powertrain & drive focus

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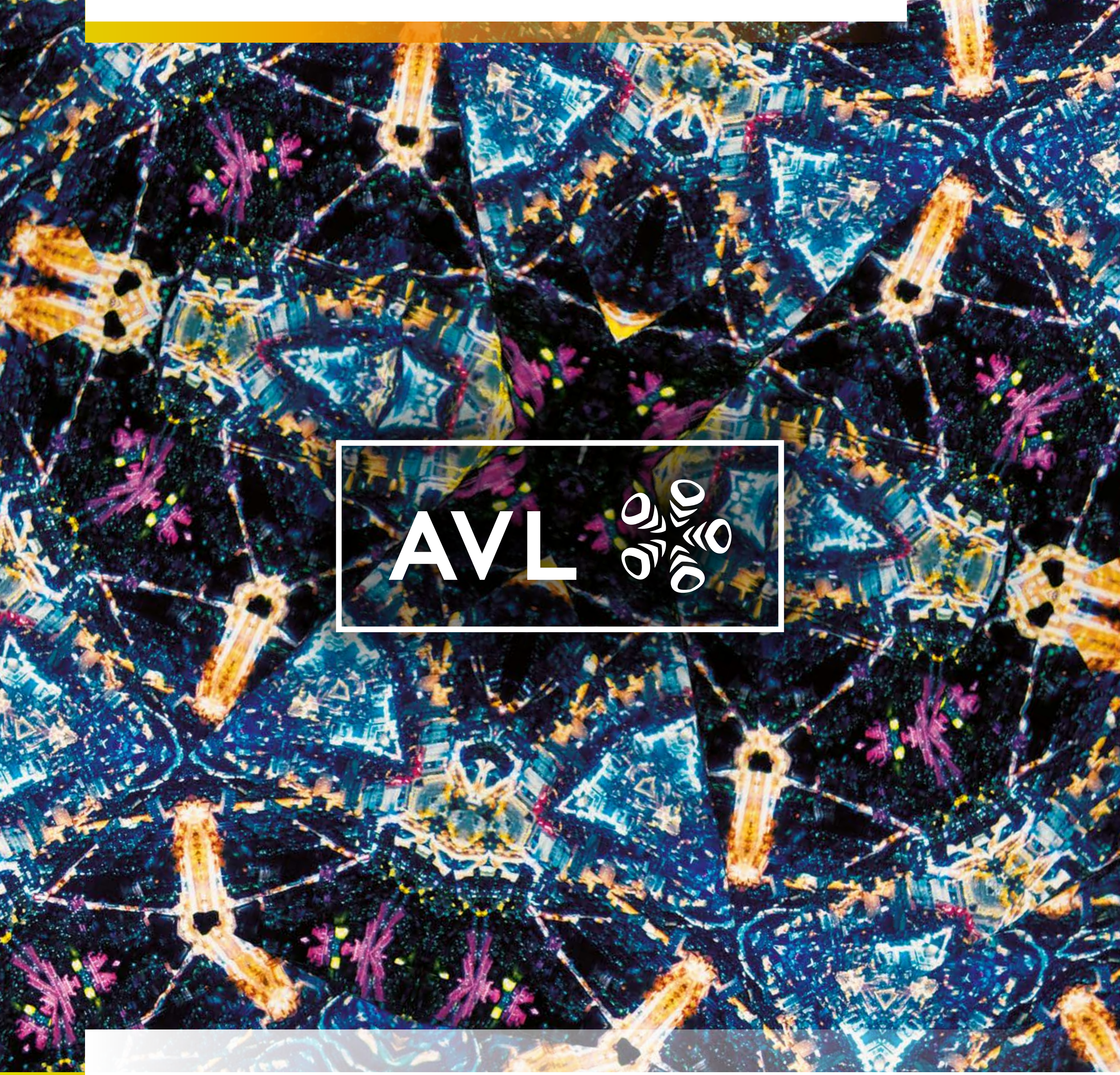
MAKE IT GREENER, MORE EFFICIENT AND SAFER

Aydoğan Çakmaz
Head of Operations, Truck and Bus, Mitsubishi Fuso Truck and Bus Corporation

AVL THE AVL MAGAZINE FOR POWERTRAIN DEVELOPMENT, TESTING AND SIMULATION



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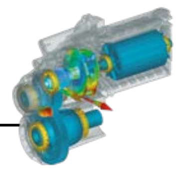

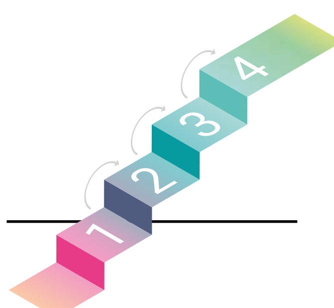

Prof. Helmut List,
Chairman and CEO AVL

Synthetically produced fuels are displaying high potential and great added value for the mobility sector. If, for example, tomorrow's drive systems were to be powered by renewable fuels like hydrogen or e-fuels, that would help to bring a swift end to fossil energy use, without requiring much modification.

When it comes to competing technologies (hybrid drive with internal combustion engine, battery and fuel cell electric drive system and their combinations), we at AVL are open to all options. The decisive factor here is that the energy sources applied – liquid fuel, electricity or hydrogen – come from carbon-free or carbon-neutral production. A new power-to-liquid facility, for example, applies a carbon-neutral process, which uses electrolysis and Fischer-Tropsch synthesis to produce synthetic energy carriers based on renewable electrical energy. By employing our high-temperature electrolysis technology, we can significantly improve efficiency in the production of synthetic combustibles and motor fuels – and thereby help to implement renewable energy options that are cost-effective, practical and storable for longer periods of time.

The use of an appropriate mix of the mentioned drive technologies will remain a key priority. For that reason, e-fuels will greatly gain in significance, because they enable carbon-neutral mobility, long ranges and short refueling times. In addition to carbon neutrality, it will be crucial to achieve maximum efficiency in every drive technology available. Thanks to AVL's focus on research and innovation, and a broad technology portfolio, we can contribute significantly to the transition to carbon-free and sustainable mobility.

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„Make it greener, more efficient and safer"

INTERVIEW with Aydoğan Çakmaz, Head of Operations, Truck and Bus, Mitsubishi Fuso Truck and Bus Corporation

— **focus:** Mr. Çakmaz, before we start our interview, I'd like to congratulate you on the new position as Head of Operations, Truck and Bus at Mitsubishi Fuso Truck and Bus Corporation. In your former position as Senior Vice President and Head of Product Engineering you were responsible for the development of the products for MFTBC.

Mitsubishi Fuso Truck and Bus Corporation is a part of Daimler. What is the strategy for global and local product development?

Çakmaz: Mitsubishi Fuso Truck and Bus Corporation (MFTBC) is one of Asia's leading commercial vehicle manufacturers, under the umbrella of Daimler Trucks Asia (DTA). DTA combines the strengths of two distinct legal entities MFTBC and Daimler India Commercial Vehicles (DICV). This unit allows the entities to collaborate in areas such as product development, production, exports, sourcing and op-

timizing research, as well as sales and market development activities to provide the best value products to our customers.

Together with Daimler Trucks Europe and North America, we are one of the 3 pillars of Daimler Truck AG. We have a strong local R&D Footprint in Japan and as well as in India, where our brand Bharat Benz is located in Chennai, Tamil Nadu. But we are also closely cooperating within Daimler's global R&D network.

Just to give you some examples: The FUSO eCanter, a forerunner in electric mobility, was developed by us and we are sharing our vast experience with electrified commercial vehicles with the whole of Daimler Trucks. And the FUSO Super Great was the first truck in Japan that offered L2 automated driving capabilities, because we could integrate advanced technology that was developed by our colleagues at Daimler Truck AG.

focus: **Mr. Çakmaz, MFTBC is a commercial vehicle manufacturer. Could you give us a short overview of your product portfolio and the positioning on the market?**

Çakmaz: Mitsubishi Fuso is offering a full portfolio of commercial vehicles and its products are being sold in more than 170 markets worldwide. With plants in Japan and Portugal, as well as different CKD operations, we are producing HDT, MDT and LDT trucks. The light duty Canter is the best-known product, a light duty truck that is used for an incredible array of use cases in Asia and all over the world.

In addition to trucks, we are also offering a complete bus portfolio, from the "Rosa" light bus up to the "Aero Queen / Aero Ace" coach.

Our core markets are Japan, Indonesia and Taiwan, but we are successful in many markets all around the world. We take great pride in being a pioneer in electric commercial vehicles. Just recently, we announced the sales of 34 all electric eCanter LDT to DB Schenker, that will be running all over Europe.

focus: **AVL worked with Fuso and DICV on many different engine projects for the Asian markets. Which were the key criteria for you when selecting AVL for these projects?**

Çakmaz: The key criteria were the following points:
- The feasibility of your development timelines to fit our given entire development timelines of every project
- AVL's capability to offer sustainable, timely solutions with competitive conditions
- Great collaboration in the utilization of assets and technical equipment such as test benches
- Another main driver was the extensive knowledge of AVL engineers with regards to current and upcoming emission-related technologies in different markets

focus: **Both companies have a global footprint, how important was this for the project success?**

This is very important because of the following reasons: Global expertise and resource availability were a key requirement for us. We took profited from information, not only in legal but also industry-relevant topics, from AVL's branch offices all over the world.

focus: **Parallel to this collaboration for engine development, AVL has supported Fuso with advanced battery projects. What were the decisive criteria for this collaboration?**

We selected AVL not for a single criterion, but because your offer was very well balanced. When it comes to a system as complex as a battery, there are many criteria that we take into consideration. Cost of course, but also the quality concept or the capability to fulfil our very specific requirements. AVL has a very progressive approach in exploring new technologies. But these are only presented to customers after experience and confidence has been built inside your company. In other words: you can rely on AVL's judgement.

focus: **In addition to the more SOP-focused projects, Fuso and AVL cooperated on the development of the Fuso eCanter Sensor Collect. What was the driver for Fuso to collaborate with AVL and what characterized AVL in this project?**

Çakmaz: Fuso's eCanter, the ideal zero emission light-duty truck for city application, is already running with over 150 units in different countries including their home country, Japan.

As part of the continuous endeavor to enhance trucking to higher levels of socially responsible operation through advanced technology, Fuso decided to explore the city garbage collection operation as a specific use case. To make it greener, more efficient and safer. Thus, the concept of eCanter Sensor Collect was born.

Since it was more efficient to work with an external partner to realize a proof of this concept, AVL, a long-standing technology partner of Daimler Trucks/MFTBC who also had the relevant know-how and made the best proposal, was chosen as our partner. AVL in this project was characterized by excellent and appropriate know-how, high professionalism, extremely high levels of flexibility and responsible cooperation in the post COVID-19 pandemic.

focus: **Since assisted driving systems and automated functions are becoming more popular and are offering attractive business cases, do you see many of these applications realized in commercial vehicles in the near future?**

Çakmaz: Automation and electrification of commercial vehicles are the two most important topics in the truck industry. As Daimler Trucks, we already announced that we will be only offering zero emission vehicles in the Triade markets from 2039 onwards. This means huge efforts on our side to further push battery electric and fuel cell electric powertrains.

Automation, at the same time, is a major issue to further enhance safety of commercial vehicles, but also to counter the lack of drivers and to reduce operating cost.

focus: These projects illustrate how important a spirit of collaboration is as vehicle systems become more complex. How essential are such partnerships in tackling the growing challenges faced by the global automotive industry?

Çakmaz: The ability to successfully build cooperations, be it for components, entire vehicles or nowadays also software and services, is crucial for our success. For example, just recently, Daimler Truck AG announced a cooperation with Volvo to develop and build Fuel Cells to be used by both companies in their vehicles.

But we are also in cooperation with different partners locally. A close cooperation with our suppliers, not so much by setting up joint ventures but on an R&D and manufacturing level, also has a long tradition and was key to successful product projects in the past.

focus: The eCanter SensorCollect has demonstrated that Fuso is a leader in innovative solutions to challenging problems. What's next for Fuso?

Çakmaz: The eCanter Sensor Collect offers sophisticated automated functions that enable it to automatically follow an operator through a street to collect rubbish – unmanned.

I cannot tell you what we are working on right now, but as you know, battery and fuel cell electric vehicles are one of our core competencies. So please, allow me and my colleagues to keep this a secret – but there will definitely be, more very innovative zero-emission projects to come from Mitsubishi Fuso as well as Bharat Benz.

Aydoğan Çakmaz

Head of Operations, Truck and Bus, Mitsubishi Fuso Truck and Bus Corporation

Mr. Çakmaz studied mechanical engineering at the Ulm University of Applied Sciences, before joining Daimler in 1985 to work on passenger car development. In 2000 he joined Daimler Trucks, before gaining experience in further roles in Turkey, Japan and India, where he worked as Head of Product Engineering for Daimler India Commercial Vehicles (DCIV).

From 2013 onwards he oversaw increased collaboration across Asia, including for example DICV and Mitsubishi Fuso Truck and Bus Corporation, with a special focus on the electrification of the Fuso product range.

The eCanter SensorCollect Concept Garbage Collection truck showed how ADAS could have practical applications in the real world.

Electric Powertrains Create a Shift in Testing

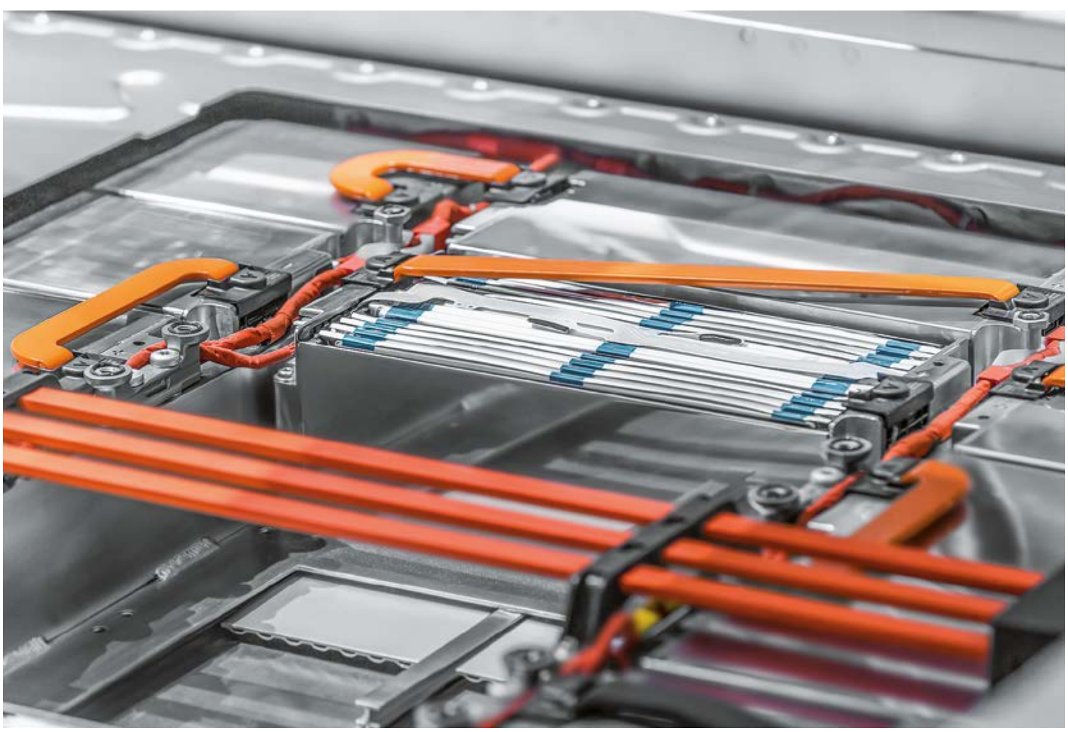
Taking high-voltage system integration, charging and safety testing of electric vehicles to the next level

— BEV (Battery Electrical Vehicle) development requires adaptations to both the development process and its environment. While the testing of physical components for the combustion engine has been fundamental for the development of conventional and hybrid vehicles, the demands for a BEV are different. Adapting to these demands presents OEMs with a new set of challenges.

But with new challenges come new opportunities. In shifting to BEV development, the opportunity arises to question and adapt the conventional testing environments such as the powertrain testbed to the specific needs of the battery electric vehicle.

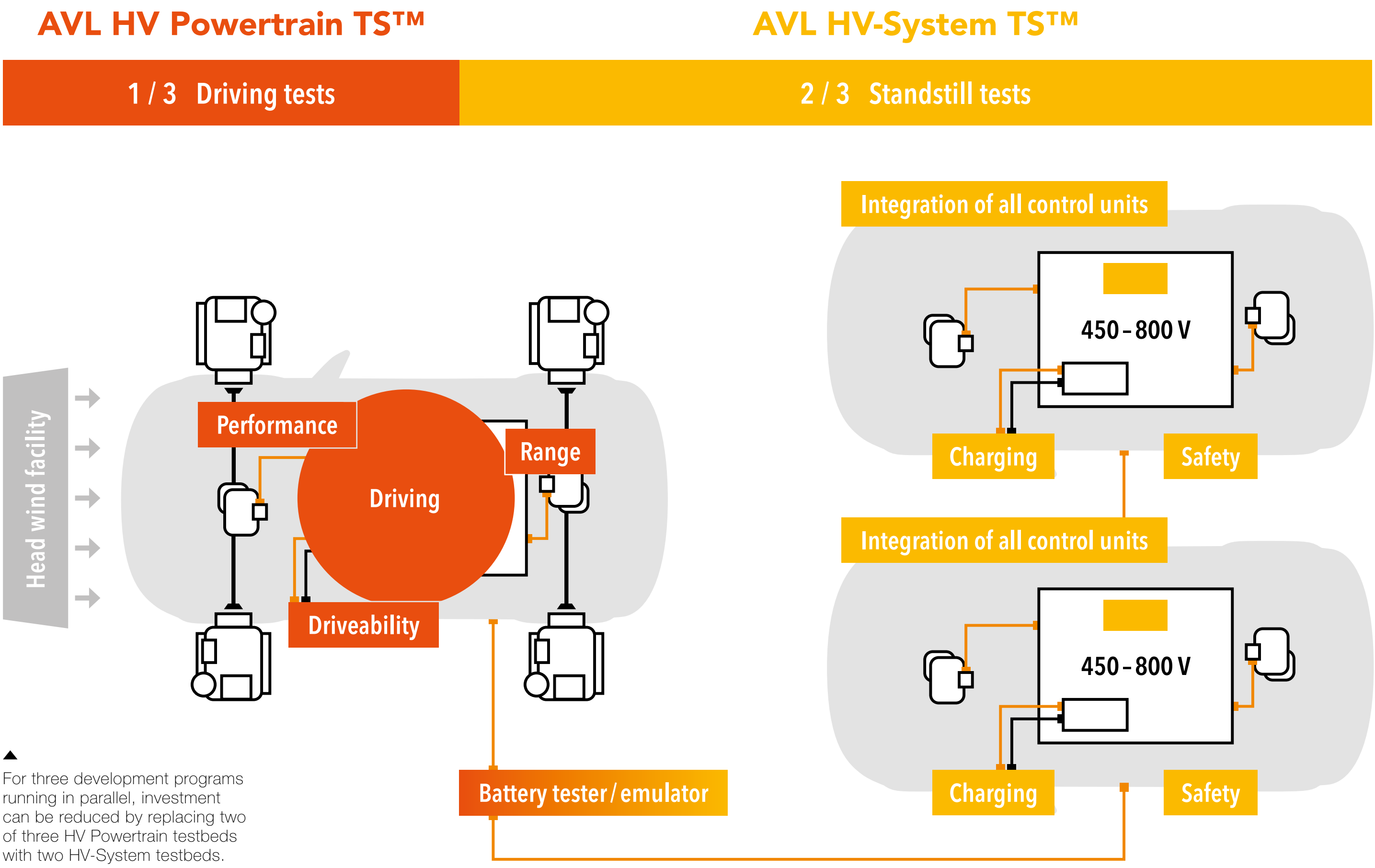
In a conventional or hybrid vehicle, calibrating the powertrain requires a lot of effort. The combustion engine interacts heavily with the transmission, the exhaust aftertreatment system and other systems, and therefore all must be present for the final OBD, driveability and emission calibration. On the powertrain testbed all of these and other relevant systems are present, and together with the high level of automation that is possible, it makes the testbed a powerful and valuable tool.

In a BEV, however, the powertrain can be largely calibrated and optimized at the component level, as there are fewer complex interactions to investigate and no pollutant emissions to consider. The calibration of the inverter is done with an inverter testbed using an e-motor emulator, and the complete Electrical Drive Unit (EDU) can be calibrated on the e-drive testbed. But with so much being done on the inverter and e-drive testbeds, what is left for the system testbed?



“The challenge lies in securing the integration of all the control units of the vehicle, especially since a BEV is typically equipped with connectivity options besides components for the electrical powertrain itself,” says Mats Ivarson, Chief Engineer Testfield Innovation and Operation at AVL.

Throughout the development process there are usually multiple loops of testing required to secure safety and functionality of the High Voltage (HV) network in the vehicle. Without all tests being passed, the software suite cannot be released for usage. Besides the HV tests for the in-vehicle systems, charging tests must also be conducted to ensure safety and the correct functionality. This effort is highly significant since there are, for example, many different component and system providers, safety and performance standards and power levels. However, when systems fail, the customer’s dissatisfaction is directed to the vehicle OEM. Therefore, there is a high level of motivation to conduct comprehensive testing in order to secure robustness to known potential disturbances, and continuously add newly discovered disturbances to the testing program.



▲ For three development programs running in parallel, investment can be reduced by replacing two of three HV Powertrain testbeds with two HV-System testbeds.

Charging tests as well as most HV safety and functionality tests are performed on a vstationary vehicle.

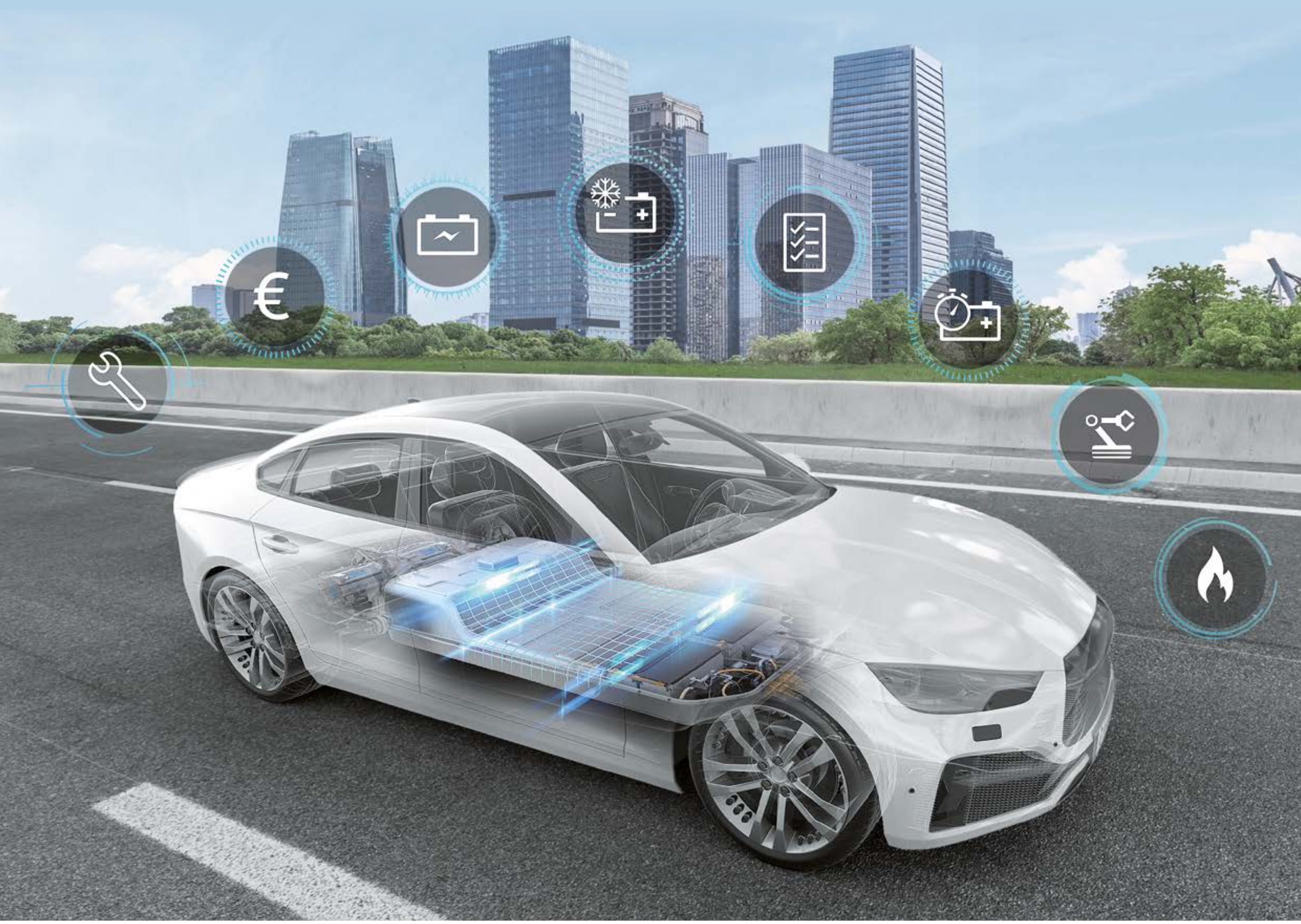
To reflect this and to take advantage of the additional connectivity of the BEV, we have created a new kind of testbed. The AVL HV-System TS™ testbed adds more simulation capabilities, including advanced restbus simulation, and does not contain the conventional dynamometers. This setup is optimized both in relation to functionality for integration testing and for the reduction of cost and complexity.

Martin Walcher, Lead Engineer Simulation Integration explains: “We have extensive experience in performing safety and integration testing as well as high-power charging tests for BEV development. For our customers it means that early integration testing possibilities are guaranteed without the requirement of having the real full prototype available.”

Our new testbed enables optimized integration testing of electrified vehicles and reduces cost, complexity and building requirements. The needed investment is reduced to about 40 % of that for a HV Powertrain testbed.

An example of the value the HV-System testbed provides is a situation where three development programs are running in parallel. Classically, we would need three HV Powertrain testbeds. But in our experience only 1/3 of all the needed tests require the full capability of this test system. It means that 2/3 of the tests can be fulfilled with two of our new HV-Systems. By combining one HV Powertrain testbed and two HV-System testbeds we reach the same testing capacity and results for a significantly reduced investment.

AVL SERIES BATTERY BENCHMARKING



HELPING OEMS FIND THEIR PLACE IN AN EVER-CHANGING MARKET

— As electrified powertrain technologies become increasingly prominent in automotive markets around the world, the focus is largely on key performance indicators such as vehicle range or performance. This places ever more demands on battery systems.

To remain competitive while satisfying market demands, the industry is constantly exploring new ways to enhance the electrified powertrain. New materials, technologies, processes and production methods are being investigated and refined in order to achieve inexpensive, large-scale high-performance battery production.

With the automotive landscape in such a continual state of transformation and change, it is difficult for OEMs to know how their products compare to others in the marketplace. To address this challenge and help manufacturers stay one step ahead of the competition, the AVL Series Battery Benchmarking program paints a picture of the current state of the market by examining the electrified powertrains of a wide range of vehicles around the globe.

IN-DEPTH ANALYSIS

Our battery benchmarking activities are not simply a tear down of the battery system. We conduct in-depth technical analysis of more than 240 benchmark criteria that examine battery functions, performance and system integration into the vehicle. This also includes a thorough analysis of the system's competitiveness with similar products on the market. And it all begins with a series of vehicle measurements.

These initial measurements include an analysis of the operating strategy and control systems. The battery pack is then subjected to detailed measurement on the testbed, with our experts examining the thermal, electrical and mechanical subsystems.

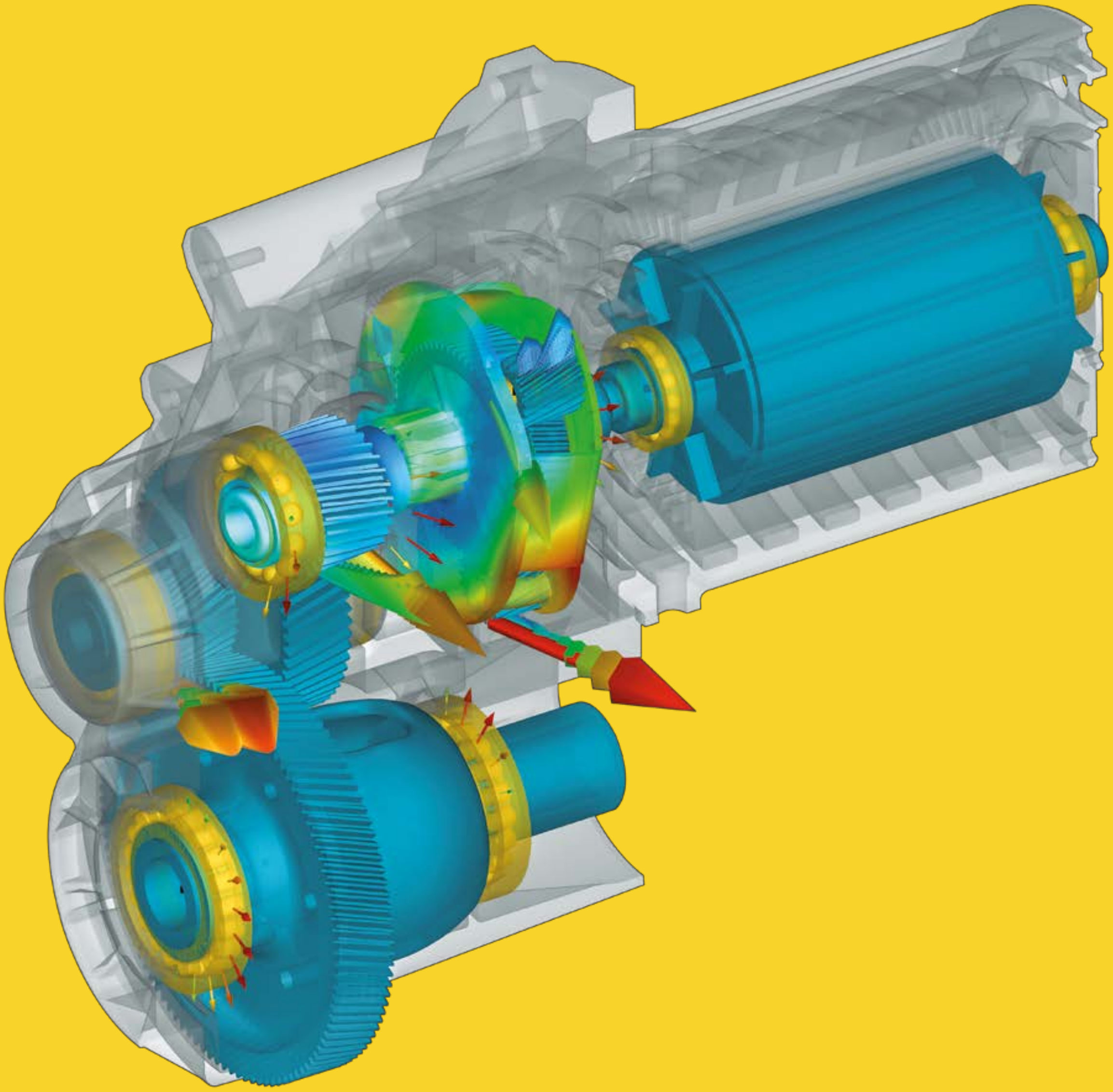
As well as a detailed safety assessment at pack and cell level, the production process and cost structure are also examined, to create a detailed specification list. Other criteria for analysis include a selection of engineering tasks such as condensate handling or an analysis of the EMC.

As an independent development and service provider to the automotive industry, we benchmark up to four innovative vehicles a year. This guarantees an outstanding depth of high-quality information and a high level of accuracy. The reports are regularly optimized not just regarding the technology and development methodology, but also on how the information is presented, to ensure clear and concise communication of the data.

To facilitate information transfer further, we also conduct customer workshops. Led by our expert representatives around the world, these allow you to get the most value and knowledge out of the data generated by our benchmarking program.

NEW DATA, IN-DEPTH VIEWS AND REPORTS

Since the AVL Benchmarking program is an ongoing exercise, our database is regularly updated. Our latest additions include the German Audi e-tron Quattro luxury SUV as well as the Korean Hyundai Kona city vehicle. And to particularly address solutions from a newcomer in China, we have also analyzed the NIO ES8. Currently we are working on the benchmark of the Porsche Taycan and have started the analysis of the first vehicle on Volkswagen's MEB-platform: The Volkswagen ID3.



ENVISIONING OPTIMAL PERFORMANCE

AVL EXCITE™ for eAxle combines accuracy and usability for transmission and e-motor simulation

— In the past, NVH characteristics of the combustion engine and transmission, along with durability analysis, have been investigated with modelling tools such as AVL EXCITE™. With electrified powertrains additional factors must be considered, such as electromagnetic influences and dynamic electrical-mechanical interactions. In pure electric vehicles, the combustion engine is not present to mask the sound and vibration of the e-motor and the transmission. These systems can generate high-frequency noise which can be uncomfortable for users, so there needs to be even more focus on NVH behavior.

Electrified powertrains are highly complex, often lightweight and flexible in construction, yet operate at extremely high torque loads. Conventional approaches with statically pre-calculated component deflections and gear transmission errors are not enough to properly investigate overall eAxle dynamic behavior. To reduce problems in later development stages, component flexibility with six-dimensional deflections and full contact interactions must be considered in a multi-body dynamic simulation model. However, investigating and optimizing the design of transmission and eAxle components and systems – especially early in the development process – can be laborious and time-consuming.

So, we have created AVL EXCITE™ for eAxle. This latest version of our world-class modelling solution features two new modules – the 'e-motor tool' and the 'e-axle tool'. These enable quick and easy high fidelity modelling of interactions between electrical and mechanical systems in greater detail than ever. With this approach, sensitivity studies can be conducted to evaluate production and assembly tolerances, focusing on design where it really matters. Investment in finding the optimal solution here will pay off in testing and production phases, while reducing costs.

EXCITE for eAxle enables the system to be optimized for efficiency and durability – vital for preserving driving range and product lifetime. Crucially, these activities can be carried out at the design stage, rather than in testing or even during the in-use phase, when issues arise with real hardware.

"A lot of OEMs work in troubleshooting mode," says Saša Bukovnik, AVL Solution Manager for Virtual Driveline Development. "Start of production is getting closer and they are finding problems with the gearbox, for example, that are impossible to rectify on the testbed. In order to understand the issue in a really focused way so that the design can be changed, and the problem solved, simulation tools are vital."

Until now several tools were needed to obtain a detailed view of electrified powertrain systems. EXCITE for eAxle brings everything you need into a single package and pairs it with a user interface that is intuitive for ease-of-use. Furthermore, its open architecture allows seamless integration into your existing toolchain, and data sharing with both AVL and third-party solutions.

"Model set up time and effort are reduced," says Bukovnik. "And it allows calculations of much more variance in order to investigate some really interesting engineering topics."

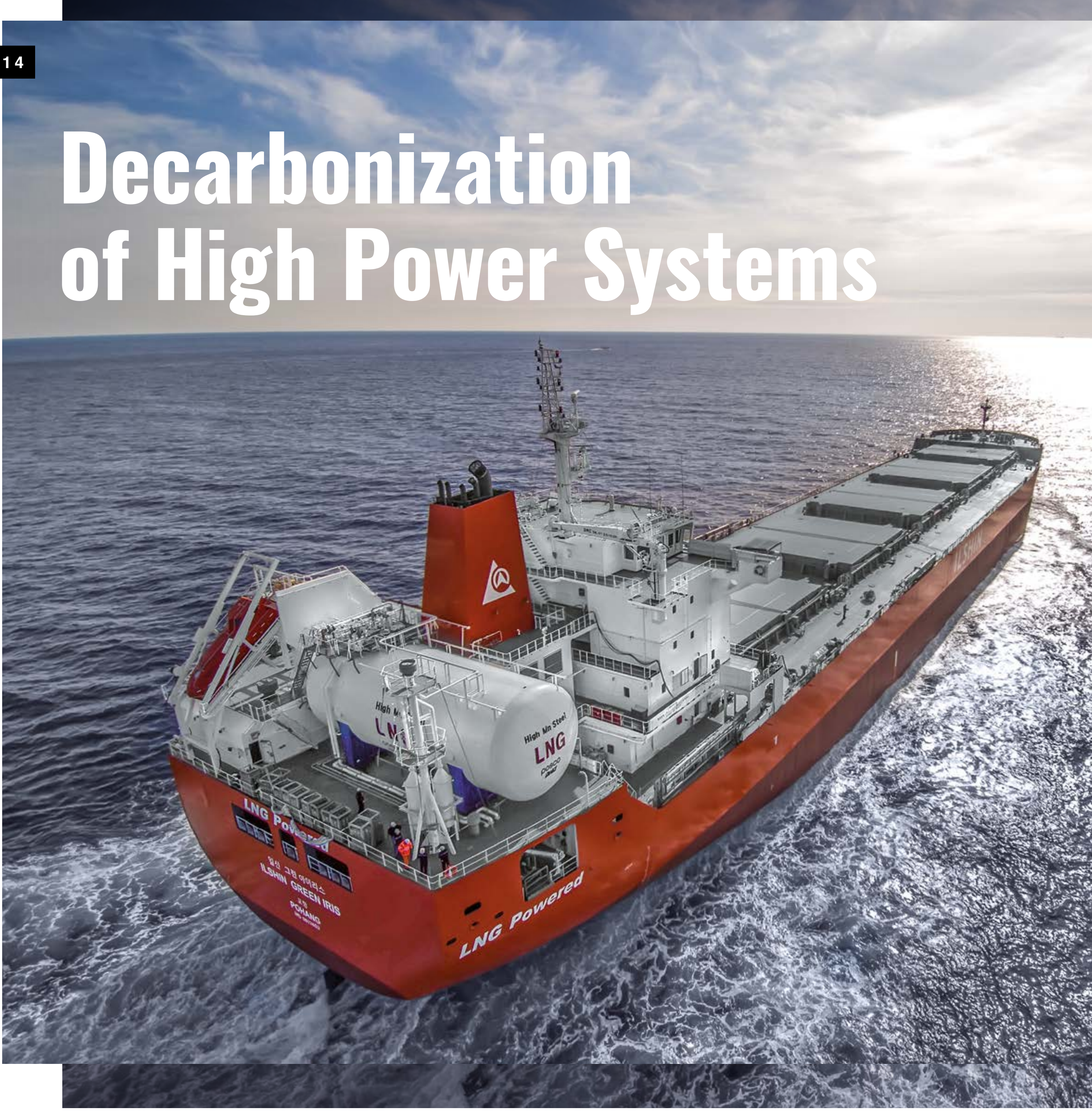
The automatic alignment of gears, including planetary gearset phasing, is supported, along with the easy import of e-motor loads or characteristics. A kinematic solution for animating the entire system lets you quickly gain insights into your designs.

With EXCITE for eAxle you can view structural loads and calculate parasitic losses, gear contact losses and roller bearing losses. These calculations can be combined with other factors such as oil splashing simulations, to give an indication of system efficiency under different temperature conditions and different speeds. This facilitates efficiency and durability optimization even before any hardware has been built.

EXCITE for eAxle accelerates the maturation of electrified technologies by considering a wider array of factors at concept stage. Production and assembly tolerances and operating wear can also be taken into account which, while generally considered to be minor, can result in noise issues or even failure with high-precision systems such as e-motors.

"This product allows our customers to investigate these sorts of things upfront, which leads to better product quality" explains Bukovnik. "With EXCITE for eAxle we have the most complete and accurate simulation approach on the market. You can now consider effects which you could not solve with simulation in the past."

Decarbonization of High Power Systems



At AVL our solutions are not just limited to the road, but reach all kinds of large applications around the world

— While road traffic gets most of the headlines when it comes to emission reduction and climate legislation, the automotive industry is not the only sector with targets to meet. High power systems are facing similar calls to improve efficiency.

AVL's High Power Systems division (formerly known as Large Engines), works on big power applications including marine, stationary power plants, locomotives and large size off-road vehicles such as mining equipment.

Statistically, large engine applications are already cleaner and more efficient than their smaller counterparts. The largest container ships, for example, can transport around 24,000 containers, whereas a truck on the road can transport just one or two at a time. Measuring the fuel-per-ton cargo in goods transportation shows that seafaring vessels are the cleanest transport solutions, followed by locomotives. Indeed, compared with air cargo, marine applications are cleaner by a factor of more than 40, and many governments are keen to get goods transport off the roads for this very reason.


© Ilshin Shipping

Though marine vessels transport more than 80 % of the world's cargo, and produce less than 5 % of the emissions, much can be done to reduce this even further. With lifecycles for ships and locomotives commonly extending well beyond 25 years, the challenge is to meet the IMO targets of a 70 % reduction of carbon emission or 50 % reduction of GHG, compared to 2008 levels by 2050.

"The ships and locomotives that are being built now will still be in operation in 25 years," says Professor Kangki Lee, Senior Vice President of AVL High Power Systems. "So that means we have to start making improvements now, because solutions must be developed well in advance of 2050 to consider time for industrialization."

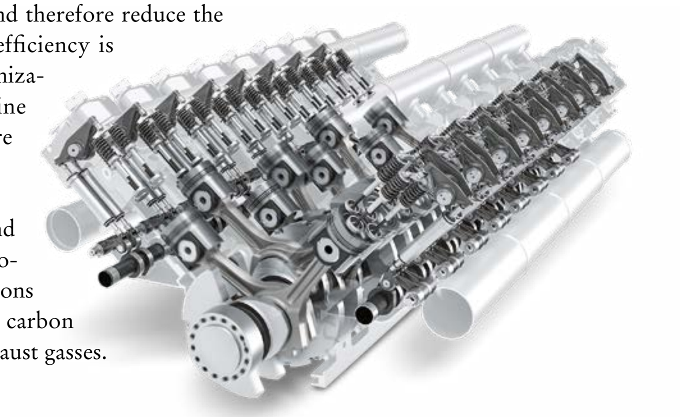
There is no single technological silver bullet to meeting these goals. Instead, technological innovations must be matched with improved operating strategies, new fuels, global infrastructure changes and a long-term perspective.

TECHNOLOGICAL APPROACHES

In many of the biggest applications, the goals are twofold. Cut pollutants and optimize existing systems with technological augmentation.

"If you look at the power range of large container ships, for example, they spend most of their life operating at less than 60 % of their rated power, depending on the trading route," explains Maria Segura, Product Manager, AVL High Power Systems. "The rest of that power is reserved for transient activities like manoeuvrability, or catching up with a schedule. With hybrid systems we can augment these transient operations and therefore reduce the size of the engine. So, the efficiency is increased by means of optimization – right-sizing the engine and then operating at a more efficient state."

As well as hybridization and optimization, AVL is also pioneering aftertreatment solutions for the removal of SOx and carbon particulates from marine exhaust gasses.



BEYOND TECHNOLOGY

All applications are different in the way that the vehicles are built, used, maintained and their role in the bigger ecosystem. But with decades of experience, a vast and comprehensive product portfolio, and a global network with a deep understanding of all the issues, at AVL we can create unique solutions that are tailored to every use case, and which seek out efficiencies throughout the energy chain, from well-to-wheel.

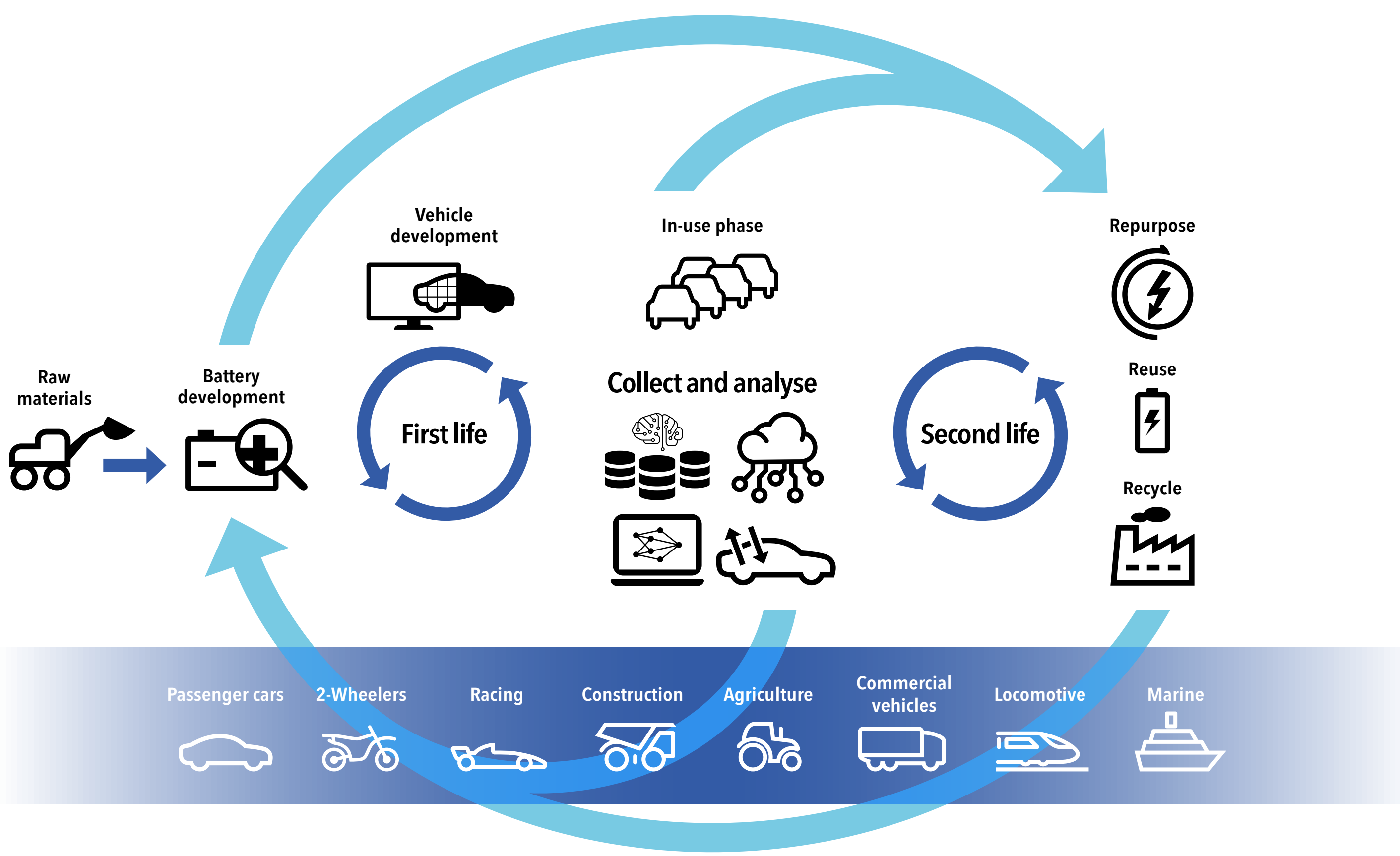
But solving the problem of emissions of high-powered systems is not just about individual applications, but also about long-term, global visions of policy and investment. This includes the reuse of captured carbon in the creation of new fuels, and the increased use of digitalization – driving intelligent, adaptive solutions that offer a wide range of efficiency and performance improvements. And it doesn't stop there.

"The main driver of these changes is climate regulations, but another is economy," says Professor Lee. "By having these new solutions you can comply with emission regulations, and because of the increased efficiency you profit from it. So, it is better for the environment, and it is better for your business."

AVL Battery Lifecycle Management

The life of a battery – from cradle to grave

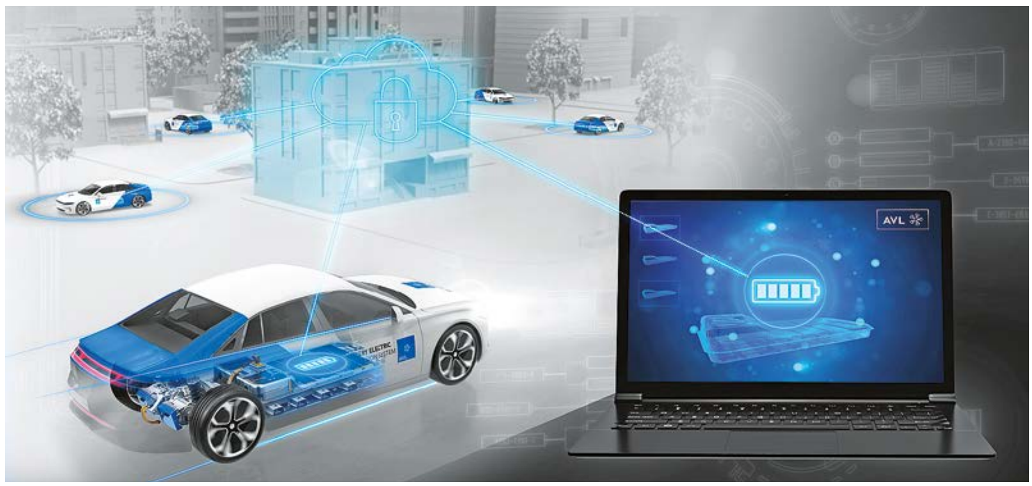
— As well as being a key component and the most expensive part in an electric vehicle, the battery only has a limited lifetime. Complex chemical and physical interactions inside a battery cell lead to degradation and aging which, over time, result in a loss of battery capacity and power. This directly impacts the range, performance and safety of the electric vehicle, and is the reason why automotive batteries are declared dead after 20–30 % capacity loss and handed over for second life applications or recycling.



How batteries age over time is heavily affected by the battery cell chemistry, battery cell, module and pack design and the battery management system. We support our customers in cell selection, testing, simulation and the development of batteries to maximize performance and lifetime, as well as in optimizing designs for battery repurpose and recycling. We have tools, methods, testing solutions and advanced data-driven methodologies to support our customers and partners throughout the life of a battery – from raw material extraction to battery production, vehicle development and in-use fleet operation, right through to second life applications and recycling.

WE HAVE TOOLS, METHODS, TESTING SOLUTIONS AND ADVANCED DATA-DRIVEN METHODOLOGIES TO SUPPORT OUR CUSTOMERS AND PARTNERS THROUGHOUT THE LIFE OF A BATTERY.

While deriving lifetime requirements from battery testing during battery development is the core target in the concept phase and basis for the quality assurance of the battery, the final operation of the battery in the vehicle needs to be included to validate and complement this approach. At AVL we utilize battery data from the vehicle fleet in-use phase and combine it with real-time capable simulation models – known as digital twins – to drive battery development and optimize and predict in-use operation. Finally, we use advanced data-driven and cloud-based methods combined with years of battery know-how, from battery production to the end of its lifecycle, to determine the remaining value of the battery after its first life. This enables us to define its second life destiny: reuse, repurpose, or recycle.



BATTERY HEALTH FOR ELECTRIC VEHICLE FLEETS

EV batteries have a tough life. Subjected to extreme operating temperatures, hundreds of partial cycles a year, and changing discharge rates, they degrade strongly during the first years of operation. The challenge for every vehicle fleet provider is to maintain performance, maximize lifetime and optimize residual value for second life applications.

We provide customized solutions to monitor vehicle fleets and battery conditions on the road by using the Internet of Things (IoT) and cloud-based analytic platform solutions. By connecting all vehicles in the fleet and sending this data to the cloud, big data and battery lifetime methodologies can be applied to analyze the fleet operation and provide recommendations on operation and charging strategy, as well as prediction of the battery's end of life and failure probability.

Our tools enable tasks such as:

- Real-time battery observation of all fleet vehicles
- Real-time battery status monitoring
- Route, operation strategy and charging optimization
- Time and cost savings with predictive maintenance

DEAD BATTERIES DESERVE A SECOND LIFE

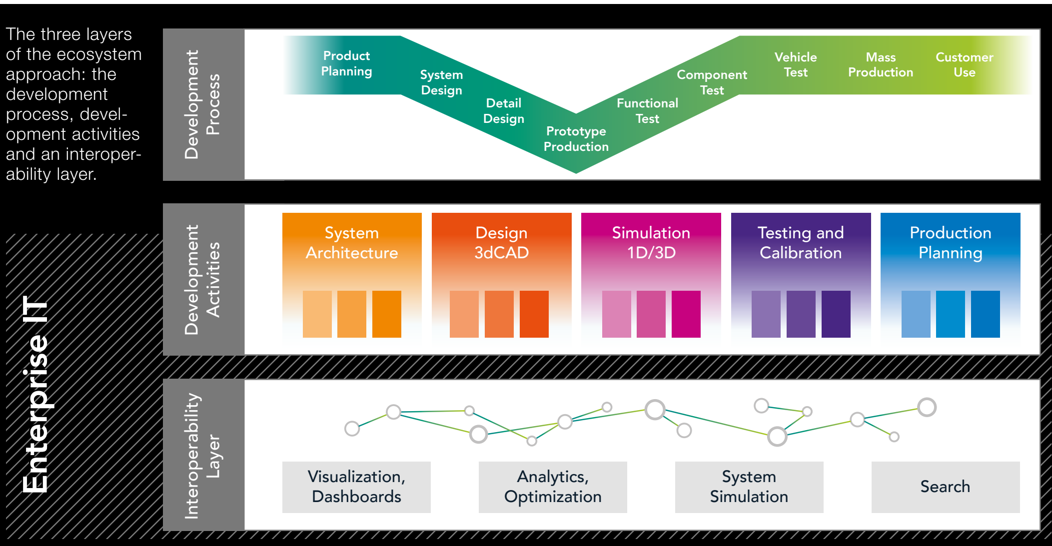
The continued global growth of electric vehicles will lead to terawatt-hours of batteries that no longer meet the requirements for EV use, but are still useful in less demanding applications. While this is an emerging opportunity for the stationary storage power sector, certain challenges need to be overcome to enable an economic and sustainable process along the battery value chain, such as a standardization of state of health definition as well as the actual value of a battery after usage.

Working closely with recycling companies and second life service providers, we are tackling these challenges by combining data-driven battery lifetime methodologies with state-of-health measurement tools and technological standards. The outcome is a method for deriving the remaining value of a used battery, while considering economical factors, sustainability and design for reusability and recyclability.

Augmented Development and the Ecosystem

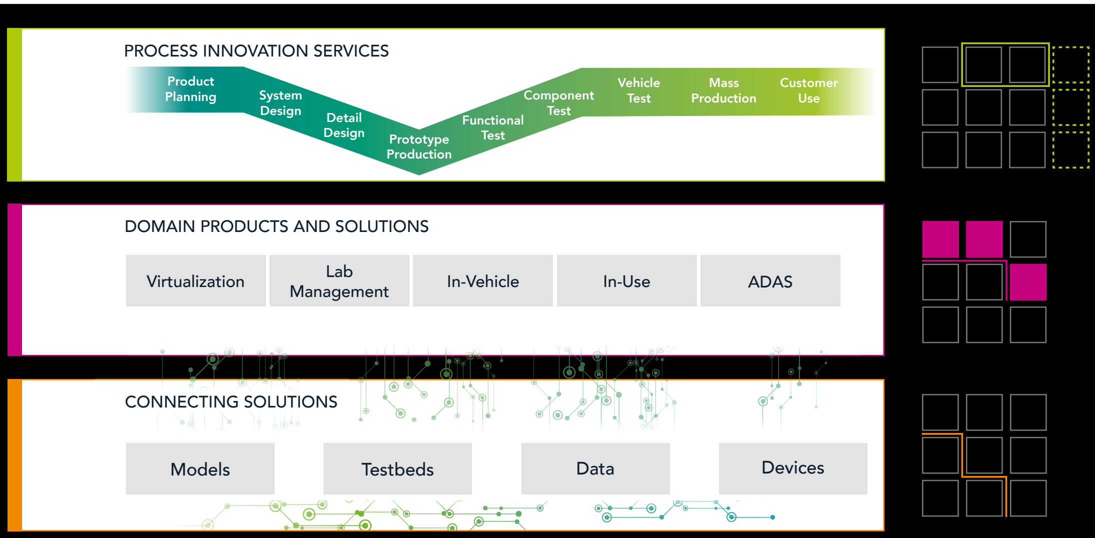
A new era of automotive technology calls for revolutionary development thinking. And that is just what AVL is offering with the development ecosystem

The three layers of the ecosystem approach: the development process, development activities and an interoperability layer.



Connecting all stages of development and augmenting it with the vehicle in-use phase and digital twins to increase speed and flexibility.

Tools, services and solutions as they relate to ecosystem approach.



For more than seven decades AVL has been creating products and solutions for every aspect of powertrain development. From combustion sensors to emission measurement systems, NVH solutions, thermal management and beyond. A broad product portfolio of tools which address every inch of the vehicle and every individual development phase, backed up with the know-how of a global network of highly skilled experts.

The conventional vehicle as we know it has been developed over more than a hundred years. But as new, highly complex electrified powertrain configurations and autonomous driving technologies represent the future of mobility, OEMs don't have the next century to bring mature products to market.

The answer to these challenges is not simply individual tools, solutions and areas of expertise. Instead it's about bringing all of these things together to realize a revolutionary new vision of what the development process should look like. And that's exactly what we're doing at AVL.

A HOLISTIC, ECOSYSTEM APPROACH

Typical vehicle development involves different teams working on individual domains and parts of the vehicle. One team might be working on thermal management for example, another on NVH characteristic design, and another on the transmission system.

While all of these teams and disciplines work towards a shared goal of the complete vehicle, they also have individual goals to meet. And it's not until systems and components are integrated – on the testbed or in costly prototypes – that the cross influences can be thoroughly investigated, and synergies understood.

This conventional approach is expensive, time consuming, and results in unwanted development loops. And in this period of automotive transformation and growing vehicle system complexity, where efficiencies must be found in every part of the development process, it is becoming increasingly impractical to develop vehicles this way.

And so, at AVL we have brought our years of expertise, our tools and methodologies together in a single, unified approach, that revolutionizes the way we approach vehicle development.

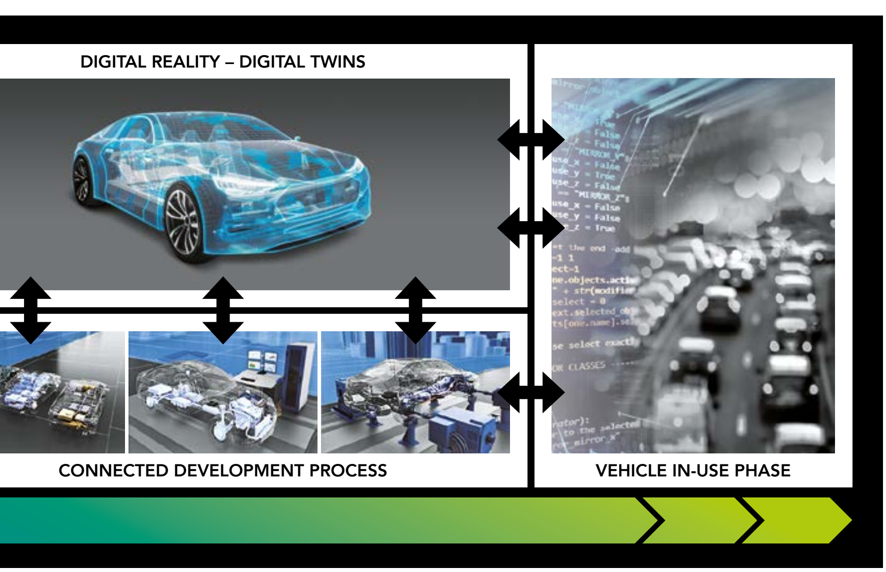
Using digitalization, simulated digital twins and an end-to-end development philosophy that extends to the in-use phase, we are helping OEMs and Tier1 suppliers break out of this siloed thinking. Our approach allows teams to easily share their work and progression, right across the project. Furthermore, it utilizes the power of data intelligence to share goals and drive optimization all the while significantly reducing the need for prototypes. This diminishes time to market, saves money and accelerates innovation.

CONNECTED TOOLS AND LAYERS

By harnessing our cross-domain know-how and our Open and Integrated Development Platform (IODP), the development ecosystem allows the rapid realization of project goals on both micro and macro levels. This ecosystem approach can be used to create new development workflows, or to augment existing architectures. It is organized into three layers: the development process, development activities and an interoperability layer. In accordance with this, AVL provides services and tools that match this ecosystem.

The first layer, Process Innovation Services, is designed to optimize each step of the process, from product planning to functional design and component testing, right through to mass production and customer use.

The second layer, Domain Products and Solutions, provides tools for specific domains / applications. It covers virtualization, lab management, in-vehicle testing, the in-use phase and ADAS system development.



The final layer is the Connecting Solutions layer. This allows the best use and sharing of data from all activities across the development process - independent of tools or suppliers. It includes our IODP solutions, Model.CONNECT™, Testbed.CONNECT™, Device.CONNECT™ and Data.CONNECT™.

These layers allow every domain, every process and every activity to be conducted with the bigger picture in mind. And, crucially, given the vast amounts of testing that are currently required for ADAS and autonomous systems, it extends into the in-use phase. This allows real world usage data from the latest connected vehicles to inform the development of the next vehicles coming off the production line.

To explore the AVL development ecosystem approach in greater detail, over the next few issues Focus magazine will be highlighting different aspects of this revolutionary approach. In this issue, we begin with a detailed look at Virtualization.

Virtualization
in the Connected Development Ecosystem

With rapidly increasing system complexity, traditional development methods are quickly becoming outdated. AVL's new augmented ecosystem approach offers a wide array of solutions and methodologies that revolutionize the development workflow. One such solution is the application of virtualization.

— Virtualization is the change process that transforms a physical and hardware-centric development process with a more extensive use of simulation technologies and methodologies. Virtualization can be applied in varying degrees which are tailored to your needs. We call this the virtualization ladder.

FOUR STEPS TO VIRTUALIZATION

The virtualization ladder starts at step one, with a development workflow that includes only physical testing in the lab and on the proving ground, prior to SoP. In this scenario, data is shared manually between the lab and the office, and there is a heavy reliance on costly prototypes. The whole process is slow and expensive, and bringing products to market takes much longer than is ideal.

In circumstances like this, where there is no virtualization competence, our role is to introduce the customer to its benefits in the most accessible way possible, taking them to step two in the process. We achieve this by recommending application-related packages that begin to streamline the relationship between the office and test environments, and reduce reliance on prototype hardware.

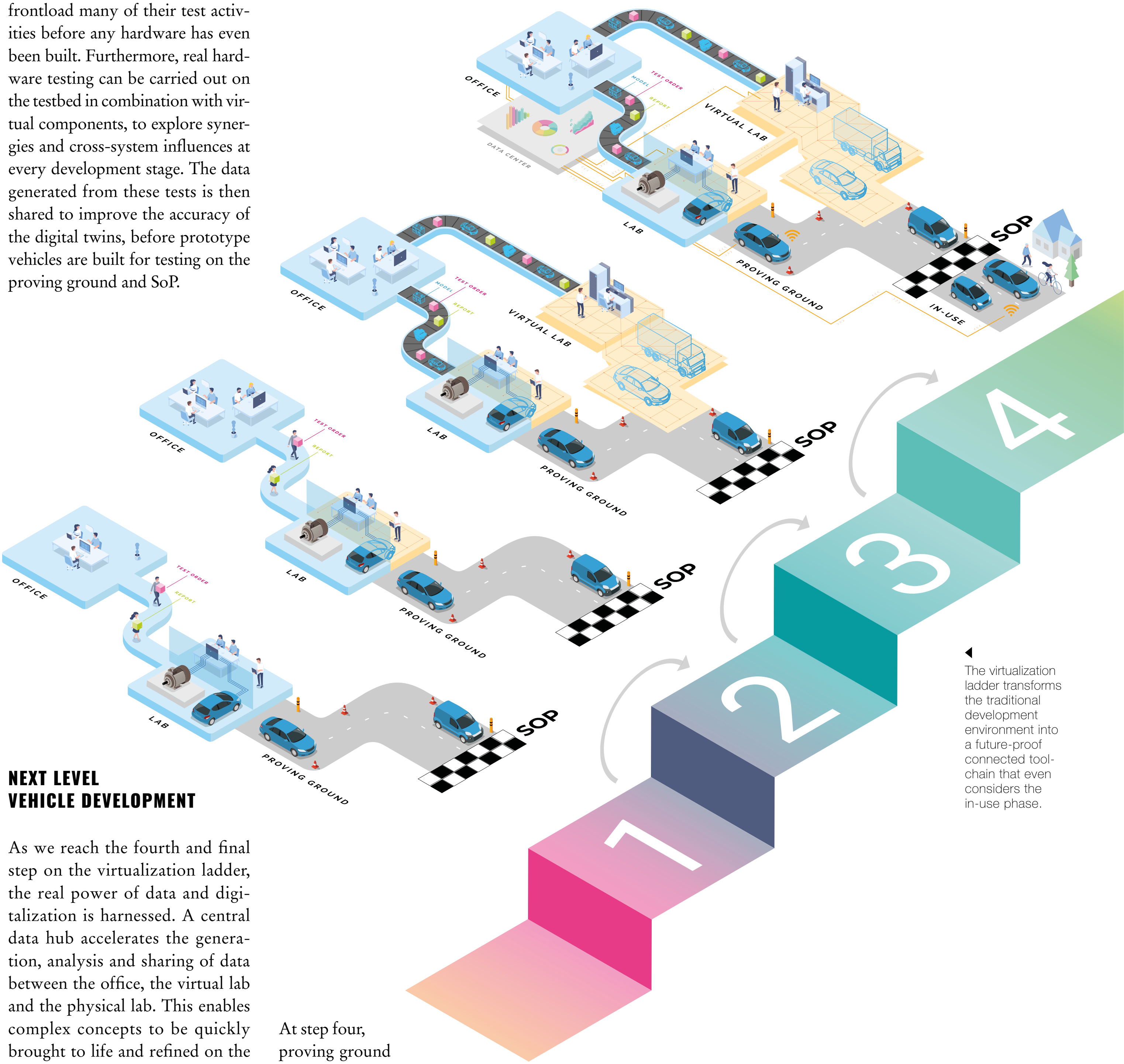
The packages we recommend are implemented locally at critical points in the toolchain. Test preparation is improved both in the lab and on the proving ground with the application of our AVL Smart Mobile Solutions™ simulation package. Complete vehicle modelling is powered by AVL ISAC™ and AVL VSM™ and test analysis is provided by AVL CONCERTO™. Crucially, at this second step of the ladder no simulation expertise is required on the part of our customer, and we offer full integration support and training to ensure the transition occurs as painlessly as possible. Integrating our tools and methodologies into a development environment where there were previously none is a simple and effective way of demonstrating the powerful impact of virtualization.

CONNECTING THE VIRTUALIZATION EXPERIENCE

At level two, most departments are still working relatively independently with test orders and test results being shared manually, and only partial system modelling happening. There is still a large requirement for hardware and proving ground testing. However, as we progress up the ladder to level three, bridged applications with more simulation tools are connected to enable data to flow more freely.

Virtual testing is facilitated with AVL Virtual Testbed™, which is supported by our complete vehicle modelling solutions to create a virtual lab where simulated systems or a complete virtual vehicle (a digital twin) can be built and tested. Testbed.CONNECT™ links the tools together in order to make the most of the data, and feed the results of the testbed activities back into the vehicle models.

With the further addition of our market-leading solutions for test preparation, optimization and results analysis, our customers can frontload many of their test activities before any hardware has even been built. Furthermore, real hardware testing can be carried out on the testbed in combination with virtual components, to explore synergies and cross-system influences at every development stage. The data generated from these tests is then shared to improve the accuracy of the digital twins, before prototype vehicles are built for testing on the proving ground and SoP.



The virtualization ladder transforms the traditional development environment into a future-proof connected toolchain that even considers the in-use phase.

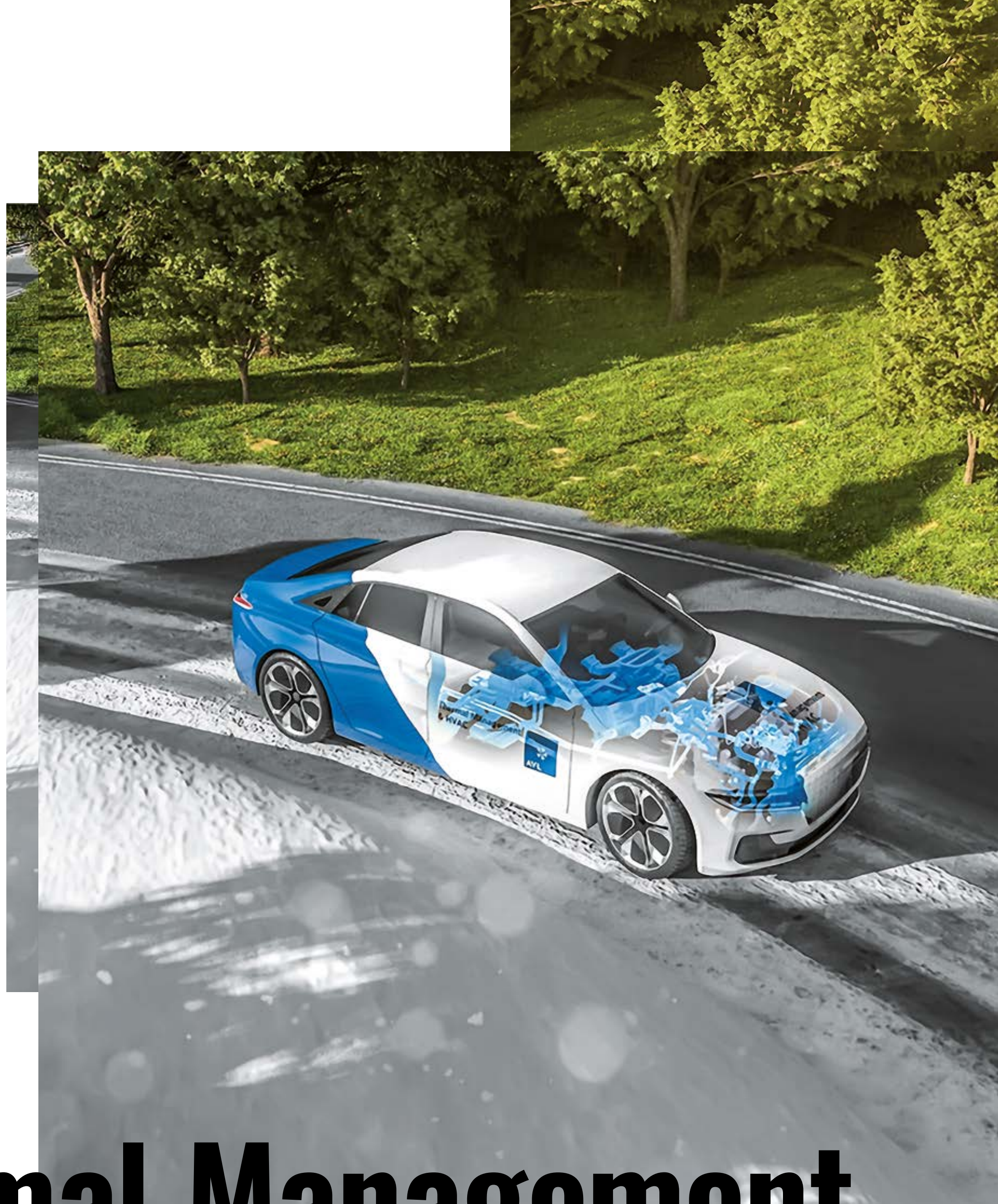
NEXT LEVEL VEHICLE DEVELOPMENT

As we reach the fourth and final step on the virtualization ladder, the real power of data and digitalization is harnessed. A central data hub accelerates the generation, analysis and sharing of data between the office, the virtual lab and the physical lab. This enables complex concepts to be quickly brought to life and refined on the virtual testbed in order to meet targets at system and complete vehicle level. As hardware is rigorously tested and validated in the lab, the results are quickly fed back to the office and the virtual lab, and further refinements and trade-offs can be quickly introduced to the vehicle model, which then further informs more hardware testing.

At step four, proving ground testing can now feed directly back into the workflow, further validating the simulated models, and enabling thorough testing under real conditions. Crucially, with the advent of connected vehicles, development can now be extended to the in-use phase. Real drivers become part of the development team, and their behavior, maneuvers, and fleet-wide data that is simply impossible to collect during formal testing can now be fed back into the development loop.

This in-use data can inform the next generation of vehicles, and can be used to create firmware updates to improve vehicles already on the road.

Virtualization is a key tool in the acceleration of complex vehicle development, and at AVL we are already employing it to help OEMs shape the future of mobility.



Thermal Management and HVAC

— Understanding thermodynamics is the foundation to successful vehicle integration as well as the efficient interplay of all systems and components. An integrated vehicle thermal management strategy (VTMS) balances energy consumption, improves durability and overall efficiency. Most of all, it assures the highest possible comfort and safety for passengers.

THERMAL MANAGEMENT STRATEGIES FOR TODAY'S EFFICIENCY CHALLENGES

Do efficiency and comfort present a conflict of objectives? Under extreme conditions, the range in the Battery Electric Vehicle (BEV) is reduced by up to 50 percent as soon as the heating or cooling in the passenger compartment is activated. The imposed challenges of electrification, therefore, demand energy balancing and maximum comfort with minimal energy consumption. This means that a VTMS can only be 'smart' on the vehicle level, with predictive controls, optimized cabin models and cooling strategies, heat pumps and isolation. So, how does AVL master this complexity in thermal management and HVAC?

Foremost, we commit to digital: Within the next years, we want to make physical vehicle validation redundant up to the pilot series. Digital twins are just way more flexible and in proprietary AVL toolchains and development environments, they allow us to reliably and rapidly take the next functional leap. Subsequently, we reduce complexity and help you find unique, optimal solutions. And, digging deeper, it shows how coupled, integrated simulation and testing fit the challenges of the market.

STRONG AMBITIONS AND HOW WE LIVE UP TO THEM

We are aiming to reduce the simulation effort for xEV modelling by up to 40 percent. We expect an increase in overall development efficiency of more than 25 percent and an increase in the accuracy of model prediction by 30 percent. But how are we planning on getting there? And how is this vision compatible with our goal of making test mules redundant?

At AVL we are developing a holistic simulation environment for all xEV configurations. As a result we will be able to account for thermal KPIs and externalities at the vehicle level. The sub-models – electrical components, inverter and e-machines, battery, cooling and refrigerant circuit, the cabin model and control actuators – are integrated and interconnected with Model.CONNECT™. Thermal and HVAC experts then set up exemplary cooling and refrigerant circuits as well as an element pool for the straightforward exchange of circuit components. On our way to achieving automation, we then develop generic test cases based on vehicle and powertrain targets and increase standardization.

Putting things into perspective, we specify the sub-models to such an extent that a continuous adjustment and switching of the parameters and a holistic view of its effects are possible at vehicle level. The gathered know-how is accumulated for the development of predictive models. We enhance the model with additional target values, such as economy (cost-based solutions) and ecology (consumption-based solutions). In the end, this process will allow us to move from component to system validity – digitally.

There is no one-size-fits-all solution, but with proven and established methods we will find the right system design for each vehicle's architecture and each characteristic, no matter if there is a focus on high performance or on high comfort with balanced energy efficiency.

AVL THERMAL MANAGEMENT AND HVAC

Our team of specialists serve as an independent development partner for all powertrain concepts, we have a wide-ranging experience with both ICE and xEV, and are researching future technologies such as fuel cells. We have mastered more than 25 successful thermal management integration SOP projects in different industries: passenger cars, high-performance sports cars, racing, commercial, heavy-duty, two-wheeler, aviation, trains and yachts, and are creating a vision for the future of electrified mobility.

Collaboratively Powering a Battery Testing Evolution

ISP invests in battery testing solutions

— ISP is an independent automotive testing institute with facilities in Germany, France and China. It provides testing services to the automotive and mineral oil industry and thus serves as an important development partner. The testing portfolio of ISP includes the engine and powertrain, as well as vehicle emission and performance tests. The availability of in-house rating and chemical analysis services demonstrates the holistic approach to testing pursued at ISP.

Yet in the face of climate change, the automotive industry is being forced to explore alternative powertrain solutions, and most OEMs are focusing their efforts on developing efficient electrified powertrains. This process, however, is still in its infancy and extensive research and development is needed to bring battery performance, safety and reliability on par with modern combustion engines. ISP aims to aid this transition by supplying the OEMs with a range of battery tests. These will be conducted in the all new ISP Battery Test Center, which, with a total investment volume of more than EUR 60 million, will become one of the world's largest battery testing facilities when fully completed at the end of 2021.

By supplying the testbeds and related equipment needed to conduct said tests, at AVL we are continuing our long-term relationship with ISP and building on the experience we have gained in the field of combustion engine testing. Our involvement, however, goes beyond simply delivering hardware. Having a considerable amount of industry and application ex-

pertise we have assisted ISP from the early planning stage of the project. This began with a thorough market analysis in May of 2019 on the basis of which the concept of the Battery Test Center was laid out in partnership with ISP.

In a first construction phase several performance and lifecycle testbeds will start operating by the end of this year. Facilities to conduct abuse, environmental and safety tests will follow in a second construction phase.

When fully completed the ISP Battery Test Center will offer a complete package of battery pack and module testing services. Designed with future expansion in mind, the entire project has been conceived to react to future industry demands and thus stay competitive for years to come.

AVL PUMA 2™ Fuel Cell for Cell and Stack Testing

— The development and testing of fuel cell stacks and cells is gradually becoming an integral part of automotive series development programs. This growth comes as many OEMs and Tier suppliers prepare for a wider market introduction of fuel-cell-powered passenger cars, busses and trucks. To address this market demand, we are going to launch AVL PUMA 2™ Fuel Cell for Cell and Stack Testing by the end of 2020.

With our new tool you can now operate fuel cell test stations from Greenlight, the leading global supplier of fuel cell testing equipment. This allows you to integrate PUMA, the industry standard for testbed automation, into your fuel cell electric vehicle development infrastructure and benefit from our proven toolchain. AVL PUMA 2 Fuel Cell allows the control of various sub systems to handle stack reactant supply, coolant supply, and load – from single cells to full-size stacks.

FIND OUT MORE:
www.avl.com/puma2-fuel-cell

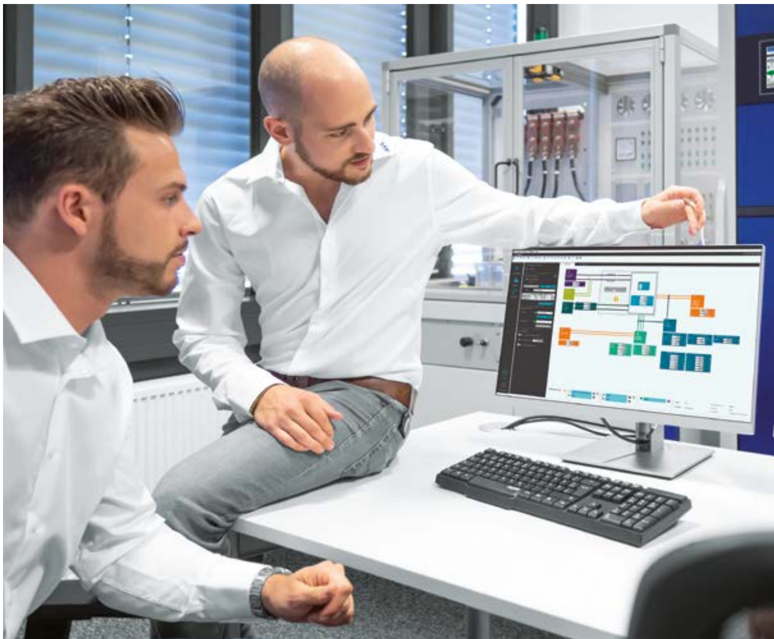
AVL PUMA 2™ Inverter

— The inverter is a key component in electrified powertrain systems. Conventionally, validation of the inverter has required a variety of tools, making this activity expensive and time-consuming. AVL PUMA 2™ Inverter solves this problem.

The leading automation system to test and validate inverters, it allows easy parameterization and online operation of the AVL E-Motor Emulator™. This results in efficient operation of the inverter testbed.

PUMA 2 Inverter features an intuitive user interface for ease-of-use, and an open architecture to facilitate connectivity and seamless integration into the testfield.

FIND OUT MORE:
www.avl.com/puma2-inverter



AVL PUMA 2™ Production

The Ease of Automation

FIND OUT MORE:
www.avl.com/puma2-production

— The shift in the automotive industry towards electrified propulsion has led to a rapidly increasing demand for End of Line (EOL) and Conformity of Production (COP) testbeds in the production environment.

We are meeting this trend with the forthcoming release of our new automation system, AVL PUMA 2™ Production, alongside our AVL End of Line Testing Systems. The first phase of development will be the implementation of a package for e-axle testing. PUMA 2 Production pays particular attention to the special requirements of the production environment, such as 24/7 operation, unmanned operation and statistical data evaluation of all measurement results. This ensures that the end product meets the highest quality levels. AVL PUMA 2 Production is characterized by robust and fail-safe design with very competitive pricing.

The global product launch is due to take place in Turin in early 2021 and later expanded to include battery and fuel cell testing capabilities.

AVL X-ion™ e8/e16 for Real-Time E-Power Analysis

— AVL X-ion™ e8/e16 is the latest product to join our AVL X-ion™ family of data acquisition devices. It provides you with highly precise and accurate measurement data for the testing of inverters, e-drives and complete drivetrains.

We have built X-ion e8/e16 with loss-free bi-directional time-stamped data exchange to deliver data for use with the included AVL IndiCom™ software and its e-Power Toolbox, as well as connected tools such as AVL PUMA™ and AVL CAMEO™. When paired with the latest version of IndiCom V2.10, computations can even be carried out on the device itself, creating a world of possibilities for the automation of dynamic calibration and measurement tasks. Real-Time Processing allows algorithms to be run on the integrated hardware, such as space vector decomposition (d,q) for the calibration of drivetrains featuring permanent magnet synchronous machines (PMSMs).

AVL SlimLine™ Dilution Systems Win Red Dot Award

— The one-of-a-kind AVL SlimLine™ Dilution Systems range of products have been recognized by the prestigious Red Dot design awards, in the Innovative Products category. The devices combine an intelligent service concept with unique flexibility and a small footprint, to bring market-leading emission measurement into the already crowded testfield.

More than 6,500 products were submitted to the annual awards for consideration by an international panel of renowned designers. The SlimLine Dilution Systems were chosen as the winner for their world-class concept and for setting new standards in the industry.

reddot winner 2020
best innovative product

AVL Cell Tester™

Exploring New Horizons

— The AVL Cell Tester™ is a bi-directional, multi-channel DC power supply that tests, characterizes and validates battery cells. It features an ultra-small footprint to save space in already crowded testfields, and achieves output currents ranging from ± 2 A to ± 1500 A. This is made possible thanks to its multiple variants and the parallelization of its channels.

With high control and measurement accuracy and smart utilization of multi-measurement ranges, it offers precise and repeatable measurement capabilities. Super-fast current and voltage dynamics, high-speed data acquisition and control are also included in this turnkey product, which can be tailored to the specific needs of your testbed.

FIND OUT MORE:
www.avl.com/-/avl-cell-tester-

AVL PEM Fuel Cell Simulation Solutions

Mastering the complexity of future mobility

— Fuel cell electric vehicles, which are powered by Proton Exchange Membrane (PEM) fuel cells, are becoming increasingly popular as an option for reduced emission mobility. But optimizing them for best performance and durability requires a comprehensive approach that scales from the smallest, most detailed cell level, up to a bigger system perspective. And it must also include integration with other systems into the whole vehicle.

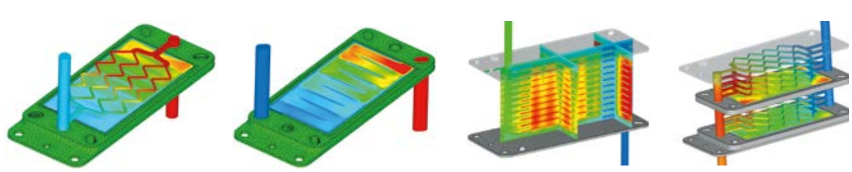
Right-sizing ancillary systems and components, creating your controls, operating and cooling strategies, and making the best choices regarding energy split between the fuel cell and the battery must all be carried out with precision. One wrong decision at the concept stage can impact efficiency, performance, and system lifetime, and have a negative influence on development costs and time to market.

AVL PEM Fuel Cell Simulation Solutions address these challenges. This package helps you design and optimize fuel cells and stacks and their supporting systems, and make the best decisions concerning integration.

It covers everything from the modelling of gas flow, reaction, transport and conversion processes with AVL FIRE™ M, to system simulation using AVL CRUISE™ M. It is designed to enable you to understand how your concept will work under different driving conditions, to help you choose the right Membrane Electrode Assembly (MEA) components for your application, and right-size other Balance of Plant (BoP) system components in order to make the most of your fuel cell's potential without causing failure or degradation phenomena.

"So, our scalable PEM Fuel Cell Simulation Solutions provide everything you need for choosing the right components, integrating them together, and also understanding how they will behave under all operating conditions, such as idling or full load, or somewhere in between," explains Reinhard Tatschl, Research and Technology Manager at AVL Advanced Simulation Technologies.

From developing your fuel cell controls strategy to designing your entire vehicle cooling concept, our system lets you quickly and easily understand what is required to meet your targets – before any hardware has even been built. It even lets you predict system degradation. And, as with all AVL eSUITE™ solutions, it does all of this with a single user interface keeping everything in one place, for simplicity and ease-of-use.



Modular Solutions for Challenging Problems

AVL is thinking outside the box to provide solutions for Non-Road Mobile Machines (NRMM)

— Global emission legislation is putting pressure on the commercial vehicle industry, including both on-road and Non-Road Mobile Machinery (NRMM) sectors, to fulfil its obligations under the EU Green Deal by 2030 and 2050.

OEMs and Tier1s in the on-road sector, which represents around 80 % of the commercial vehicle market, are exploring a range of options in order to increase Brake Thermal Efficiency (BTE) by up to 50 % (170 g/kWh brake-specific fuel consumption) while maintaining performance. These include strategies such as:

- Increased thermal efficiency
- Reduced heat losses
- Reduction of mechanical friction

However, the NRMM segment – which includes agricultural, construction and material handling industries – has smaller production volumes and a lower market share of the commercial sector. It also faces different product requirements such as low total cost of ownership, high system robustness, and low noise, all of which must be tackled with a much smaller development budget that doesn't allow for such complex solutions.

AVL'S FUTURE VISION AND SOLUTION: A SMART, MODULAR APPROACH

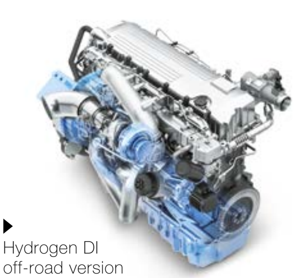
Reducing production costs in the NRMM segment is vital for maintaining commercial viability. To support this goal, we are enabling clear product target setting and a modular product development approach.

This modular approach involves the adaptation of existing components from the on-road market, in consideration of production boundaries. For example, this could mean using the same cylinder head raw parts with different machining, ready for different fuel types (including hydrogen). Another approach involves the use of alternative materials and system specifications for key components to fulfil application requirements, and the replacement of sheet metal with structural oil pans for tractor applications. Augmenting low power range engines (< 56 kW) with mild hybrid technology is an additional option to reduce costs and complexity.

One main strength is helping our customers realize their goals, by sharing far-sighted visions and supporting them with the tools and methods to define the correct options for their unique needs. In this way we are building a cleaner, more efficient world for everyone.

Base engine Diesel and Gas

Off-road version with structural oil pan



Hydrogen DI off-road version

SWITCHED ON AND FULLY CHARGED

AVL Electrification

From mild and plug-in hybrids to battery electric and fuel cell electric vehicles, AVL has the expertise to support you in making the right architecture choice for your electrification portfolio. With our development support, test and validation solutions, simulation tools and comprehensive know-how in these technologies, we are the ideal partner to help you succeed in this forward-looking technology landscape.

Find out more
www.avl.com/electrification