the 2019 Sutherland peatland wildfire

On 12 May 2019 a wildfire broke out on the internationally important peatland of the 'Flow Country' of north-east Sutherland in Scotland's Highland region. This is an environmentally sensitive area under consideration for UNESCO World Heritage Site status because of its globally rare type of sphagnum moss blanket bog peatland which is estimated to store 400 million tonnes of carbon. The fire burned for a total of six days, with an estimated area burned of 54.9 square kilometres, of which around 98 percent was dominated by blanket bog.

An analysis carried out by Ricardo under contract to World Wide Fund for Nature (WWF) Scotland in the aftermath of the fire was based on two approaches. The first used satellite images to estimate the extent of the burned area, alongside a literature search of the likely carbon losses due to peatland fire, focusing on studies of fires and terrains as similar as possible to those of the Flow Country. The second approach was to use the methods used in inventory calculations by the Intergovernmental Panel on Climate Change (IPCC). Both approaches provided close agreement, albeit within a broad range.

Illustrating the significance of carbon dioxide emissions from this type of peat wildfire, the study provided a low-range estimate of 174,000 tonnes of carbon lost from the peatland into the atmosphere during the six days that the fire burned. To put this into perspective, this carbon release to the atmosphere is equivalent to the average greenhouse gas emissions of the entire country of Scotland for 6.2 days.

As such, for the time that the wildfire burned, the Ricardo team was able to show that this effectively doubled Scotland's carbon dioxide emissions. This clearly demonstrates the significance of peatland as a terrestrial carbon store.

Business as usual– **and unusual**

Ricardo's response to the Covid-19 pandemic has been multi-faceted. Business as usual continues uninterrupted thanks to massive remote working, new partnerships are being forged in the healthcare technology sector, company specialists are supporting efforts to provide personal protective equipment to front-line medical and care teams, and laptops have been provided to a local school to help to deliver distance learning under conditions of lockdown. **Anthony Smith** reports

The chance of a pandemic outbreak of a novel pathogen might perhaps have featured on the risk registers of most developed nations and multinational companies, Ricardo included, as a low likelihood but potentially high impact event. Yet in our individual and collective memories this would have been something viewed by most people as a remote outlier in risk terms – at least until early 2020.

From its initial identification in December 2019 in the Chinese city of Wuhan, the Covid-19 virus spread across the globe rapidly, helped by the modern transportation infrastructure of mass air travel. In doing so it created social and economic shockwaves as governments put their populations into protective lockdowns in order to flatten the curve of infections and protect health and care services.

Thanks to its operations in China, Ricardo was able to gain an early insight into the probable effects of the pandemic on everyday working life, and how the business might reconfigure itself in order to continue to deliver its service to customers in the 'new normal' of protective lockdown. With a technical centre in Shanghai and divisional offices throughout China, a significant cohort of Ricardo employees were affected by lockdown regulations as early as January

2020. The transition of the company's Chinese employees – followed quickly by those in other east Asian nations – to remote home working provided a valuable case study for the business as a whole when lockdown reached Ricardo's larger facilities across Europe and North America.

'Digital first' strategy provides '2900 new offices'

"For some time, we had been implementing a 'digital first' strategy across Ricardo," explains CEO Dave Shemmans. "This was primarily as a means of improving the flexibility of the working environment and providing a better service to customers.

"The same IT infrastructure of cloud-based computing, widespread availability of laptops, and secure internet connections required for this digital first strategy enabled us to very quickly adapt to a new form of business as usual," he continues. "When European governments and state and federal authorities across North America moved to implement lockdown measures from March of this year, I was able to announce that we had, almost overnight, effectively opened 2,900 new Ricardo offices in the homes of our employees."

Site-based operations maintained

With so many staff working remotely from home, Ricardo was able to reconfigure its continuing site-based operations – primarily those activities using specialist high-value capital equipment such as vehicle and powertrain test labs and manufacturing units – to adhere to strict social distancing guidelines to protect the health of staff.

The early implementation of the company's digital first strategy, along with the effective piloting of remote working in those nations such as China that were early into lockdown, were thus instrumental in enabling Ricardo to move quickly to maintain the service provided to its global customer base in the new locked-down world .

Having reconfigured itself to secure its ability to serve existing customers, Ricardo's strategic and manufacturing consulting teams found their skills in demand from a new sector: healthcare technology.

Helping Isansys Healthcare scale up production

UK-based digital healthcare provider Isansys has developed the Patient Status Engine (PSE), an innovative patient

Ricardo has helped Isansys to scale up production of the innovative PSE patient monitoring system *[right]* **that uses digital and wireless technologies to generate near-ICU grade data and analytics**

monitoring system which uses digital and wireless sensor technologies to enable near-ICU grade monitoring and advanced analytics of patient data. The world's most complete, real-time monitoring system, the PSE creates and utilizes data to provide more time for nurses to care for their patients and save patients' lives by providing early warnings of life-threatening events.

The PSE is a fully certified CE Class IIa and FDA Class II medical device which has been deployed in multiple major hospitals globally since 2014. With the advent of the Covid-19 pandemic, however, the demand for this advanced patient monitoring system has increased at an unprecedented rate. For this reason, Isansys sought assistance from Ricardo to scale up production as quickly as possible, and simultaneously also build up longer-term capacity.

Ricardo's manufacturing and strategic consultants are ideally placed to assist with this work. Ricardo specialists have extensive experience in product creation processes all the way from design for manufacture and assembly through to supply chain development. In addition to producing a diverse range of complex products including engines, driveline systems and transmissions for motorsport and high-performance road cars, Ricardo also manufactures precision parts for a range of other industries, including aerospace and defence.

Surge in orders

"We are seeing a surge in orders for our Patient Status Engine (PSE) product as a result of the Covid-19 pandemic," said Keith Errey, CEO of Isansys Lifecare. "Hospitals are seeking to deploy the PSE to rapidly increase capacity and numbers of higher dependency beds and isolation wards in order to monitor ventilated patients and to use it to provide high-grade monitoring of patients at home or other locations outside the hospital itself. Our collaboration with Ricardo has helped us to scale up quickly, making us confident that we can meet the current demand, and also form plans to further increase our own production capacity."

The first stage of the collaboration between Isansys and Ricardo has focused on a full review of the existing production process for the PSE. Ricardo's manufacturing specialists have reviewed the details of current operations, identifying how bottlenecks can be addressed and how the processes of assembly and end-of-line testing can be made more efficient. The next stage, already underway, is to focus on the implementation of measures identified, with the aim of improving efficiency and reducing assembly time. This work includes an examination of the supply chain, investigating for example the alternative of additional external sourcing of pre-assembled components.

Beyond the current collaboration, Isansys and Ricardo are also planning to explore possible longer-term improvements, including an evaluation of the design for assembly of the current product, as well as wider issues of supply-chain development and management.

Creating much-needed PPE for care homes and hospitals

In a further departure from what might be considered business as usual, Ricardo is contributing to the UK national effort to provide much-needed Personal Protective Equipment (PPE), in the form of face shields, to frontline workers in care homes and the NHS. The shields were made to a bespoke Ricardo design and benefit from the company's experience of high-value, rapid-response assembly and supply-chain management. Local NHS doctors assisted the Ricardo design team by testing the new face shield for enhanced comfort and wearability over extended periods.

The face shield frames were manufactured by longstanding supply chain partner Stephens Plastic Mouldings, using tooling funded jointly with Ricardo. To ensure that the face shields reached care home and NHS staff as quickly as possible, facilities at Ricardo's Technical Centres at Shoreham by Sea and Leamington Spa were repurposed as assembly lines and logistics centres for this much-needed PPE. The process was made safer and more straightforward by the large-scale implementation of remote home working that had already taken place.

Although the requirement for the face shields was urgent, Ricardo followed the usual industry standards and best practice for testing. Company specialists worked with the industry-leading test provider SATRA to secure fast-tracked testing of its protective face shield to EN166. Crucially, this testing enables the PPE to be NHS approved for Covid-19 emergency use.

Recipients of the first 2000 face shields donated by Ricardo included Richmond Manor, Bedfordshire, of the Hamberley Care Homes group, Shelley Care Home in West Sussex, and the city and county councils for Brighton & Hove, Avon and Wiltshire, and Warwickshire; these authorities are distributing PPE to care homes in their respective areas. In addition, supplies were also delivered to NHS teams including those at the Avon and Wiltshire Mental Health Partnership, the Charter Medical Centre in Hove, and the Burgess Hill Covid Clinical Assessment Service. A further 7000 have since been donated by Ricardo.

"We are delighted to have received 250 visors from Ricardo and would like to thank them for their kind donation," said Paul Hill, CEO of Hamberley Care Homes and Inspire Neurocare. "The safety and wellbeing of our residents and staff is our highest priority and I'd like to take this opportunity say a huge thank you to our care teams for their continued dedication and commitment during this challenging time."

"We firmly believe that the correct and comprehensive PPE is absolutely key to delivering a robust service for patients, as we don't want to shy away from clinical need, whilst keeping our staff safe," added Dr Esther Bird of the Burgess Hill Covid Clinical Assessment Service. "Ricardo's assistance and foresight is very much appreciated."

Helping a local school move to distance learning

Ricardo was also able to assist a school located close to the company's Shoreham Technical Centre with much-needed IT

equipment. Faced with the challenge of moving very quickly from the school's usual model of classroom-based teaching to that of online distance learning at the outset of the Covid-19 pandemic, Jim Coupe, principal of the 1800-pupil Shoreham Academy, undertook a survey of the IT equipment available to students in their homes. "Quite early on we realized that moving to virtual learning would prejudice the opportunities for students from disadvantaged backgrounds, where many parents are unable to provide appropriate IT hardware for remote learning. We approached Ricardo as well as a number of firms to see if they could provide us with additional hardware in order to support these students and enable them to benefit from virtual learning together with their peers."

Ricardo is fortunate in having a largely in-house IT team with the necessary skills to prepare and reuse equipment such as laptops. Staff volunteered to come in outside of working hours to assemble as many working laptops out of the equipment that was in storage awaiting recycling. As a result, the company was able to provide a total of 12 laptop computers for use by the Academy's students during the period that the school was closed for the lockdown. Coupe was able to collect these in person from Ricardo on 21 April and, within days, the laptops were prepared for their educational role and delivered to students. "On behalf of the teaching staff of Shoreham Academy I am extremely grateful to Ricardo for this donation which has helped us to continue to provide the benefits of virtual learning for 12 children and their families," he concludes.

The new normal beyond Covid-19

As the first wave of the Covid-19 pandemic recedes, a post-lockdown new normal of increased social distancing will become established across Europe, Asia and North America. Yet the threat of a resurgence will remain present until effective treatments or a universally accessible vaccine are developed.

And with its ability to adapt quickly to mass remote working and safe testing and manufacture, Ricardo has shown a high degree of resilience in its operations. More than this, it has also shown its commitment to the communities in which it operates, and a willingness to explore new markets and opportunities in the most challenging of times.

Yet, as Dave Shemmans explains, any return to what counted for business as usual in late 2019 is both unlikely in the short term and possibly sub-optimal in the longer term: "We have all been touched by the experience of the Covid-19 pandemic. Many of us will know of friends or family members who have suffered this illness and sadly, some of us will have experienced the loss of someone close to us.

"In business, the effects of this pandemic have also been profound, but not all the consequent change will have been negative, and there are certain aspects that will serve us well into the future.

"In our working lives," adds Shemmans, "we have all seen how many tasks can be carried out remotely and flexibly using the latest web-based technologies, in some cases more efficiently and at lower cost. It is great too, to see Ricardo's manufacturing and strategic consultants making a difference in healthcare technology alongside their more traditional industrial domains.

"Things will be different," he concludes, "but it is up to us to help create a world that is truly fit for the future. The need to strive for greater efficiency of mobility and for true environmental sustainability has not gone away, so we will need to continue to focus on these wider and longer-term imperatives within the new normal of managing the aftermath of the Covid-19 pandemic."

Deliveries of the Ricardo-designed and assembled PPE face shields were made to care homes and NHS facilities by Ricardo employees, including the company's CEO Dave Shemmans

RICARDO NEWS

Latest developments from around the global Ricardo organization

Bristol aims for carbon neutrality

Bristol City Council has published a report, prepared with the support of Ricardo experts, exploring key aspects of how the UK city could achieve its declared ambition to be carbon neutral by 2030, significantly ahead of the national target of 2050.

The detailed study, which was led by the Centre for Sustainable Energy (CSE) and supported by Ricardo and consultancy Eunomia, focused on cutting to near zero the carbon emissions associated with the city's use of fossil fuels such as gas, petrol/gasoline and diesel, and emissions from the electricity it consumes and the waste it produces.

Drawing on this detailed analysis, the report outlines key interventions which are needed to establish the conditions in the city needed to achieve net zero by 2030. These include: fostering shared purpose and enabling active participation; securing powers and capacity; implementing the technology needed to achieve net zero; and sector-specific initiatives. The focus of the Ricardo contribution to the project was upon achieving carbon neutrality in transport.

Particular recommendations arising from the transport aspects of the study included major investments in encouraging a modal shift; these comprised, among other measures, the development of public transport and active travel infrastructure, the rapid reduction in vehicle miles, reclaiming road space from private vehicles, encouraging freight consolidation, and discouraging car journeys into and around the city. In terms of electrification, a controlled approach to EV charging infrastructure roll-out was recommended, with a sustained push for EV car clubs and mobility as a service. A key enabler for this was identified as the implementation of an electricity distribution network upgrade programme, including smarter operation, to accelerate the achievement of a 'network for net zero'.

Report into high-voltage fast charging for EVs

A new report published by Ricardo highlights the rapidly changing landscape for fast charging electric vehicles and examines the implications for vehicle makers, supply chains, charging infrastructure providers and equipment manufacturers.

The report – *High Voltage and Fast Charging for Electric Vehicles* – shows how automotive manufacturers and infrastructure providers in the US, China and Europe are responding to the needs of consumers in order to make electric vehicles more attractive to users. It also addresses how technologies, standards and electric powertrain systems will need to be developed to meet these consumer needs.

The publication provides an overview of the future landscape for fast charging of electric vehicles. In its five main sections it includes: a description of the latest battery-electric vehicle charging trends; an overview of planned fast charging networks in Europe, the US and China, along with fast charging network statistics; a look at current and future development of battery-electric vehicle technology; and an overview of the capabilities needed to accept faster charging and provide longer vehicle driving ranges.

As the automotive industry responds to consumer pressure for larger battery capacities, with longer driving ranges and faster charging times, the report provides insight into current and future electric vehicle specifications. The broader technical implications of high-voltage charging on infrastructure, battery life, battery chemistry and vehicle electrical architecture are also addressed.

The report is available from the Ricardo eStore at estore.ricardo.com. It provides essential information for anyone who wants to understand next-generation battery electric vehicle development, those developing or supplying on-board electric powertrain products, energy companies, infrastructure providers, and suppliers of charging equipment. It provides a concise, independent and objective overview of the current and future landscape, combining both market and technology implications.

Software brings innovation in transmission design

A completely new approach to the design and optimization of transmission systems for all types of vehicle – including the latest hybrid and pure battery electric concepts – is encompassed in the latest 2020.1 release of powertrain design and optimization software from Ricardo. The new release also comes with a wealth of new features and capabilities.

The release marks the completion of the full Ricardo transmission analysis solution: the suite now provides a seamless toolchain – based on the SABR, FEARCE and VALDYN products – enabling engineers to optimize systems intended for all types of vehicles, including the complex systems required for hybrid powertrains. This robust toolchain now provides a comprehensive virtual product development environment enabling the creation of designs offering improved fuel economy, better shift quality and driveability, and – increasingly important for pure-electric vehicles – optimized NVH characteristics. This toolchain, which is available with the 2020.1 release, enables all of these functional benefits and in addition offers the potential for much shorter transmission development timescales.

Elsewhere, the 2020.1 release provides the benefits of recent development effort in improving the fatigue life calculation for structures in FEARCE and improving the implementation and calculation speed of the German research association of mechanical engineering FKM (Forschungskuratorium Maschinenbau) method.

In the fluid simulation products, the VECTIS computational fluid dynamics suite is further enhanced in the 2020.1 release, with improved combustion physics and solver enhancements for better applicability to a wider range of simulation challenges. This has included support for sub-domains, including porous media, enabling the user to model heat exchangers, radiators and aftertreatment devices. Spray models within VECTIS are now also compatible with sub-domains so that the user can simulate rain and other particles in under-hood simulations.

Ricardo's WAVE engine performance and gas dynamics simulation product is also further improved, particularly in the faster-than-real-time WAVE-RT version. Increased integration enables users of competitor commercial products to import their models into WAVE and WAVE-RT much more rapidly and efficiently than before.

Top UK ranking for air quality work

In its annual ranking of the UK environmental consulting sector for 2020, publisher and market intelligence provider Environmental Analyst rated Ricardo first for air quality work out of the 30 leading firms assessed. The annual UK Market Assessment of the Environmental Consulting Sector report is based on financial statistics (for the FY 2018-19) and detailed company profiles of the leading peer group of 30 environmental consulting practices based in the UK, as well as Environment Analyst's wider annual company survey results. Overall, the report demonstrates that the UK market for environmental consultancy services experienced its third-highest annual growth in a decade at 6.7 percent in 2018, lifting revenues to a record £1.77 bn.

In addition to taking the top ranking for air quality work amongst its 30 leading peers in the UK environmental consulting sector, Ricardo Energy & Environment was ranked second for sustainability strategy and environmental, social and corporate governance (ESG), fourth for both waste manangement/circular economy/government and agencies work, and for environmental risk and due diligence; and fifth for climate change and energy sector consulting. Overall, Ricardo was placed 13th across the UK sector, ahead of many much larger, big-name consulting firms.

Waste audits continue during lockdown

With many UK customer sites temporarily closed or with limited access due to the Covid-19 pandemic, it has been a significant challenge for companies to meet their regulatory obligations. These are required by UK gas and electricity market regulator Ofgem for selected sites operating under the Non-Domestic Renewable Heat Incentive (RHI).

However, Ricardo's experts have been able to help in the process thanks to the implementation of the company's 'digital-first' strategy to enable the effective delivery of remote RHI sustainability audits for sites utilizing wastes as feedstocks.

The new methodology enables Ricardo's waste specialists to continue to gain an in-depth understanding of a customer's processes and procedures, but without requiring a site visit. The approach aligns with Ofgem's guidance that recognizes the importance of applying alternative approaches during 'exceptional circumstances' to ensure that companies can continue to meet their obligations.

Although alternative approaches can be implemented, audits must still be performed in accordance with the International Standard for Non-Financial Assurance Engagements, ISAE 3000. A consequence of companies not complying with the requirement for an audit is the potential for enforcement action, which can include the suspension of payments under the scheme.

Ricardo's waste experts are also utilizing the same tools and principles to deliver technical due diligence for waste technology projects. The approach enables the company to work closely with the customer's site team virtually to enable critical infrastructure to continue and providing investors with robust insight into their projects.

A biomass boiler operating on wood pellets - an example of the type of installations that require RHI audit

Helping the UK water sector towards strategic resilience

Ricardo has secured multiple new framework agreements with UK water companies to provide consulting support across a range of environmental and water resource planning areas of specialization. This represents a significant increase in business for Ricardo Energy & Environment's water sector practice.

The strategic agenda for the water industry in England and Wales is defined by the economic regulator, Ofwat, in its five-year asset management planning periods. For the seventh control period (AMP7), which runs from 2020 to 2025, the key themes of focus include customer service and affordability, long-term financial planning, corporate and operational resilience, and innovation. Ensuring companies can meet future water demands is a key area of investment, with up to £469m allocated in England alone for planning of future strategic integration of resources between regions. This comes in addition to funding for schemes within each water company region.

Since December 2019, Ricardo has secured framework agreements with many of the largest water companies, including Southern Water, United Utilities, Dŵr Cymru/Welsh Water, Yorkshire Water, Thames Water and Bristol Water. These agreements are to support the companies in planning the long-term future for sustainable water resources.

Under the terms of these flexible agreements, the water companies can draw upon a wide range of Ricardo services, technologies and experience as they strive to deliver the outcomes agreed with Ofwat under AMP7. Ricardo's expertise in delivering services under these framework agreements focuses on initiatives and projects, which include strategic environmental assessments, terrestrial and aquatic ecology surveys, habitats regulations assessment and water framework directive assessments.

Ricardo has already begun work across a number of the new framework agreements. Even during the Covid-19 pandemic the company's experts have been providing support to maintain momentum in the development of strategic water resource options to help meet the regulatory deadlines.

Ricardo wins Forbes award for fifth year

Ricardo Strategic Consulting has for the fifth year in succession been included in Forbes America's Best Management Consulting Firms, the high-profile ranking that identifies which management consultancies are providing business sectors with the best guidance on their practice. To compile this list of America's Best Management Consulting Firms, Forbes collaborated with online statistics provider Statista. Some 7500 partners and executives of management consultancies were surveyed, as were 1000 senior executives who worked with such firms over the last four years.

'Made in the Midlands' awards

The Made in the Midlands awards recognize and reward manufacturing companies based in the central England region that have demonstrated success in innovation, product development and revenue growth in either domestic or overseas markets.

Ricardo's manufacturing division – Ricardo Performance Products – has been shortlisted in two categories: Automotive and Innovation. Its citation for the Automotive award recognizes the company's work in the design and production of high-quality prototypes and in the low-volume manufacturing of complex products and assemblies, predominately engines and transmissions for high-end automotive and motorsport applications.

The Innovation award shortlisting centres on the work of Ricardo engineers and manufacturing specialists in designing the transmissions for highly advanced hypercars.

Investment in cutting-edge manufacturing techniques and processes, combined with the use of highly specialized materials, ensures that Ricardo's products can meet the ever-increasing demands of the world's hypercar manufacturers - without compromising on packaging and aggressive weight targets. In executing this type of project, the Ricardo Performance Products team draws extensively on its experience of motorsports engineering, in which the company is active in the very highest levels, including Formula 1 and Formula E.

The winners of all ten categories will be announced at a gala dinner on Thursday 3 September at the Macdonald Burlington Hotel, Birmingham.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