automotion

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AGORA VERKEHRSWENDE

If Germany wants to become climate-neutral in 2050, policymakers must move up a gear in several areas.

ECO BATTERY

IAV has developed a concept for a sustainable battery with a 20% reduced CO_2 footprint.

ROBOTICS

Field test: A harvesting robot developed by IAV automatically picks fruit and vegetables. First application: the strawberry field.

Under power

E-mobility takes off: Smart engineering in the age of the battery – how IAV is shaping the future of the e-vehicle.

Dear Readers,

The automotive world is under power. Hardly a month goes by without the announcement of new e-models, record sales for plug-in hybrids and battery-powered vehicles or the publication of pioneering technical developments. In short: The e-vehicles are here. Here and now.

And now, just when manufacturers are scaling up their production and more e-vehicles are rolling off the production line, IAV is producing a booklet on e-mobility? That's a bit late, you might criticize. Or ask: Has IAV missed the developments in e-mobility so far?

We can reassure you. We have not. On the contrary. We believe that the time has never been better for an issue on e-mobility that highlights details and does not keep the topic to a few brief tweets. Even if the first customers are already reeling off electric kilometers - the work for us as developers has only just begun.

From the optimization and further development of e-kits, the use of artificial intelligence in development, monitoring thereof in practice, to the advantages of a modern and powerful test bench infrastructure as well as efficient high-voltage storages in new vehicle generations - we open the tabernacle of e-mobility and show which technologies and methods we intend to use to develop the next generation of e-vehicles more cost-effectively, launch these on the market faster and, on top of that, design these more ecologically sustainable.

Sustainability is also a disputable keyword in this context and not just since the tightening of the German Climate Protection Act [*Klimaschutzgesetz*] that was hastily passed overnight. The fact is: The e-vehicle alone will neither save the climate nor catapult us onto the fast track towards CO_2-neutrality. From raw material extraction to electricity generation to recycling-friendly battery design: The basic conditions must be right, blanket statements must be avoided, and alternative drive concepts taken into consideration depending on the usage scenario. This is why in this issue we also look at e-mobility from the point of view of the never-satisfied developer striving to achieve the best solution. We leave marketing and core messages to others.

Whereby: Nevertheless, we still want to do a little marketing for ourselves. Our electrically driven and autonomously controlled HEAT shuttle is back in Hamburg. The passenger service will start in midsummer. You, dear readers, are cordially invited to come on board and experience the electric mobility of the future live. A brief registration is all it takes – conveniently via the IAV HEAT app (available in the App Store).

We wish you an electrifying read!

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"You can't stop the waves, but you can learn to surf"

Jürgen Müller moved from VW to IAV in April. In his function as the new Head of Connected Software Systems & Services, he takes note of his first midterm report.

automotion: Mr. Müller, you moved from Volkswagen to IAV in the midst of the pandemic. How did the lockdown launch go?

Jürgen Müller: The pandemic poses major challenges for the entire industry. Considering this, my debut has been quite calm. I was already able to have many interesting discussions with colleagues. This gave me a good overview of the topics and an initial impression of the mood. The variety of topics and the concentrated know-how inspire me and at the same time represent a challenge.

automotion: Which topics are at the top of the agenda for you and your team?

Müller: My priority is clear: Together with the colleagues, I would like to substantially expand the business fields Software, Connected Systems, and Data and Services. The quality of modern mobility solutions is measured less in terms of horsepower or engine capacity than in the degree of maturity of the software or connectivity solutions. With our know-how, we can support our customers throughout the complete life cycle of software - from development and implementation to updates and maintenance.

automotion: What role can and should IAV play in the field of software?

Müller: This is not just about the software itself. An intelligent system and software architecture are essential for integrating and operating the increasing number of services in an uncomplicated manner. We would like to offer our customers this foundation, a "digital backbone", which allows us, to surf the digital wave properly. Hence my motto: "You can't stop the waves, but you can learn to surf."

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We2Run

Virtual on the run – for the good cause

Put your sports gear on and head out to do good together! Unfortunately, it is not possible to start together this year either, but it is possible to run together - at IAV's second virtual cross-location running event.

On the weekend of June 5 and 6, colleagues tied up the laces of their running shoes. They ran or walked, at a time of their choosing, at their own pace and on a course of their own choosing. Not the speed was important, but the distance. Each participant tracked their individual distance via smartphone, smartwatch or app and at the end the kilometers of all IAV runners were added up. For every kilometer that was run, IAV donates one euro to the charity Herzenswünsche e. V.

On the course alone, but virtually together, the enthusiastic IAV colleagues covered a total of 3,651 kilometers. For a good cause, IAV rounds up the total so that we can support Herzenswünsche e. V. with a donation of EUR 5,000. This way, despite the pandemic, we achieved something together and showed our team spirit!

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We2Run

MIT and IAV want to make heavy-duty transport greener

Heavy commercial vehicles not only transport valuable raw materials and goods, they also usually carry a heavy CO_2 in their luggage. In a joint research project, engineering specialist IAV and Prof. William Green's team from the Massachusetts Institute of Technology (MIT) are now pooling their expertise to compare and evaluate the potential of innovative drive types in the heavy commercial vehicle sector. In addition to electric and CNG drives, the focus is on hydrogen combustion and fuel cells.

The aim of the transatlantic research, which will initially run until spring 2022, is to determine the appropriate drive concept in line with the respective applications and requirements on both American and European roads.

However, it is not only the environment that should benefit from the results. In particular, the research project is intended to provide crucial added value and additional guidance for companies in the field of hydrogen mobility, especially European and U.S. commercial vehicle and component manufacturers of fuel cells, injectors and tank systems. The first results of the research project are to be presented to the public in the second half of 2021 and the final report is to be published in 2022.

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Cem Özdemir tests autonomous test vehicle "Hugo"

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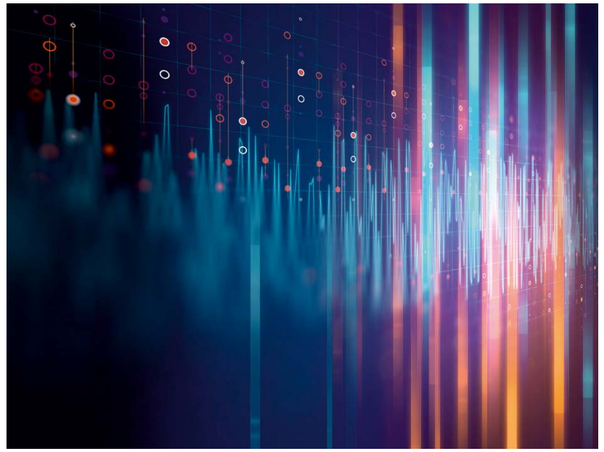
Narrow parking garages are one of the horror scenarios of many drivers, even with their ever-larger vehicles on the road. It would be so nice to be able to navigate through the parking decks in a relaxed and autonomous manner, without scratches and without stress.

Cem Özdemir (Bündnis 90/Die Grünen) got a first taste of this during a visit to IAV's development center in Stollberg. In the test vehicle "Hugo", a converted E-Golf, the 55-year-old experienced an automated drive followed by a parking maneuver.

An excursion that apparently whetted the appetite for more, as Özdemir subsequently described autonomous driving as "an important future technology that should definitely be researched and developed in Germany". IAV, according to the Chairman of the Bundestag Transport Committee, seems to be one of the leading companies in this field from his point of view.

In addition to these practical impressions, Özdemir discussed, among others, the basic regulatory conditions of autonomous driving, necessary adjustments to the infrastructure and the social acceptance of automated and autonomous vehicles with IAV's Managing Director Matthias Kratzsch.



This algorithm gets in your ear

When it rattles, grinds and squeaks on and in the car, it is one thing above all: annoying, because in serial production, as little unpleasant background noise as possible should reach the ears of the vehicle occupants. Over the course of vehicle development, engineers therefore use the VDA scale to test whether components have the potential to disturb customers – and, in this case, they revise the affected parts. A team of engineers at IAV has now developed a self-learning algorithm that provides a forecast of the expected acoustic behavior of individual components and the expected VDA test result – even before the component is actually integrated into the vehicle. This allows manufacturers to reduce additional development loops, saving time and money. Electric car development in particular can profit from this technology, because individual components must be designed very precisely acoustically, since the powertrain can no longer drown out their noise. The method can also be applied to components beyond the automobile.

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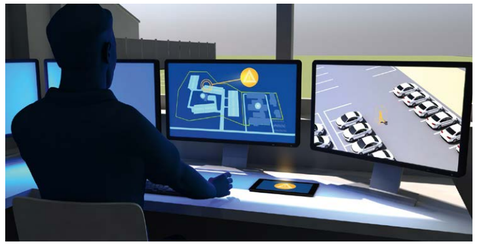
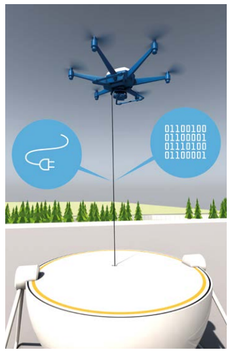
On a long leash

Enrico Neumann (left) and Dr. Amilcar Do Carmo Lucas (on the right) are part of the IAV team that developed the tethered drone.

Sirens wail, the hangar opens and a drone takes off. What sounds like the intro to an action movie is, in this case, the beginning of a demonstration mission of a tethered drone via livestream at the digital Hannover trade fair. The entry resulted in the longest viewer dwell time in VDMA's Industrial Drone Arena.

Currently, the tethered drone is being used in a pilot project at Volkswagen's Wolfsburg factory site. Equipped with an intelligent surveillance camera, the drone recognizes a human being as such from a lofty height, captures thermal images and geo-references – all the while flying in a highly automated manner. Through the wired connection to the hangar, the drone supplies itself with power and simultaneously transmits control, image and video data, so it not only operates 24/7, but can also be seamlessly integrated into existing infrastructure and available IT systems. Another feature is the connection to the intrusion detection system and the possible automatic response to incidents. The next step is to pilot the OSPA (Outstanding Security Performance Awards) winning tethered drone with other interested parties.





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The work has just begun

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Germany is to stop emitting greenhouse gases as early as 2045 - that is the aim of the new Climate Protection Act of the German federal government. This should make it clear that there is no alternative to the battery-electric propulsion as a decisive solution. Actually: Because there are still many challenges to overcome on the road to the electric happy end, from infrastructure expansion to recycling to low-emission mobility concepts.

DEMAND FOR CHARGING POINTS UNTIL 2030

Stock in 2021

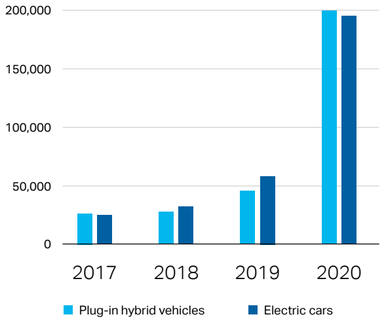
41,751 charging points (normal and fast charging points)

Demand 2030

up to 843,000 public charging points (total)

Source: Federal Network Agency, Now GmbH, National Charging Infrastructure Control Center, BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)

NEW REGISTRATIONS IN GERMANY (PURE E-CARS AND PLUG-IN HYBRIDS)



German federal government target of 7 to 10 million pure e-vehicles and plug-in hybrids by 2030

Experts' forecast 14.8 million pure e-vehicles and plug-in hybrids by 2030

Sources: KBA, BMU (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), Now GmbH

Germany's automotive industry has flipped the switch. The conversion to electricity-based mobility is in full swing. In 2020 alone, the number of newly registered pure e-vehicles (BEVs) more than tripled. And this is just the beginning: The share of BEVs and plug-in hybrids is expected to rise to around a quarter of all new sales by 2025, experts predict.

But despite all the joy at this success, which has no reason to fear an international comparison, the automotive industry should not rest on its laurels. The first step has been achieved, but there is still some homework to be done on the road to a mass phenomenon with broad acceptance among the population.

CHARGING INFRASTRUCTURE AND ENERGY MIX: TWO MAJOR CHALLENGES

Christian Hochfeld, director of Agora Verkehrswende, calls for progress in expanding the charging infrastructure and includes this in the new German federal government's performance specifications (guest article page 14). Up to 843,000 public charging points, according to a study commissioned by the German Federal Ministry of Transport, will be needed by 2030 to meet demand in line with planned model registrations.

Another major challenge is the development in the electricity sector. "If the electricity mix in Europe and in particular also in Germany does not become greener as soon as possible, the scaling of e-mobility could lead to rising rather than falling CO_2-emissions in the transport sector over the next 1-1. 5 decades, then energy and vehicle production will be added to it," predicts Marc Sens, specialist division manager for Powertrain Advanced Development at IAV. E-cars are very much in need of electricity. However, the expansion of wind and solar power is progressing very slowly.

In many places, citizens are protesting against green power projects and the complex approval processes mean that it takes almost a decade from planning to completion of a wind farm.

Moreover, it would be better if industry, policymakers and society would think more broadly about e-mobility. Zero CO_2 emissions in driving mode are all well and good - but in terms of life cycle assessment and practical application, the pure e-car still leaves a lot to be desired, says Sens. Here, it is important to weigh up whether hydrogen drive or CO_2-neutral synthetic fuels could be a sensible supplement to the BEV, for example in heavy-duty traffic where large batteries become a mortgage, according to an IAV study on the potential of H_2-drives (page 50).

HV BATTERY: THE UNEXPLORED TERRITORY

Almost 135 years after the birth of the first practical automobile and fully developed diesel and gasoline engines, the e-vehicle is still unexplored territory in many areas. The focus of research and development is the battery system, the heart of any e-vehicle. The focus of the industry is still placed on range and durability of the battery. But the fact is, the more electric cars come onto the market, the further the topic of recycling will be seen as more important on the agenda - at the latest when the batteries of the first generation of e-cars reach the end of their lives.

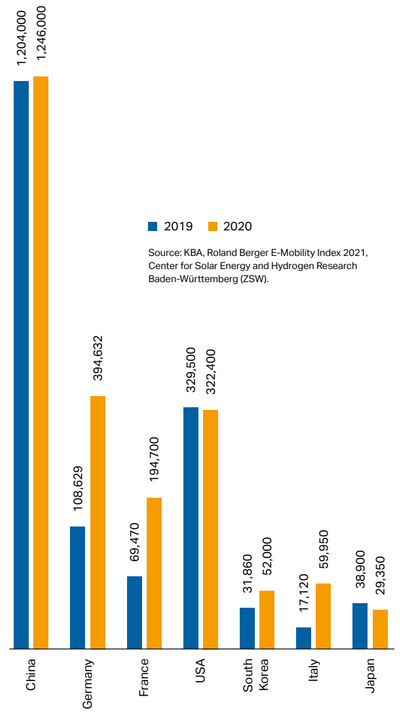
"However, common connection techniques and the combinations of materials make it difficult to disassemble them and thus to high-grade materials recycling," says Michael Clauß, specialist for battery development at IAV. This problem can be countered with new ideas and approaches, as shown by an IAV concept for a recycling-friendly battery concept (page 30).

The e-car is thus a fine thing if it is produced, driven and recycled with green electricity. But on its own, it will not solve the problem of congested city centers. The aim is to combine the digitization of the vehicle and traffic with e-mobility and to develop new mobility solutions from this. What that might look like can currently be observed in Hamburg and will soon be tested again: the fully electric and autonomously driving IAV shuttle HEAT. From late summer, the minibus will once again be available to passengers - and for the first time on a complete test route. There is still a long way to go before such technologies are ready for serial production. But HEAT shows where the journey is headed.

Dr. Christian Malorny, Head of Automotive Consulting at Kearney, summarizes: "Overall, we are still pretty much at the beginning of the transition to e-mobility. The e-drive is a comparatively young technology with enormous innovation potential. But whether its components, materials or software, the developments we will see over the next 10 to 15 years will be enormous."

In short: The work has just begun.

NEW REGISTRATIONS OF E-CARS (BEV AND PHEV) IN THE LARGEST SALES MARKETS



Source: KBA, Roland Berger E-Mobility Index 2021, Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW).

ENERGY DEMAND BATTERY ELECTRIC E-CARS

45 million

passenger cars are on the road in Germany.

150 TWh

they would approximately consume per annum if they were all e-cars.

236.5 TWh

were generated from renewable energies in 2020.

Source: BMU (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)

"The pure battery vehicle has the best climate footprint"

A comment by Christian Hochfeld, director of Agora Verkehrswende.

If Europe wants to become climate neutral by the middle of the century, transport emissions must fall significantly now. And this after zero reduction in emissions in the last 30 years! One important lever is the electrification of vehicle drive systems. However, the e-mobility targets set by policymakers are far from sufficient - the new German federal government must step up the pace in several areas, demands Christian Hochfeld, Director of Agora Verkehrswende.

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With the "Green Deal," the European Union has committed itself to no longer releasing any additional greenhouse gases by 2050 and is consistently gearing the economy toward climate protection. In this framework, Germany must also step up its action if it is to make its contribution to the EU's tightened interim target of 55% CO_2 emissions reduction by 2030. In the transport sector, which accounts for about one-fifth of Germany's CO_2 emissions, there is a large gap between EU targets and national contributions. Battery-electric vehicles can make a growing contribution to climate protection. Their new registrations in Germany more than tripled in 2020 alone, and more than a hundred new models are expected in the coming years.

Our analyses show that the pure battery vehicle has the best climate footprint over the entire life cycle of the vehicle and the drive energy - compared to hydrogen-based fuel cell technology or vehicles with combustion engines that run on electricity-based fuel. All technologies have in common that they require electricity from the sun and wind to enable climate-neutral mobility. The electric car has an enormous advantage in terms of energy efficiency. For the same driving distance, the fuel cell vehicle needs two to three times as much electricity for the hydrogen than the electric car with batteries. In the case of the combustion engine, it is even five times the amount if it is operated with synthetic fuels.

Since electricity from renewables will remain a scarce commodity for the foreseeable future, hydrogen and synthetic fuels should preferably be used in those sectors where no alternatives are available - for example, in air and sea transport, to some extent in heavy goods transport, or even in basic industries such as steel production. For these purposes, there is no alternative to building a hydrogen economy based on renewable energies if climate neutrality is to be achieved by the mid-century.

The necessary quantities of green electricity cannot be produced in Germany for lack of capacities. We will therefore have to rely on imports from third countries within and outside Europe, where renewable electricity is available in large quantities at particularly reasonable prices. It will be years, if not decades, before the relevant capacities are built up - and then these drive and fuel options will be associated with higher costs than electro-mobility. However, the expansion of e-mobility is also strategically imperative for companies in the automotive industry: Three out of four vehicles produced in Germany, regardless of the drive form, are destined for export, while more and more countries are setting their sights on phasing out the combustion engine. A strong focus on e-mobility is also important for maintaining Germany's competitiveness as an automotive location.

We therefore explicitly welcome the fact that OEMs and component suppliers are now increasingly committing to e-mobility as a pioneering technology of the future. It is important now that the automotive industry and policymakers, as well as industry and consumers, pull together to make e-mobility a success.

It will be crucial for achieving the climate protection targets that policymaker seize their opportunities now and act swiftly. The market ramp-up of electric cars must be accelerated in several areas up to 14 to 15 million vehicles by 2030, instead of seven to ten million as targeted by the German federal government.

The key to success lies in the expansion of charging infrastructure, in particular in a financing model for charging points in public areas, where charging will become increasingly important. The German federal government's Charging Infrastructure Master Plan of 2019, with its target of one million public charging points by 2030, was only a first step. By the beginning of 2022 at the latest, we need a new version of this concept, which should then no longer be just about quantitative targets, but also about the quality of the charging infrastructure as well as integration into distribution grids and energy industry regulations. In the case of the latter, we need above all a significant simplification of the Renewable Energy Sources Act (EEG) levy, which in its current form hinders the development of charging points at company locations. Companies are willing to invest in e-mobility in many places, and could play a driving role in the expansion of the charging infrastructure. In order to press ahead with the electrification of road transport, numerous regulatory and taxation changes are also required in the coming legislative period, such as a tightening of the EU's CO_2 fleet limits, a Europeanization of CO_2 pricing on fuels, the redesign of vehicle tax to a CO_2 oriented bonus-malus system, a reform of company car regulations, and preferential treatment for plug-in-hybrid vehicles only when used predominantly electrically.

Clear is: With the battery-electric drive, a technologically market-ready and increasingly competitive technology exists to advance climate protection in a cost-effective manner in transportation. What we don't need are discussions along the lines of"Wait a little longer, then other technologies will come along and they will be so much better". This situation will not occur. To believe that we already have a choice today or in the near future between equivalent climate-friendly alternatives to diesel or gasoline, is an illusion.

CHRISTIAN HOCHFELD,
Director of Agora Verkehrswende

"To believe that we already have a choice between equivalent climate-friendly alternatives to diesel or gasoline today or in the near future is an illusion."

Agora Verkehrswende

Spending instead of scrimping

in the Middle Empire

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Europe experienced a boom in e-mobility in 2020 thanks to purchase premiums and a growing range of models. But China is already a big step ahead. In the Middle Empire, a rapidly expanding market for e-cars has been flourishing for years, promoted with government subsidies and smart city initiatives. In order to ensure that China maintains its role as as leading e-auto nation in the future, the central government is pushing ahead with technology research and planning a massive expansion of the charging infrastructure by 2035.

China has been intensively promoting electric vehicles for several years and is pleased to record rising sales volume. The market for so-called New Energy Vehicles (NEVs) is now so stable that even a reduction in purchase subsidies, which were recently extended by two years to 2022 because of the corona

pandemic, is not expected to harm growth. Sales of NEVs, or battery-only, plug-in hybrid and fuel cell vehicles, are expected to soar by nearly a third this year, despite a one-fifth cut in subsidies for models up to about EUR 37,500. This is predicted by the Ministry of Industry and Information Technology in Beijing in a study.

The reason: Numerous e-car manufacturers have now established a stable supply chain in the largest and most important vehicle market and, thanks to modularization and scaling in production, are benefiting from falling costs for e-components, which enables them to cut prices. In addition, China is the world's largest battery manufacturer, which is why the most expensive e-car components in particular are available at comparatively low prices.

PRIVILEGES FOR E-CARS IN MAJOR CITIES

"E-mobility is of high priority in transport," explains Yonghui Shen, Manager of the Powertrain Competence Center at IAV China in Shanghai. "In the past, there were still many uncertainties, but today the following applies: Technological development and the expansion of e-mobility are on the fast track in China." BEVs and PHEVs are expected to more than double in China to around 50 to 60% of all newly registered vehicles by 2035, up from 15 to 25% in 2025, according to an estimate by China's Association of Automotive Engineers (SAE). It is expected that BEVs will account for more than 95% of the total NEV fleet in 15 years.

NEV growth rates are particularly high in major cities. In view of rising environmental pollution, megacities such as Beijing and Shanghai are putting the brakes on vehicles with conventional drives when it comes to issuing license plates. In Shanghai, owners of NEVs are allowed to use parking spaces in shopping malls and receive their number plates for free, while owners of combustion vehicles pay around EUR 12,000 to acquire their license plates. Shanghai does not even want to give preference to hybrid models any more with the allocation of licenses in 2023. Fittingly, the world's largest auto show, Auto Shanghai, during pandemic times was held in the port metropolis at the end of April, where battery-electric mobility was one of the dominant themes of the opulent vehicle show.

MASSIVE EXPANSION OF CHARGING INFRASTRUCTURE

The rapid growth of NEV fleets is accompanied by government plans for a massive expansion of infrastructure for charging and exchanging batteries, and for generating and refueling hydrogen. In its new 15-year plan, the central government expects to increase the number of normal charging points by more than tenfold the current number to over 150 million units by 2035 - from around 13 million in 2025 - and nearly double the number of public fast charging points from 800,000 to 1.46 million units.

In order to prevent vehicles of unsatisfactory quality from entering the market as a result of this expansion, the Chinese government is imposing stricter quality and safety guarantees for NEVs and encouraging more thorough research and development of the models. "Manufacturers are making efforts to improve their innovation capabilities. However, in the past ten years, the product quality of Chinese OEMs has also increased significantly due to cooperation with Western manufacturers, ", says Yonghui Shen. "The difference with German products in the field of e-mobility has become smaller, partly because e-motors are not as complex as combustion engines."

It is clear that: The Chinese government is developing and creating basic conditions to make e-mobility an essential part of transportation and energy structures. With production targets for NEVs, there is a clear perspective for OEMs in China in terms of e-mobility. The country in the Far East is and remains the most attractive market for electric cars, where important future technologies and trends are not only emerging but are also being implemented.

"Companies that do not have the ability to transform will be eliminated"

China's central government is cutting financial subsidies for e-car purchases in an effort to transform the rapid rise in vehicle sales into qualitative growth. Zhao Huichao, Vice President of FAW Group's NEV Institute, puts the policy measures in perspective and describes the structure and dynamics in the world's largest market for pure battery vehicles.

automotion: What is the long-term target behind the Chinese government's subsidy policy and what impact will subsidy cuts have on e-vehicles this year?

Zhao Huichao: The reduction of EV subsidies will affect the profitability of EV enterprises to a certain extent in the short term, but in the long term, it is a positive measure to promote the healthy development of the market. On the one hand, it will force EV manufacturers to accelerate product upgrades to improve competitiveness and profitability, on the other hand, companies that do not have the ability to transform and upgrade will gradually be eliminated.

We do not know the long-term target of the Chinese government's subsidy policy. Our judgement is that by setting higher and higher technical thresholds to promote the technological progress of the industry. The subsidies will be removed after profitability is achieved, and eventually the development of EVs will definitely return to be driven by market competition."

Zhao Huichao,
Vice President of the
NEV Institutes of the FAW Group

automotion: How competitive is the Chinese market for e-vehicles given the growing number of domestic manufacturers and start-ups? What characteristics does a company need to have in order to survive in this tough environment?

Huichao: The Chinese electric vehicle market will enter a phase of fierce competition, and companies with different backgrounds will continue to rely on their existing strengths to expand their technology and resources, in order to make up for their shortcomings.

The strength, background and development orientation of each company are different, and it is not good to judge the characteristics that all companies must have. Our perception is to grasp the trend of industrial development, combine our own brand-positioning, center on the needs of our customers, learn quickly and actively accept new requirements, and respond to market competition quickly, efficiently and flexibly.

automotion: European manufacturers, especially German OEMs, are increasingly focusing on pure e-drives in their future product lines. Which drive technology will power the Chinese automotive market in 2030?

Huichao: China is encouraging the use of pure electric vehicles based on energy security considerations and a strategic national choice of route. At the same time, the progress of battery technology continues to accelerate. If the cost of electricity does not increase or moderately reduce, the TCO cost will have a large advantage over traditional fuel vehicles. By 2030, pure electricity will be able to dominate the market.

Nothing works without a system

Until now, vehicle developers have above all focused on individual components. With the advent of e-mobility, the system concept is coming more to the fore. IAV has therefore established new structures for cooperation and defined new roles in customer projects. This ensures that the quality and functional safety of our development solutions will continue to be guaranteed in the future.

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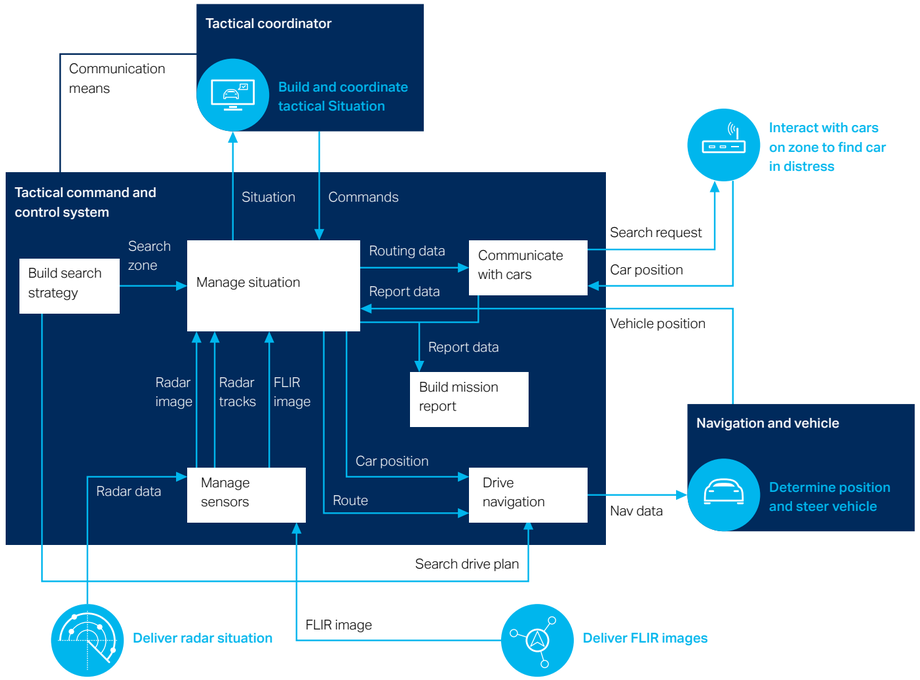
In the development of conventional vehicles, engineers usually only dealt with individual subsystems, such as the transmission or the engine and the respective control unit. "With electric vehicles, such a clear separation is no longer possible: Here, you have to consider the systemic interaction of technology across component boundaries," explains Hans-Martin Schulz, Senior Project Manager Powertrain Mechatronics Drivetrain at IAV. For example, the battery, e-machine and air conditioning are closely interlinked. This is because while a combustion engine conveniently supplies enough heat for heating, this role has to be taken over by the battery in the e-car. So propulsion depends not only on the e-motor, but also on the battery and the air conditioning.

Cross-system collaboration is also required with regard to the "battery" issue. It loses capacity during the useful life of the vehicle - to the point at which the driver notices the declining performance. "The question is how an OEM should deal with this situation. It can, for example, give the battery power reserves that are gradually unlocked over the life of the vehicle," Schulz says. "But it can also permanently monitor the vehicles and replace an aged battery in good time." However, this idea can only be implemented if engineers for concept design, battery monitoring, vehicle networking and customer service work together across the traditional work areas right from the start of development.

TOOLS FOR MODEL-BASED SYSTEMS ENGINEERING IN USE

IAV has adapted to these requirements and established new structures for collaboration – both when working on individual ECUs and across diverse ECUs. "Our customers have a central contact , who is competent in systemic thinking and also lives it in the projects," says Schulz. "For each project, we bring on board all the experts who are important for the overall system." In addition, there are special tools that support the work of the developers: IAV uses tools for Model-Based Systems Engineering (MBSE), which also represent the new approach graphically. "They typically come from object-oriented software development, to be mentioned here would be the Systems Modeling Language (SysML)", Schulz explains. "The key to success is to adapt these familiar tools to the requirements of automotive development."

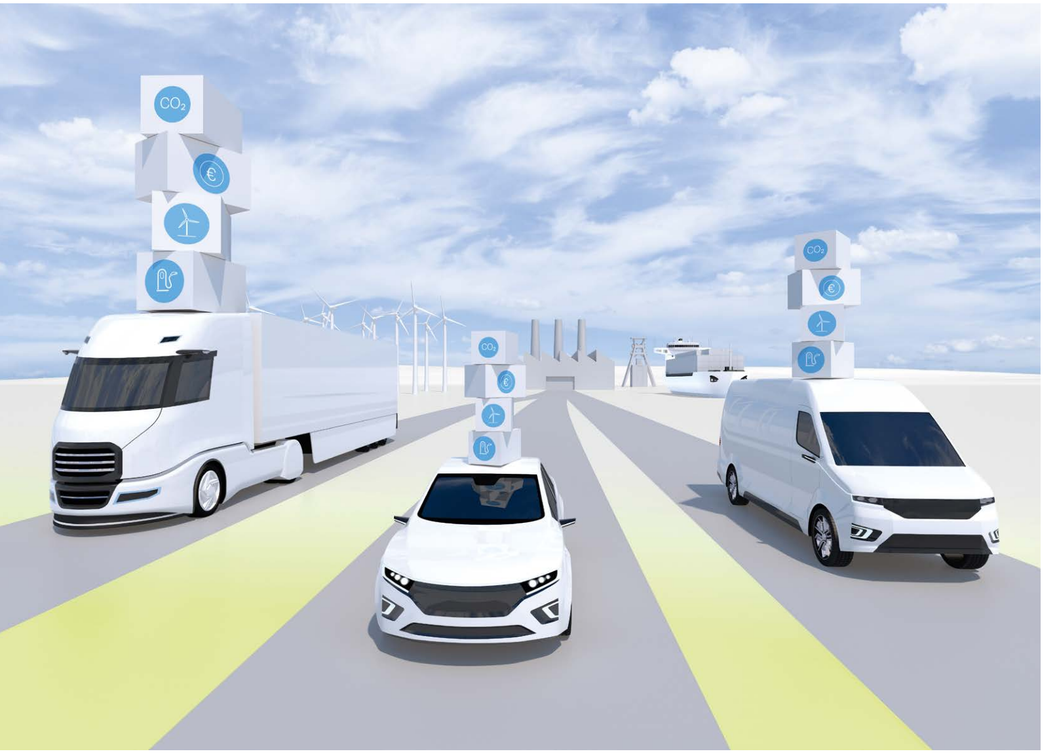
At IAV, the new approach means that all developers an ECU work on the same database. "The project manager uses the same architecture model as the colleague responsible for functional safety," says Schulz. "In the past, this was separate - today, both work on the same synchronized model that bridges the worlds." But the systems approach also comes into play when working across the boundaries of individual ECUs: Because multiple ECUs



(battery, e-machine and power electronics) are assigned to the "propulsion" function in an e-vehicle, there is now a new role of function realization responsible colleague. These think in systems, take into account all cross-connections and can also give specifications to the specialists involved for the individual components.

Drivers of this variable architecture development are the realization of mixed architectures starting from different vehicle platforms, cost optimization and the regrouping of software according to its safety classification.

"While modularization used to primarily affect hardware, it now also plays a central role in software," Schulz summarizes. "We therefore have to add or omit functions depending on the derivative." This requires fast interaction between the individual trades, which now work together online and must always have access to the synchronized data stock. This way, modularity and variability can be achieved without having to compromise with regard to the high requirements in the automotive sector.



Mastering diversity

Efficiency is crucial for electric cars not only in driving operations but also in the development and production phase of the vehicle. With the fleet optimization method, IAV supports manufacturers and component suppliers in developing scalable kits to bring a maximum number of vehicle variants to market with a minimum number of components. Sales volume and life cycle balances are also taken into account.

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Electric powertrains are opening up a new diversity for vehicle developers - which is both promising and challenging. "There exists a huge amount of combinations for technologies and parameters for different vehicles and markets," reports Dr. Christoph Danzer, Team Leader Powertrain Concepts and Life Cycle Assessment at IAV. "For example, we can vary the switching frequency of the inverter to specifically reduce losses in the e-machine and in the inverter in individual operating conditions. Such detailed optimization lead to greater efficiency and thus also to a greater vehicle range."

However, the diversity of technological possibilities also has its weak points, as vehicle manufacturers ultimately want to produce as many models as possible with a small number of components. "The aim is to get the variants under control and not to develop a separate powertrain for each vehicle," says Dr. Danzer. "If you can use many components for a wide range of models, development and manufacturing costs drop significantly." Scalable powertrain components, that can be easily adapted to different requirements are therefore in demand.

SALES FIGURES ARE ALSO IMPORTANT IN FLEET OPTIMIZATION

Finding these is a complex task. This is because numerous individual parts have to be systematically optimized across an entire portfolio of vehicles. In doing so, technical requirements in terms of performance and consumption, cost aspects and the varying importance of individual vehicle segments for a vehicle manufacturer must be taken into consideration in equal measure. "It may occur, for example, that a compact-class SUV needs to be particularly efficient because of its high sales figures," says Dr. Danzer. "Thus, with regard to the fleet optimization, sales figures also plays an important role beside technology."

IAV uses two unique tools for this purpose: IAV powertrain synthesis and the IAV fleet optimizer. The former finds the optimum combination of transmission, e-machine, power electronics, battery system and powertrain topology for customers from millions of concept possibilities, by taking stipulated basic conditions into consideration. The IAV fleet optimizer builds on these data: It provides a ranking of possible component kits in which the number and scalability of components are deliberately weighed up against perfection for a single vehicle. In addition to technical requirements, parameters such as manufacturing costs, total operating costs or the results of a life cycle assessment can also be incorporated. "In the end, there is a clear recommendation for the best possible powertrain and fleet mix", says Dr. Danzer.

MODULARIZATION OF ELECTRIC POWERTRAINS FOR COMMERCIAL VEHICLES

Several of IAV's customers have already successfully used the two methods. IAV itself has used the methodology, among others, to develop a modular platform for battery-electric drive solutions (page 26).

The fleet optimizer is currently being further developed so that it can soon also be used to optimally modularize the electric powertrains of commercial vehicles. "We are also expanding the functions in the area of sustainability," reports Dr. Danzer. "Today, we can already take the complete life cycle emissions into consideration and thus determine which powertrain types for which vehicle need to be used to best meet the OEM's CO_2-budget. Such analyses will become more important in the future."

In the age of defossilization, the complete life cycle balancing ("cradle-to-grave") need to be adressed, which includes not only energy consumption in operation but also all greenhouse gas emissions from fuels and vehicle production. In this approach, the energy efficiency of production facilities and the material supply chain, as well as recycling technology, also play a major role. Such an approach can be taken into consideration in fleet optimization as well as, for example, in the use of hydrogen powertrains - including hydrogen production. Tools and methods of IAV thus enable both vehicle manufacturers and component suppliers to systematically develop their products for an entire life cycle.

An e-kit for all cases

From micro cars to SUVs and light commercial vehicles: With its modular platform for battery-electric vehicles, IAV demonstrates how electric drives can be developed cost-effectively and consistently aligned with the technical as well as market-specific wishes of vehicle manufacturers and component suppliers. Components such as batteries, battery management systems and inverters are also on offer.

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The success of e-mobility decisively depends on customer acceptance. In addition to comfort, performance and sustainability, the costs plays an important role. This is where IAV comes in: "We asked ourselves whether a single battery-electric drive platform could be used to cover the wishes of customers and the requirements for an entire fleet of e-vehicles (Battery Electric Vehicles, BEV) - from small vehicles through the compact and mid-size classes to large SUVs and light commercial vehicles," says Rene Kockisch, Team Leader System Development Mechanics at IAV. "For this challenging task, we used our self-developed tools like Powertrain Synthesis and Platform to find the best. With the latter we find the best possible grid for components such as e-machines, transmissions and power electronics, so that as many of the same parts as possible are used throughout the fleet."

As a starting point for the development of the BEV platform, IAV defined the characteristics and performance features of six e-vehicles. This includes a compact car weighing 1,200 kilograms, with a range of around 380 kilometers and a maximum speed of 180 kilometers per hour, and a mid-sizelimousine weighing 1,700 kilograms, with a maximum range of 500 kilometers and a top speed of 225 kilometers per hour. Also included: a light commercial vehicle that weighs 2,500 kilograms, has a maximum range of 250 kilometers and reaches speeds of up to 160 kilometers per hour. "These are not fictitious values - rather, they correspond to customer expectations and, in many respects, to the characteristics of vehicles already on the market as well as those under development," Kockisch emphasizes. "We have also taken into account operation with a trailer, because this is important for many customers."

Vehicle fleet with common platform		Small car (A)	Compact (C)	Compact SUV	Mid-size car (D)	Full-size SUV (J)	LCV
Vehicle configuration							
Powered axle		FWD	RWD	RWD	RWD / AWD	RWD / AWD	RWD
Estimated curb weight	[kg]	1200	1500	1700	1700	2200	2500
Vehicle requirements							
Cruising range	[km]	250 – 380	350 – 500	350 – 400	450 – 500	350 – 500	250 – 400
Max. velocity (continuous)	[km/h]	130 – 150	150 – 170	150 – 170	160 – 200	160 – 200	150 – 160
Max. velocity (peak)	[km/h]	160 – 180	160 – 200	170 – 190	180 – 225	180 – 225	–
Acceleration 0-100 km/h (peak)	[s]	8.5 – 14	6 – 10	7 – 9	5 – 9	6 – 10	9 – 11
Gradeability (continuous)	[%]	> 15	> 15	> 15	> 15	> 15	> 15
Gradeability (peak)	[%]	> 25	> 25	> 25	> 25	> 25	> 25
Trailer mass	[kg]	–	1,500	1,500	1,800	2,200	2,500

24 MILLION POSSIBLE CONFIGURATIONS EXAMINED

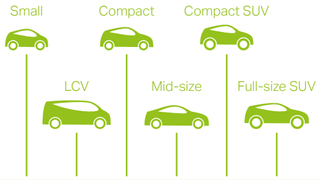
After running through the powertrain synthesis and platform optimizer, a spectrum of three vehicle topologies (front-wheel, rear-wheel and all-wheel drive), three transmissions with one or two gears, ten e-machines with 100 to 220 kilowatts of power and 200 to 350 Newton meters of torque emerged. In addition, there were five inverters with three or five phases based on silicon carbide MOSFETs or silicon IGBTs (Insulated Gate Bipolar Transistor). The five battery variants have capacities ranging from 42 kWh to 115 kWh and operate at different voltage layers.

Approximately 24 million drivetrain configurations were studied for the BEV platform. " With the resulting modular kit we cover the requirements of the entire fleet we have defined", explains Kockisch. " Within the vehicle classes, we can also vary - for example, in the case of the SUV from the low-cost solution to the high-performance version."

The core properties defined at system level on the basis of powertrain synthesis were followed by intensive work on the powertrain components from layout to design and optimization, in which IAV was able to draw on extensive and broad experience. With the help of this development expertise effective development of the entire electrical platform was implemented and conclusions as well as system-level effects were presented in a transparent manner.

The BEV platform has been available since the middle of 2020. "We are already conducting intensive talks with customers who are either interested in subsystems such as the e-machine or transmission or are looking for solutions for their second- or third-generation electric powertrains," reports Kockisch. "With our systematic approach and tools, we can also take a manufacturer's individual requirements into account by building on our BEV platform or going through the entire process again with its stipulations. In doing so, we can guide customers from the beginning as well as keep an eye on their entire platform."

Entire BEV vehicle fleet
Entry level to high performance and LCV



Modular EV platform
- Power range: 100 to 440 kW (AWD)
- Energy range: 27 to 115 kWh
- Voltage levels: 400 and 800 V
- Diversity of combinations and technologies

Platform electric motors
- 4 power levels from 100 to 220 kW per axis
- 2 voltage levels

Platform power electronics
- Power levels from 100 to 220 kW
- 2 voltage levels
- Si and SiC chip technology

Transmission platform
- 1 and 2 speeds, 3 torque levels
- Up to 4,150 Nm per axis
- Modules for clutch, parking lock, disconnect and torque vectoring

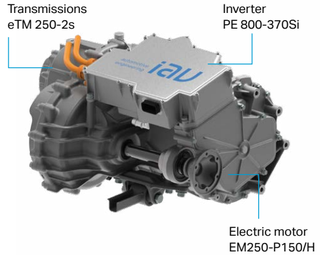
Battery platform
- 5 battery systems from 27 to 115 kWh
- 2 voltage levels
- 3 thermal management modules

MODULAR FRAME FOR FUTURE PROPULSION PLATFORM

With its modular BEV platform, IAV has defined a basic structure and at the same time created the basis for further developments. Within this framework sub-platforms for battery, power electronics, e-machine and transmission were created that are coordinated and ready for use across the entire fleet. A spectrum of drive systems for 400 volts and 800 volts with system outputs from 100 kW to 440 kW is used. Based on these basic structures, IAV experts are working on new solutions to meet the various requirements of the e-vehicles of tomorrow and beyond.

"We are currently building a modular power electronics system," says Kockisch. "A dedicated IAV battery management system already exists, but we also see great potential here in terms of sustainability." While energy storage systems are currently mostly designed to last only one lifetime, eco-design that reduces a product's environmental impact over its entire life cycle is expected to be in demand in the future. "We are working on new batteries of this type," says Kockisch.

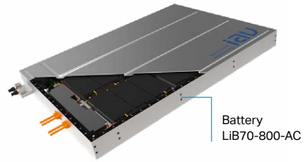
150 kW – 800 V – 2-dpeed - EDU



Results for C-Class

Max. Speed (cont.)	[km/h]	171
Max. speed (peak)	[km/h]	210
Acceleration 0-100 km/h	[s]	6.9
Range (WLTP)	[km]	606

70 kWh – 800V – Battery with active fluid cooling



Variation ranges of powertrain parameters and technologies.

Vehicle / Powertrain
- BEV fleet with 6 vehicle classes
- 3 powertrain topologies available: FWD / RWD / AWD

Transmission
- Seamless and synchronized shifting
- No. of speeds: 1 ... 2
- Spread: 1.00 ... 2.00
- Max. ratio: 6.0 ... 14.0
- 2nd speed without drag losses of shifting element

Electric motor
- P_{Peak}: 50 ... 300 kW
- T_{Peak}: 100 ... 400 Nm
- Max. rotational speed: 8,000 ... 18,000 rpm
- Max. effiency: 94 ... 96 %
- PMSM / IM motor type
- Air gap: 95 ... 155 mm

Inverter / Battery

Inverter
- Chip type: SiC-MOSFET or Si-IGBT
- Phases: 3 / 5 / 6

Battery
- Vehicle specific battery capacities
- Voltage level 400 ... 670 V

The reusable battery

Remanufacturing, second life and recycling: The vocabulary alone shows that sustainability has become a central issue in the development of high-voltage batteries. With a specially developed battery in ECO design, IAV has an energy storage unit on the shelf that saves both costs and CO_2 emissions, from production to recycling.

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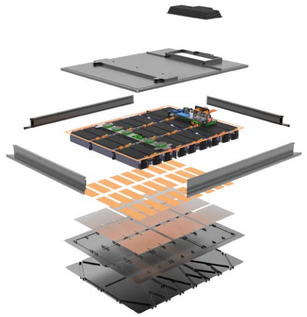

Last year, Clauß and his team made the peripheral structures of a battery more sustainable. Steel instead of aluminum, fewer screws, less welding.

For several years now, engineers at IAV have been working on ECO batteries and topics such as recycling processes, material selection, connection technology and system architecture. Last year, they succeeded in turning the ideas into a concept: a specially developed battery designed for maximum sustainability in every aspect. "We took trends such as Second Life and remanufacturing into accoun – even disassembly by robot is included in the design," says Michael Clauß, specialist for battery systems at IAV. The result is a battery that has already attracted keen interest from OEMs and component suppliers. It offers a capacity of 62 kWh and a CO_2 footprint that is one-fifth smaller compared to conventional designs. In addition, the cost of peripheral elements such as the lid, base,and side structures, as well as their disassembly over the life cycle, was halved. The method can also be applied retrospectively to previously developed battery and module designs, regardless of brand and storage capacity. The external dimensions were retained, but the interior operation was rethought.

MANY PATHS LEAD TO GREATER SUSTAINABILITY

Thus, the ECO battery pays tribute to one of the currently most important trends in the battery market: Sustainability. An ecological plus can now be achieved through a wide variety of methods. For example, batteries can be remanufactured and reused in a vehicle. A second approach is hidden behind the keyword Second Life: Used vehicle batteries can start a new career, for example in solar storage. Finally, Second Use describes the use of new vehicle batteries in other fields of application. This can occur when a vehicle manufacturer has more batteries in stock than it can actually fit into cars to be produced. In this case, the OEM can sell its battery surplus, for example to energy companies that use rechargeable batteries as stationary storage.

But Clauß and his team are also receiving more and more inquiries on the subject of recycling used batteries: "We sense that greater emphasis is being placed on the recyclability of batteries and raw materials in design." As yet, he says, recycling efficiency is not satisfactory. Pressure is also coming from Brussels. From 2022, the EU will prescribe mandatory recycling quotas and a "battery passport" to move more toward a circular economy for high-voltage batteries. "However, manufacturers are likely to be much more ambitious than the EU, if only for cost reasons," Clauß believes.

Another trend in battery development is to refrain from using cell modules. "Cell to pack" is the name of the approach in which the individual battery cells are installed directly in the battery housing. A further development conceivable for the future is the "cell-to-platform" approach, in which the cells are integrated directly into the structure of the vehicle's underbody. In addition to the modules , the battery packs previously installed in the underbody with their bulky housings will also be superfluous. With the "cell-to-platform" method, more cells could then be accommodated in the same installation space. As a result, energy density and range increase. IAV has been working on such a concept since 2014 as part of research projects on the platform-integrated bipolar battery (EMBATT).

THE BATTERY HAS LONG SINCE CEASED TO BE A PURELY SUPPLIER COMPONENT

At the same time, the demands on safety are also increasing: Problems with one cell must be detected more quickly because otherwise they can quickly spread throughout the battery. In this case, drivers must visit the workshop or even leave the vehicle. That is why IAV is currently investigating in detail "thermal propagation" within the battery and ways to predict, detect and stop fires in the energy storage system at an early stage, to make batteries not only greener but also more reliable.

The trends described show: The battery has long since ceased to be a purely supplier component. "Car manufacturers are influencing the material, design and production of the cells - they have already been taking care of the purchase of raw materials for longer," says Clauß The focus of IAV's work has also shifted: While in the past the engineers were primarily in demand as system integrators, they are increasingly becoming materials developers. "We already dealt intensively with such things during the EMBATT research project. In the meantime, our customers are also increasingly asking for electrochemical simulations or support in the selection of housing or cell materials," says Clauß.

3 Questions for Michael Clauß

"The industry is still at the beginning of the journey!"

Michael Clauß on current IAV projects and methods in the field of high-voltage batteries.

automotion: What is IAV's focus when it comes to recycling batteries?

Michael Clauß: We are involved with a whole range of processes, but in particular with "direct recycling". This is a further development of hydrometallurgical processes that help us to better separate the anode and cathode materials. Today, mainly copper, cobalt and nickel are recovered, but in the future – also because of the upcoming EU Directive – more materials are expected to be recycled. This is already generating a lot of interest among our customers.

automotion: What is IAV's unique selling point when it comes to battery sustainability?

Clauß: Thanks to appropriate in-house developments, we are in a position, for example, to advise battery manufacturers on all aspects of development - from material selection, design, data mining in production to connection technology. Our unique selling point is that we look at batteries holistically and as systems, using state-of-the-art development techniques such as "digital twins" to look deep inside the battery and to simulate individual cells. Furthermore, cost engineering and life-cycle assessments are a matter of course for us so that all design decisions are made on the basis of objective figures. For prototypes, we also offer our customers our own battery management system, which is constantly being further developed.

automotion: What challenges do you see ahead?

Clauß: Our customers expect falling costs, increasing ranges, a high level of safety and more sustainability. In addition, we are confronted with a wide range of various topics: We have to deal with materials, processes, the suitability of solutions for serial production and the different standards worldwide. To meet these various and nationally divergent requirements, we intend to rely even more on data analyses and artificial intelligence - so that we can get by with fewer tests during application. Thus, with regard to the battery, the entire industry is still at the beginning of the journey.

With the ECO battery and current material research for better recycling, Clauß is already focusing on the stricter requirements of the EU Battery Directive of 2025/26.

IQ test for e-components

Using artificial intelligence (AI) for a better understanding of key e-mobility components: IAV transfers the latest findings from AI research into development in order to monitor the e-machine and battery system, for example - and thus makes e-mobility more efficient and safer.

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E-machines are sealed components - in the true sense of the word: Their encapsulated rotor makes it almost impossible to monitor the condition inside. For example, temperature sensors cannot be installed inside the motor with reasonable effort, and such solutions are not robust either. "But temperature in particular is an important indicator of the current load on the motor," explains Dr. Thomas Orlik, specialist for electric drive control at IAV. "If it could be measured precisely, it would be possible to get closer to the limit when designing and operating the electric motor."

Precise determination of the local losses in the motor is essential for accurate temperature calculation. Currently, these can only be determined via intensive measurement campaigns and approximation formulas that incorporate existing measured values in the drive, such as current, voltage, speed and temperatures. However, to better exploit the power of an electric motor, this is too imprecise and also very time-consuming. This is why IAV has joined forces with the German Research Center for Artificial Intelligence (DFKI) to develop a new method for determining a rotor temperature: A neural network learns to infer the condition in the engine more precisely from existing measured values. In its training phase, data collected by IAV with the help of a test engine equipped with sensors is used.

"In the process, we were able to fully automate large parts of the development from measurement to model, thus substantially reducing development time. For example, we can check the plausibility of the measurement data without any manual intervention – for example, determine whether the sensors are working correctly – and select representative data," reports Dr. Orlik. "Automation always helps us in development when large quantities of data have to be processed, such as in classical temperature calculations." The cooperation project with DFKI has now been successfully completed and the results can be immediately incorporated into series development. By cooperating with the non-profit public-private partnership, IAV has access to current research results and can develop these further with a view to the automotive sector.

USING AI TO DETERMINE BATTERY AGE

AI is also expected to play an important role in forecasting battery aging in the future. The most valuable and important component of an e-car must function reliably for more than ten years and is therefore often planned rather too conservatively. "It would be very interesting for vehicle manufacturers to know and forecast the actual age of a battery," says Michael Clauß, specialist for battery development at IAV. "It depends, among others, on the influences during the production of the battery cells and on the load exerted by the driver(s). This is why you cannot currently implement accurate long-term aging predictions."

IAV is working on the technology to aggregate fleet data, development data and parameterization data in a cloud with the aim of optimizing range and utilization of batteries. With the help of AI, for example, the current "state of health" of individual batteries can be inferred and further progress predicted. "Our goal is to have the development data and measured values from the field flow back into development in order to then make new application parameters for the fleet available online," says Clauß. "This would allow us to reduce safety margins and if necessary, also release more power during operation. It would also allow us to identify outliers in the data to further improve the issue of safety."

A use case for increasing range and predicting maintenance was implemented in an exemplary manner by bringing together the topics of cloud, measurement data acquisition, data exploration, function development, electrochemical modeling and AI methods. IAV was able to draw on a broad knowledge of methods from different fields.

There are still no production-ready algorithms for online evaluation of fleet data, anomaly detection or determination of battery aging. "But we have shown that it works and such methods can be developed," says Clauß "We are already working on further developing our ideas, and we're getting a lot of interest from customers."

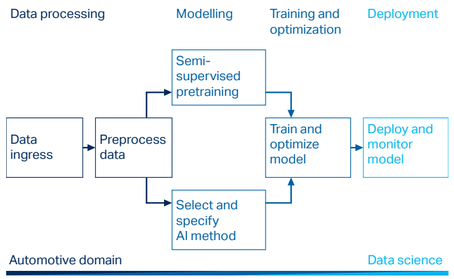
In the future, predictive health monitoring via AI will also be used in other components of the electric powertrain, for example in the power electronics and transmission. They should not fail suddenly under any circumstances – above all not during autonomous driving. An electric vehicle must not stop abruptly but must have sufficient reserves for a controlled interruption of the journey. AI could soon take care of this too.

German Research Center for Artificial Intelligence

PREDICTIVE HEALTH MONITORING

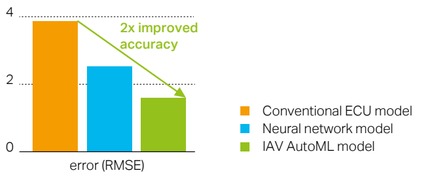
END-TO-END PIPELINE FOR DATA-BASED MODELING.

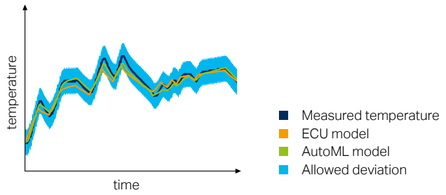
Using IAV AutoML, the automated and scalable end-to-end framework for data-based modeling, reduced the development time of data-driven models by a factor of 10.



ROTOR TEMPERATURE MODEL

The accuracy of temperature calculations has doubled compared to the state of the art by using data-driven models.





The maturity test

The requirements for manufacturers to validate their products are constantly increasing. IAV is therefore further expanding its testing capacities in the field of e-mobility: At the Chemnitz/Stollberg Development Center, customers now have access to four test benches for electric axles and a test bay for plug-in hybrid powertrains in addition to the new high-voltage system test bench.

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There is a clear trend toward networking, and not only in electric vehicles. It is all the more important that all components in the system compound can be tested even without setting up a test vehicle. After all, this is the only way to guarantee that central components for e-drives are optimally dimensioned and matched to one another and that relevant approvals are granted in time. For this reason, IAV has designed and commissioned a new high-voltage (HV) system test bench at its Chemnitz/Stollberg location. "This is the most complex test bench available in this field - a unique facility in the industry," says Sven Hönicke, Head of Department Test Center Chemnitz/Stollberg at IAV.

IAV experts can test the entire range of electrical components in a network on the HV system test bench. "Whether power electronics, e-machine, battery or refrigerant compressor: We can put everything under the microscope there that is connected to an orange cable," says Hönicke. In contrast to pure component test benches, the reaction of individual components in the HV network for interferences or errors can also be analyzed there. For example, failures of HV components such as refrigerant compressors must not lead to critical driving conditions because they would confuse the HV system

NEW HIGH-PERFORMANCE E-AXLE TEST BENCH

The HV system test bench is not the only innovation at the Stollberg location. From the beginning of 2021, four test benches for electric axles will also be available there, which can be used for application and functional endurance tests. "We also developed, built and qualified these test benches ourselves," says Hönicke. "In doing so, we followed a modular concept: Each test bench offers 250 kilowatts of electrical power, but we can also combine several energy systems up to a total power of one megawatt." This scope of performance was recently brought to bear during test runs of a super sports car from Croatian manufacturer Rimac Automobili, where IAV focused on the about 600 and 1,000 kW drive units on the front and rear axles. In addition to axles of such hyper-sports cars, those of commercial vehicles can also be studied on the facility, which can map up to 2 x 23,000 newton meters of torque.

In addition, IAV operates a purpose-built test bench with HV pre-integration stations (VIP) at its Sindelfingen location. The VIP is, so to speak, the little sister of the HV integrated test bench. It covers all of its functions, with the exception of driving. This means that powertrains can be commissioned and initial clearances run through without having to use the large test bench.

The next step in Chemnitz/Stollberg: In August, a test bench for HV composite testing of plug-in hybrid (PHEV) all-wheel drive systems will start operating at the development center. In combination with the HV system test bench, IAV experts will then also be able to test PHEVs. This means that IAV's test facilities in Saxony are ideally equipped for the forward-looking validation of high-voltage vehicles and components.

In the box

A rollable rack with everything you need for extensive testing of e-components: That's IAV Auros. The mobile technology turns any room with a 63-amp connection into a high-voltage test bench in no time at all. In addition to sufficient power supply, IAV Auros also offers complete automation to control the peripherals of the test object.

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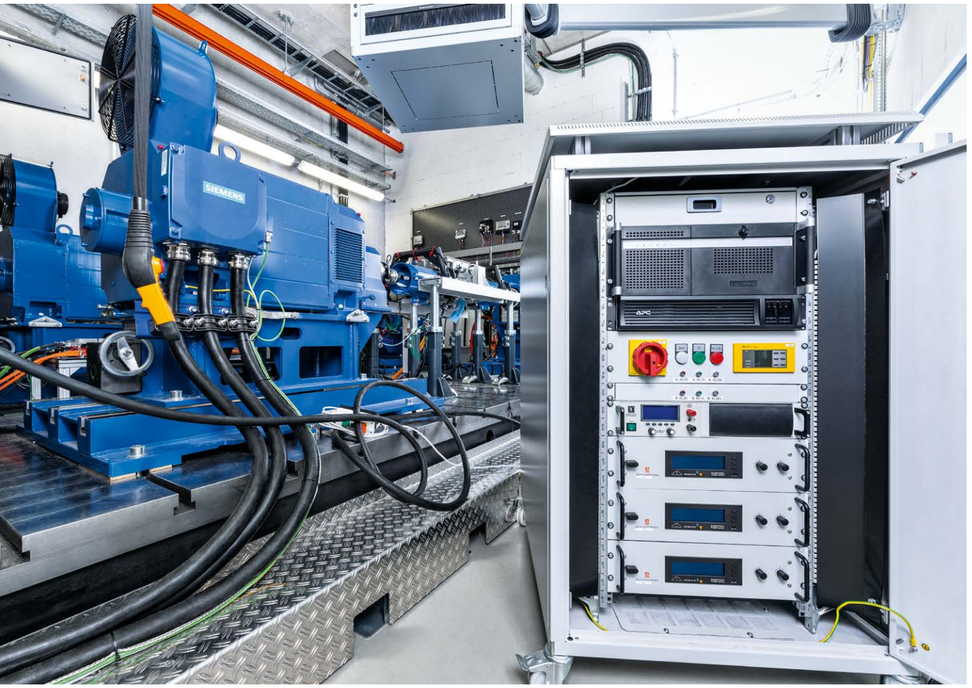

Advancements are being made with the electrification of powertrains. At the same time, demand for solutions for high-voltage testing is also increasing. "In many cases, the infrastructure required for this is not available," reports Jens Liebold from IAV's Measurement Products and Automation Technology department. "Often, the connection technology to supply power and voltage to an electric powertrain is missing."

IAV Auros provides a simple and cost-effective solution to this problem. The portable 19-inch rack contains a power supply of up to 1,500 volts, supplying a maximum of 45 kilowatts of power. The only prerequisite for operation is a 63-amp connection, as found in most garages. This way, IAV Auros saves costly investments in a specific infrastructure and extends the range of applications of existing test benches to include tests in the field of e-mobility.

UP TO 150 KW IN BACK-TO-BACK OPERATION

In addition to the power supply, IAV Auros also provides the complete automation technology. "We use the same automation software for IAV Auros as on our large e-mobility test benches," says Liebold. "Users can preset all test parameters and address systems such as control units, oil pump or fan."

Another special feature of IAV Auros: The mobile test bench can also be used to control and monitor two test items in parallel. In this case, one operates as a drive in motor mode, the other as a brake in generator mode. With this back-to-back setup, only the power loss has to be fed in from outside, so that drive motors with up to 150 kW of mechanical power can be tested in this configuration.

FLEXIBLE USE BY CUSTOMERS

IAV uses the test facility internally in numerous projects, for example for investigations on a vibration test bench or as a high-voltage source for hybrid motors on a test bench for combustion vehicles. Vibration tests of electric motors and e-axles are also among the most frequent applications for users of IAV Auros. "One of our customers has a large test chamber with a shaker, but it lacks the power supply for the electric drive components," says Liebold. "Thanks to IAV Auros, it can now use its costly infrastructure for e-mobility testing."

IAV offers the mobile test facility as a product and, at the customer's request, also takes over the integration into the test chamber, the commissioning of the system and configuration of automated operation. Alignment to customer-specific requirements with regard to current and voltage is also possible. "But you can also borrow IAV Auros and use it only temporarily," Liebold explains. Thanks to its compact dimensions, the test bench can be easily transported to the place of use in a van. This way, any room can be transformed into a self-sufficient test center for e-mobility within a short period of time, as Liebold affirms "In theory, you can even run tests in a garage with IAV Auros – thanks to the back-to-back process and IAV Auros."

IAV AUROS

Mobile test bench automation for electric drives is an innovative system that can be easily transported and contains everything needed for test bench automation. The system transforms any room with a three-phase socket into a high-voltage test bench of DC systems.

Product by IAV

Radical change in the truck market

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Climate targets, customer expectations, capital: Several factors are causing movement in the market for commercial vehicles. Unburdened by traditional processes and existing model ranges, start-ups and logistics giants can bring new approaches to production maturity. IAV supports developments by both, new and established players as a systems integrator, focusing on modularization and sustainability.

The established commercial vehicle manufacturers are facing turbulent times. New providers such as Hyliion, Arrival or Hyzon are taking advantage of the radical change in the commercial vehicle sector to enter the market with new technologies and concepts. The timing is no coincidence: The ambitious climate targets are one of the driving forces of this development; after all, the EU wants to be CO_2 neutral by 2050. According to EU regulations, OEM fleets' CO_2 emissions must fall by 15% by 2025 compared to 2019, or face fines of EUR 4,250 per gram of carbon dioxide and vehicle. Five years later, CO_2 emissions are expected to drop another 15%, at which point an overrun will cost as much as EUR 6,800 per gram per truck.

"Even the first 15% by 2025 are very difficult to achieve by optimizing diesel powertrains," says Florian Brandau, Director Business Development Commercial Vehicles E-Mobility at IAV. "This is why manufacturers need to switch to battery-electric or fuel cell-electric vehicles." In addition: Many logistics companies also want new propulsion concepts - because of climate protection and image but also in the hope that this will reduce their total cost of ownership (TCO)

ESTABLISHED OEMS MUST RESPOND

"New manufacturers are benefiting from the trend towards electric powertrains because their design and development poses a lower barrier to entry the market than developing their own diesel powertrains," says Erik Schneider, head of the e-traction and hybrid powertrain division at IAV.

This means that the up-and-coming suppliers from the USA, Asia and Europe can enter the market quickly and permanently improve their products through updates - just as some OEMs are already doing. Additionally, while companies like Rivian and Arrival are new players in the commercial vehicle market, they also have large amounts of capital from investors like Amazon and UPS, which distinguishes them from trendy startups. "For OEMs, this means that new products and technology solutions are emerging at an increasing pace to their left and right that may soon rival their own products. While existing OEMs have many years of expertise, they have to deal with shortened development cycles," says Schneider, summing up the situation.

ALTERNATIVE DRIVES READY FOR USE

The new technology is ready to use in commercial vehicles in many areas already. Electric drives are already on the road for short distances, and there are also initial solutions for regional transport with 200 to 300 kilometers to cover. Even heavy commercial vehicles can be operated on longer distances in the future with battery-electric drives thanks to increasing energy density of batteries. The prerequisite, however, is that the necessary charging infrastructure is in place and that the operational scenario allows sufficient breaks for recharging. In addition, another technology is "on the edge" of commercial viability: "The fuel cell will be the game changer," says Brandau. "This is because hydrogen, as an energy carrier,

enables very long ranges with short refueling times at the same time. In addition to fuel cells, hydrogen combustion engines are also appealing because this technology enables parallel entry into the hydrogen mobility."

IAV, as a systems integrator, supports both, established manufacturers and new suppliers in bringing electric drivetrains in commercial vehicles into serial production – in addition to delivery vehicles and trucks, also buses or construction machinery. In order to reduce costs, the experts are relying on modularization. This allows synergies to be created across product classes and technologies to be used in numerous models. "This not only saves manufacturers unnecessarily high development costs, but, above all, time, and enables them to keep up with the agile newcomers," Brandau makes clear. "In addition to modularizing entire powertrain, IAV also provides support with solutions for extending the service life of battery systems and helps manufacturers to make the relevant components much more sustainable and recyclable," adds Schneider.

In order to be able to offer component development and system integration from one provider, IAV cooperates with automotive component supplier Webasto, among others. The component supplier contributes its expertise in components such as batteries, high-voltage heaters and heat pumps. IAV contributes its expertise in the areas of complete vehicle development and system integration, for instance in high-voltage systems. "We are additonally contributing an energy efficiency through an hollistic view on energy- and thermal management,", says Brandau.

"The Future Truck is not an unapproachable concept"

IAV has developed the "Future Truck", a commercial vehicle with alternative drives and optimized aerodynamics. Florian Brandau reports on the status of the project and applications beyond classical trucks.

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automotion: What is behind IAV's Future Truck?

Florian Brandau: Under the name Future Truck, we designed a series of commercial vehicles with different powertrain technologies such as battery-electric drive, fuel cell and hydrogen combustion engine. The design is innovative: For European truck drivers, the long hood at the front is certainly the most striking innovation. Thanks to changes in EU legislation, it can now be 80 to 90 centimeters long. This extension and other measures such as the more inclined and curved windshield reduce air resistance and thus increase the range. Thanks to better aerodynamics and the new drives, we are safely complying with future emission limits in all Future Truck variants.

Florian Brandau, Director Commercial Vehicles E-Mobility at IAV, likes to use the Future Truck for discussions with customers to develop new ideas together.

automotion: How far has the project progressed?

Brandau: There is already a digital prototype in which systems and subsystems have been designed in great detail - for example, the electric motor or the active cooling and heating systems, which have to meet higher requirements in battery-electric and fuel cell vehicles. There is now a separate industry for auxiliary components such as air compressors, air conditioning and hydraulics, and we integrated their components into our high-voltage electrical system. There are currently many ideas on how this basic platform could be used for further applications, for example in municipal vehicles or construction machinery.

automotion: What are you using the concept of the Future Truck for?

Brandau: First of all, the project is a good opportunity for us to think unconventionally and try out new things. But we also use the Future Truck in discussions with our customers, to identify potential for optimization or jointly develop new ideas. We are constantly refining the design. The key parameter is: The Future Truck is not an unapproachable concept but can be built with technologies available today.

"Thanks to better aerodynamics and the alternative powertrains, we are safely complying with future emission limits in all Future Truck variants."

Keep it simple

The major challenge in e-mobility is to make the complexity of the overall system of hardware and software components manageable and reliably assessable. Vehicle manufacturers are relying on consolidated architectures and concepts to shorten development times. When it comes to validating electric drive hardware and software, IAV uses a whole toolbox of methods, tools and special testing infrastructure to reduce complexity and achieve readiness for serial production faster.

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Vehicle development is in a state of radical change. All manufacturers are focusing on e-traction - their developers are confronted with a complex system of e-machine, power electronics, DC/DC converters and battery. This complexity is further increased by a high number of hardware and software variants. Moreover, a new control unit architecture is finding its way into vehicles: A few, very powerful computers are replacing dozens of individual devices, resulting in higher data volumes and greater functional scopes. And with all the technical requirements, the time to market is also shortening: Both established OEMs and ambitious newcomers are fighting for market share, which is why new functions are often developed on prototype ECUs long before real hardware is available.

"This is why smart testing is more important today than ever before," says Dr. Jörg Müller, Head of Department System Development Transmission & Hybrid Driveline at IAV. "We rely on efficient methods, both across the board and in software and hardware." With the help of a generic Design and Validation Plan (DVP), IAV experts avoid superfluous tests. Such a customized DVP defines test requirements at system level and then allows these to be broken down into individual components as needed. "For example, it shows us how to test an e-machine in such a way that you do not have to re-examine every derivative," Müller says. "As a result, just a few investigations are sufficient for many powertrain configurations."

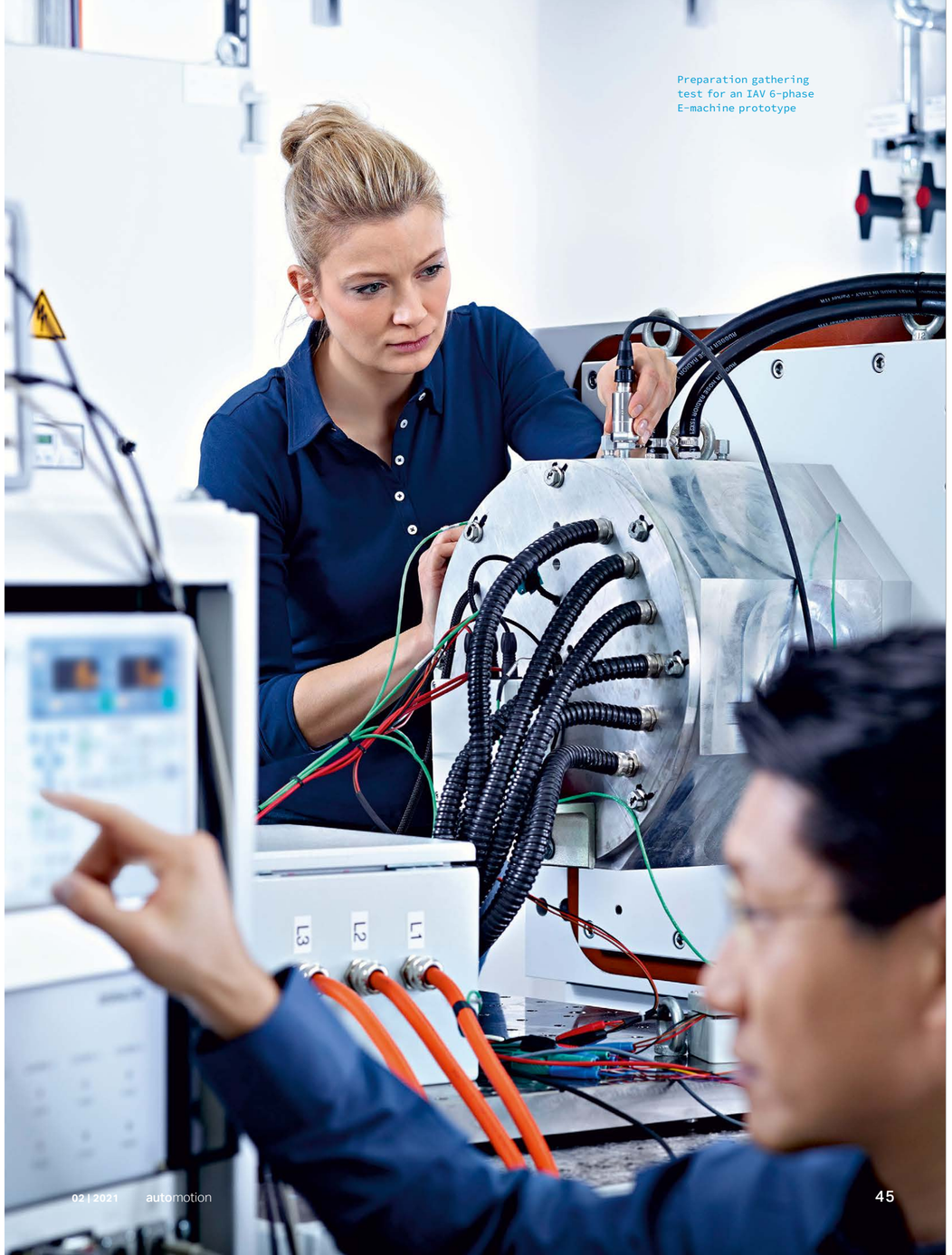
COMPLETE AUTOMATION AND VIRTUALIZATION OF SOFTWARE AND HARDWARE TESTS

IAV increases the efficiency of software tests by completely automating all individual steps from test specification to results evaluation. With IAV's FIL tool, it is possible to derive all further steps from the specifications from the test case performance specifications - right through to automated report generation. Not only does this save time and money, but such a high degree of automation also improves quality and guarantees that scarce test bench resources are used to the full.

Virtualizing ECUs also benefits IAV in software development. "We can load all the analog and digital interfaces of the later control unit via a configuration file," reports Müller. "Our modular virtual ECU can be used on the test bench to test networking with other ECUs. And we can give the hardware developers early conclusions." In order to be able to test production codes without a real vehicle, IAV experts use not only hardware-in-the-loop but also PCs with emulation software, which allows them to test production functions more quickly without any target hardware.

Refining cycles for hardware tests have a similar effect: Critical components are identified and by simulation a new stress regime with adequate damage is defined so that test duration is partly reduced by a factor of 20 or more. Another example of virtualization of testing is particle-based simulations of oiling, which can partially replace bench tests in early stages of design. So-called back-to-back test benches additionally accelerate hardware development and represent cost savings. They allow simultaneous testing of two e-axes, for example, by mechanically coupling both test objects, one acting as a motor and the other as a brake. As a special feature, IAV also offers back-to-back tests with specially developed coupling gears and without locking the differentials, resulting in a higher degree of freedom for such tests. Efficient wear measurements are also made possible by radionuclide technology (RNT): Components are radioactively activated so that abrasion can be tracked in real time by measuring the radiation in the oil circuit.

"We have been living the system idea for more than ten years and always have the big picture in mind," Müller summarizes. "Thanks to our experience from numerous customer and in-house projects and our extensive infrastructure, we can offer our customers efficient engineering and consulting from one provider."



Preparation gathering test for an IAV 6-phase E-machine prototype

Batteries in quarantine

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More and more vehicle manufacturers are launching electric cars on the market - and testing these in crash tests beforehand. This is not without risk, which is why vehicle safety tests with e-cars require a special procedure and additional safety measures. IAV's crash facilities in Gifhorn and Ingolstadt are staffed and technically prepared for all eventualities - including decay tank and insulated forklift truck.

Complex preparation: Dummy in the high-voltage vehicle

"The future requirements on the range of high-voltage vehicles will lead to the use of higher and higher voltages."

DR. BURKHARD SCHOLZ,
Head of Department, IAV Fahrzeugsicherheit GmbH

In conventional vehicles, crash tests follow a relatively simple script: The car is disassembled for the purpose of installing sensors and cameras. After mechanical and electrical preparation, the dummies take their place inside. Now the climax: At ten to 80 kilometers per hour, the test vehicle crashes into an obstacle. A photo analysis on the crash plate provides initial findings on the damage. More details emerge later when the car is disassembled for further analyses. So far, everything is a well-practiced routine - there is hardly any danger for the team in the crash hall.

Electric cars with their high-voltage (HV) systems are fundamentally changing the tests: "Future demands on the range of high-voltage vehicles are leading to the use of higher and higher voltages," explains Dr. Burkhard Scholz from IAV Fahrzeugsicherheit GmbH. "While voltages of around 48 volts were the norm for the first hybrid vehicles, today there are voltages of up to 800 volts in battery-electric vehicles. In the future, even more than 1,000 volts can be expected." Without properly designed safety precautions, people's lives are at risk here.

HIGH-VOLTAGE SYSTEM FIRST SWITCH TO INACTIVE

Before a crash test, the vehicle is fitted with the sensors with the HV system switched off. In addition, voltage and temperature are measured at the battery. The next step is the commissioning of the software, which is particularly complex because of the new wiring system architectures. "All the components have to work because everything is connected to everything else," says Florian Mayr from IAV Fahrzeugsicherheit GmbH. "Even the exterior mirror has to work, otherwise nothing works." Once the software is updated, the e-vehicle is metrologically prepared. After this, it rolls onto the crash track, always accompanied by a specially trained electrician. Now the crash can take place.

Not only the preparation, but also the phase after the crash differs significantly from tests with conventional cars. "We have to quarantine the vehicle for at least ten minutes, because a battery fire does not happen suddenly," says Scholz. "During this process, there are always two firefighters in protective suits standing by. They are equipped with thermal imaging cameras and gas detectors." In an emergency, they use a forklift truck with insulated tines to tow the car to a pool of water, where it only poses little danger still to its surroundings in the event of a fire. "Burning battery modules cannot be extinguished. However, the waste heat causes other modules to be destroyed," Mayr explains. "In the past, this has led to complete vehicles burning down."

INTENSIVE STAFF TRAINING

After the quarantine, an electrician checks whether the HV voltage is switched off and the body is voltage-free. Only after this are the test results documented. However, this is not the end of the complex procedure: A second quarantine may follow for 24 hours in a special garage. "Because problems with the battery can still occur," Mayr explains. "This is why, depending on the situation, we use battery monitoring to measure whether the temperature or voltage is behaving conspicuously." If this is the case, the battery monitoring system sends a message to the emergency call system, leaving enough time for countermeasures. Should the car be used for further tests - up to five crashes per vehicle are possible - the next tests are prepared. To do this, the IAV experts will have to get the cooling system going so that the battery can be charged, among others.

"E-vehicles pose a manageable safety risk during testing," Scholz sums up. "But as with all new topics, we have to take a lot of precautions with the procedures and train our personnel intensively." The qualification takes place internally and externally at TÜV and is oriented to the qualification levels stipulated by the German Statutory Accident Insurance .

In Ingolstadt alone, IAV runs ten tests a week and around 400 a year - and the trend is rising. The company operates one of the most modern crash facilities in Europe there and can support customers in any crash phase with e-mobility. "We have trained employees at all levels," Scholz emphasizes. "Thanks in no small part to our employees and our modern infrastructure and measurement technology, there has never been a major accident to date."

This substance belongs in the powertrain

With zero CO_2 emissions in driving operation, the all-electric car (BEV) is a fitting response to climate problems in the transport sector. However, the BEV still leaves much to be desired in terms of its CO_2 balance over its life cycle and in practical use. In a comprehensive study of alternative powertrain technologies based on life cycle assessment, IAV shows that, in addition to the BEV, hydrogen propulsion is also beneficial to the environment.

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In order to make Germany climate-neutral, the main emitters of greenhouse gases must achieve noticeable successes in savings in the coming years. The transport sector, the third-largest CO_2 polluter, is expected to reduce greenhouse gases by 57% by 2030 under the German federal government's new climate protection law. Benefiting in particular from the ramp-up of e-mobility in road transport, its principal emissions driver. However, maximizing the contribution to climate protection over the entire life cycle requires more than just the battery-electric powertrain - rather, it is about achieving an effective interaction of efficient powertrain and technology concepts in different vehicle segments, emphasizes Marc Sens, Head of Powertrain Advanced Development at IAV.

"From our point of view, the public and political debate too often focuses on the pure battery-electric vehicle, while the common fuel-to-wheel view neglects essential CO_2 polluters," argues Sens, head of the study. "We need alternative technologies that we can introduce in addition to e-mobility. Here, hydrogen propulsion is very interesting."

ALTERNATIVE DRIVES IN MORE COMPLEX COMPARATIVE STUDY

For the study, which IAV recently presented at the Vienna Motor Symposium, IAV experts examined the assumed CO_2 footprint of three vehicle classes (medium-duty SUV, light commercial vehicle and heavy commercial vehicle) for the year 2030. For each segment, the CO_2 equivalents that would be produced by using a pure battery electric powertrain, a fuel cell, and a hydrogen combustion engine were assessed. Calculations were made according to a tank-to-wheel (TtW), well-to-wheel (WtW) and life cycle (LCA) balances. For the latter, the entire impact chain from raw material extraction through production and usage phase up to the recycling processes was analyzed. In the TtW assessment relevant for the current EU legislation, the BEV has the greatest advantage among the studied powertrain types due to its high efficiency in the energy conversion. However, with today's technology status, the battery-electric powertrain is not yet universally suitable for all applications, such as long-distance operation. "For light and heavy commercial vehicles in particular, a large battery becomes a disadvantage," explains Dr. Christoph Danzer, Powertrain Configuration Team Leader at IAV. "Here, the advantages of a fuel-based system dominate. By contrast, with hydrogen the advantages of two worlds can be combined: on the one hand the high energy density of the liquid or gaseous fuel and, on the other hand, the good efficiencies, especially with the fuel cell."

HYDROGEN POWERTRAIN AS A SENSIBLE SUPPLEMENT TO THE BEV

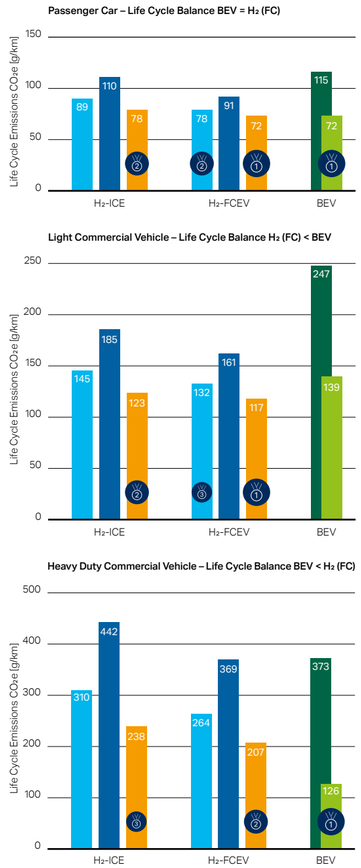
When fuel production is included under WtW considerations, both fuel cell propulsion and hydrogen combustion engines (H_2-ICE) can significantly reduce the CO_2 footprint in the three vehicle classes in 2030 compared to fossil fuels. Depending on vehicle class, H_2-production pathway, and electricity mix for the e-vehicle, the H_2-ICE proves to have a similar CO_2 footprint to the BEV, while the hydrogen-based fuel cell actually outperforms these results. For the hydrogen production paths, the IAV experts compared the processes electrolysis, methane pyrolysis and steam reformation with and without CCS (carbon capture and storage), while for all hydrogen production processes the two electricity scenarios were calculated according to the Federal Environment Agency's database with 24 g CO_2 e per kilowatt hour (kWh) (renewable sources) and 220 g CO_2 e/kWh (energy mix 2030).

"Significant saving potentials are also possible by 2030 in vehicle classes such as light commercial vehicles when LCA is taken into account. According to our calculation, the fuel cell (132 and 117 g CO_2/km, respectively) is even slightly superior to the purely battery-electric drive with electricity generated entirely from renewable sources (139 g CO_2/km) due to its battery size required for the 500 km target range, says Sens. However, the prerequisite is that the hydrogen is also generated entirely from renewable electricity or imported from the MENA (Middle East & North Africa) region, for example. For heavy-duty commercial vehicles, significant CO_2 savings potentials are also available from an LCA perspective for all powertrain variants.

Overall, the study shows a considerable CO_2 reduction potential in the year 2030 of purely battery-electric as well as hydrogen powertrains. But it is also clear: A significant reduction in greenhouse gases in the transport sector can only be achieved with a rapid expansion of renewable energies, both for the cleanest possible electricity and hydrogen generation and for use in all phases of the vehicle's life. And here the hydrogen can play a major role. Hydrogen's renewable production does not only depend on the sluggish national expansion of renewable energies – it can also be produced regeneratively in regions with large renewable energy potentials and imported relatively easily to Germany.

TECHNOLOGICAL-ECONOMIC STUDY

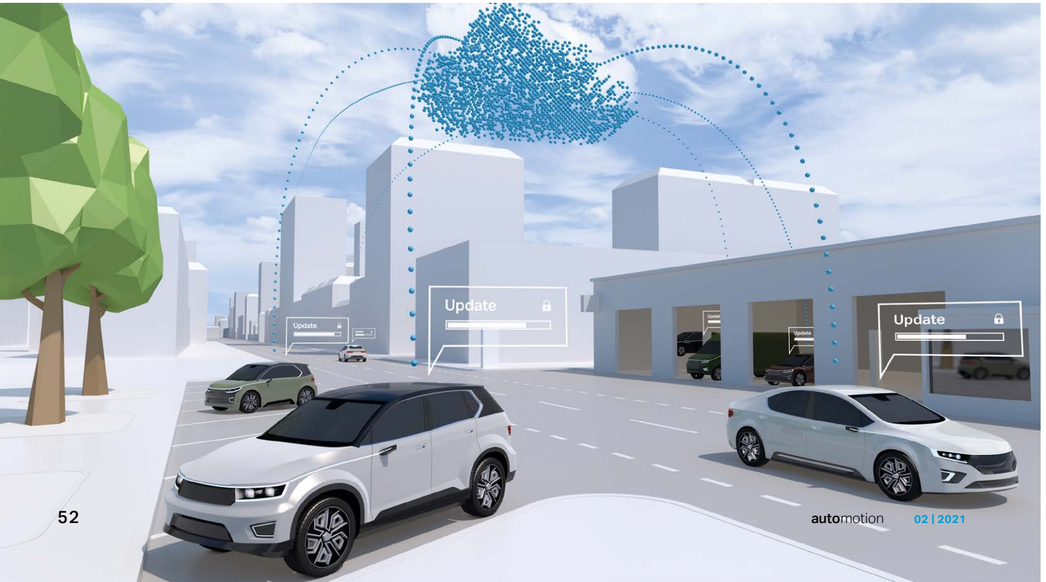
Results: Break-even of BEV production footprint vs. CO_2 emissions from hydrogen over life cycle (CtG)



Don't give cybercriminals a chance

New international standard secures vehicles

Digitized, automated and connected vehicles increase the risk of cyber attacks. UN Guideline No. 156 is designed to help reliably protect vehicle software from manipulation on an international scale. IAV supports its customers in software update management of control units and in implementing new guidelines.



Software updates are known to everyone from his smartphone or laptop: They close weak points, prevent hacker attacks and data theft. It is no different in the car. The following is important here: The software updates must themselves conform to new standards and be securely transmitted to the vehicle in question - today and much more so in the future. Because with the increasing digitalization, automation and networking of vehicles attack surfaces and cyber risks multiply.

UNECE GUIDELINE NO. 156

New international standards and regulations are the basis for ensuring that vehicles, no matter where they come from, are on the road everywhere with standard safety levels. For example, the United Nations Economic Commission for Europe (UNECE) recently adopted the Guidelines No. 156 for Software Updates and for Software Update Management Systems (SUMS). According to the new regulations, the vehicle manufacturers are responsible for ensuring that their software can be updated and that it is securely provided. In order to define the processes required for this, manufacturers must implement a SUMS. "Time is pressing: In Japan, the regulation will apply to all new type approvals from the beginning of 2022 and the European Union will follow from the middle of 2022," says IAV project manager Dr. Chi Hieu Tran. By then, he says, it will be necessary to implement new workflows, expand quality management systems, meet new monitoring and documentation requirements and provide proof.

IDENTIFY STANDARDS AND EVALUATE PROCESSES

IAV supports its customers in this process, develops solutions and implements these "Our colleagues have a high level of expertise in software update management systems as well as in networking electrical systems in the vehicle," says Christian Pranschke, Team Leader ECU Flash Programming and Tools at IAV. "We help our customers worldwide to identify relevant standards as well as evaluate processes in production and homologation up to type approval." In addition to the new UNECE Guidelines, the specialist staff always keep an eye on national regulations.

UNECE Guideline No. 156 is designed to help protect vehicle software from tampering. With increasingly flexible "over the air" (OTA) updates, it also provides transparency about which software versions are in the vehicle and how a change affects driving behavior. The ultimate goal is to ensure that the vehicle can be safely adapted to changed regulations throughout its lifecycle. Independent certification bodies audit vehicle manufacturers' implementation of the guidelines every three years. In type approval, the manufacturer is also responsible for the work of component suppliers.

SECURITY OF OTA TECHNOLOGY RATE

With its expertise in automotive sector and all topics relating to software update management of ECUs, IAV supports its customers in designing and implementing the solutions. "We can evaluate existing SUMS, develop new processes and implement a software identification scheme with efficient solutions," says Pranschke. "With software and system testing, we evaluate the security and stability of OTA technology and take care of issues such as Integrity Validation Data (IVD), RxSWIN verification, vehicle diagnostic protection and flash data security."

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Safety First - An AI that knows what matters

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How does a vehicle's adaptive control react when a vehicle ahead suddenly brakes? Such scenarios are easy to run through in classical test check. In automated driving, however, the number of influencing parameters increases rapidly. To ensure that the effort required for testing and release remains manageable in the future, IAV offers an efficient alternative based on machine learning.

With a new technology, IAV makes testing and modeling for new vehicles and their components quick, easy and accurate. In combination with algorithms and artificial intelligence (AI), test scenarios are generated in an accurate manner and checked to see whether a specific event - such as an accident - occurs. This way, the parameter reduced to be considered for validation can be limited considerably. The software also indicates the probability of an event, thus creating a measurable basis for the release decision of safety-critical functions.

ARTIFICIAL INTELLIGENCE AS THE KEY TO SUCCESS

By using artificial intelligence, the developed methodology goes far beyond the approaches of classical optimization. In doing so, it finds relevant parameter combinations and specifies a residual uncertainty. "We first define events relevant to us. The tool varies the parameters in an iterative process to provoke these events, and at the same time indicates the probability under the changed parameter settings," says Mike Hartrumpf, a development engineer in the Simulation & Modeling team at IAV.

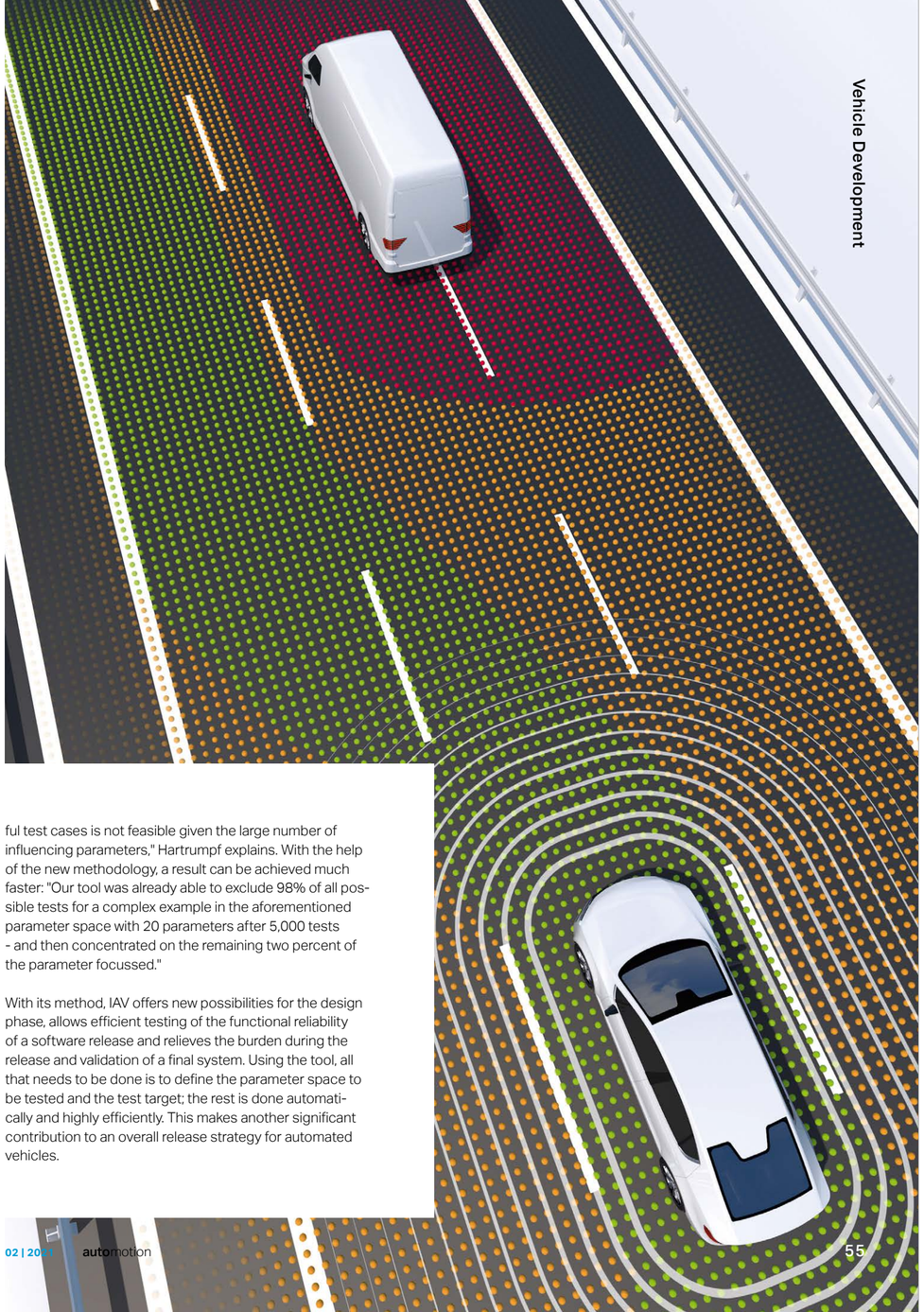
In an exemplary use case, this looks as follows: In automated parking, a vehicle maneuvers autonomously through a parking lot. In doing so, the vehicle is designed to avoid colliding with pedestrians or other road users in a wide variety of situations. For such scenarios, 20 or more parameters can easily be defined. These can be, for example, scenario parameters or function parameters. On the basis of tests of some of the functional combinations and their results the AI predicts the results of the entire parameter space, together with the respective probability of their occurrence. In doing so, the tool proceeds iteratively: Based on the system responses, the uncertainty of the generated model, and the relevance criterion it places new points in the parameter space at relevant locations. This way, the model quality, i.e. the accuracy of the predicted results, is improved in a targeted manner. "For points with similar measurement results and no further gain in knowledge, the AI does not perform further tests. However, if the system ratio changes quickly or in critical directions, this is a system response for the algorithm of a possible important situation – the tool then specifically its search further it is in this range of parameter values, thereby increasing the understanding of a potential critical situation," says Hartrumpf.

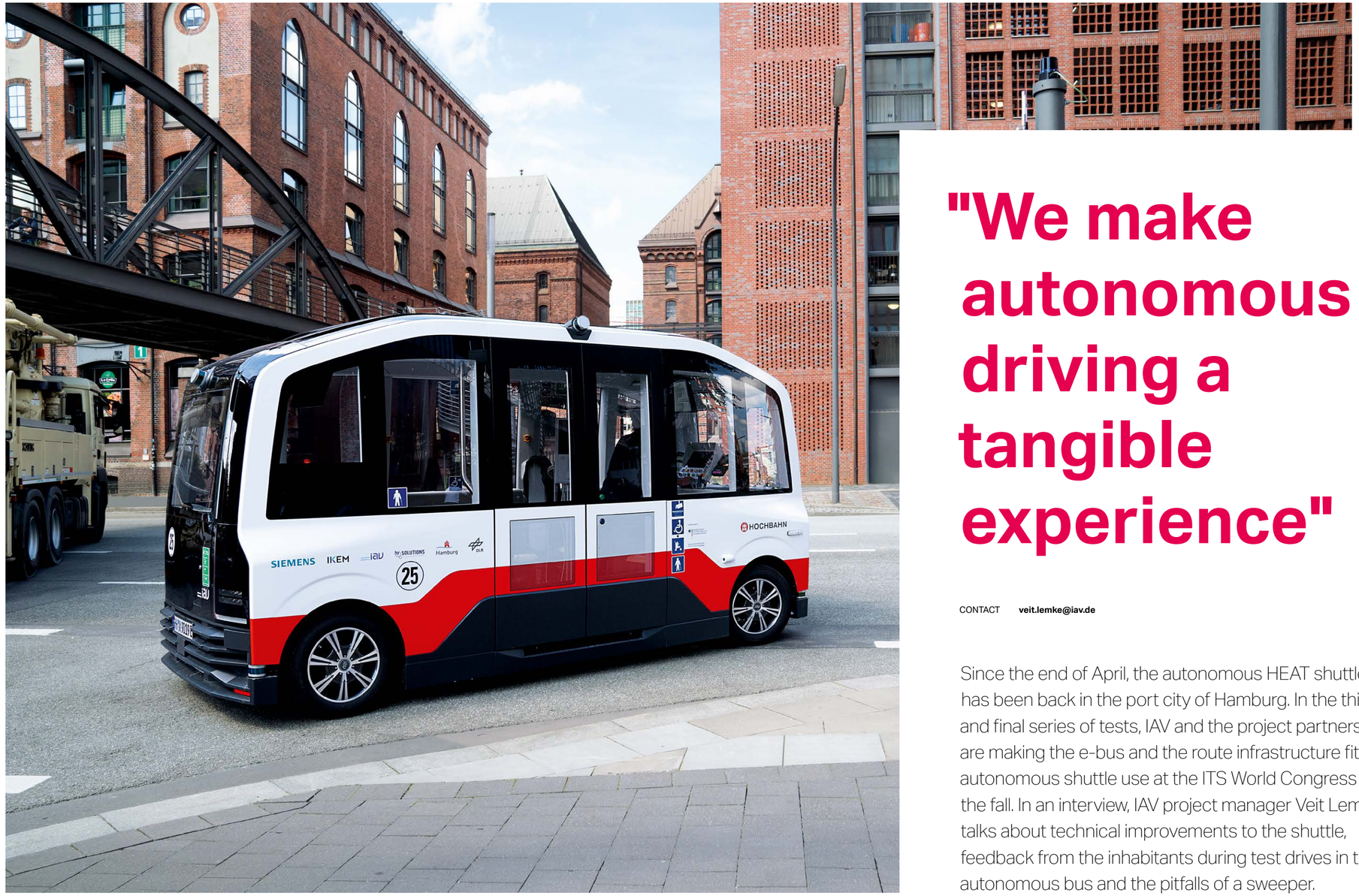
EFFICIENCY AND RELIABILITY

Current methods lack support for the reduction of the parameter space considered for validation as well as statements about the residual uncertainties to underpin the release. "The approach can also be used whenever efficient modeling methods are required for the development or release of complex systems - for example, in fuel cell design, robotics or even in aviation," says Dr. Roland Kallweit, head of the Automated Driving Function and Simulation department at IAV.

With the tool, IAV has an efficient method for significantly reducing potentially large test scopes. "For example, if you want to check 20 parameters with three values each - the highest, the middle and the smallest - without a methodology, you would need 3.5 Billion tests for all combinations. Even at one second per trial, a test series would take far too long, and even trying to manually select meaningful test cases is not feasible given the large number of influencing parameters," Hartrumpf explains. With the help of the new methodology, a result can be achieved much faster: "Our tool was already able to exclude 98% of all possible tests for a complex example in the aforementioned parameter space with 20 parameters after 5,000 tests - and then concentrated on the remaining two percent of the parameter focussed."

With its method, IAV offers new possibilities for the design phase, allows efficient testing of the functional reliability of a software release and relieves the burden during the release and validation of a final system. Using the tool, all that needs to be done is to define the parameter space to be tested and the test target; the rest is done automatically and highly efficiently. This makes another significant contribution to an overall release strategy for automated vehicles.





"We make autonomous driving a tangible experience"

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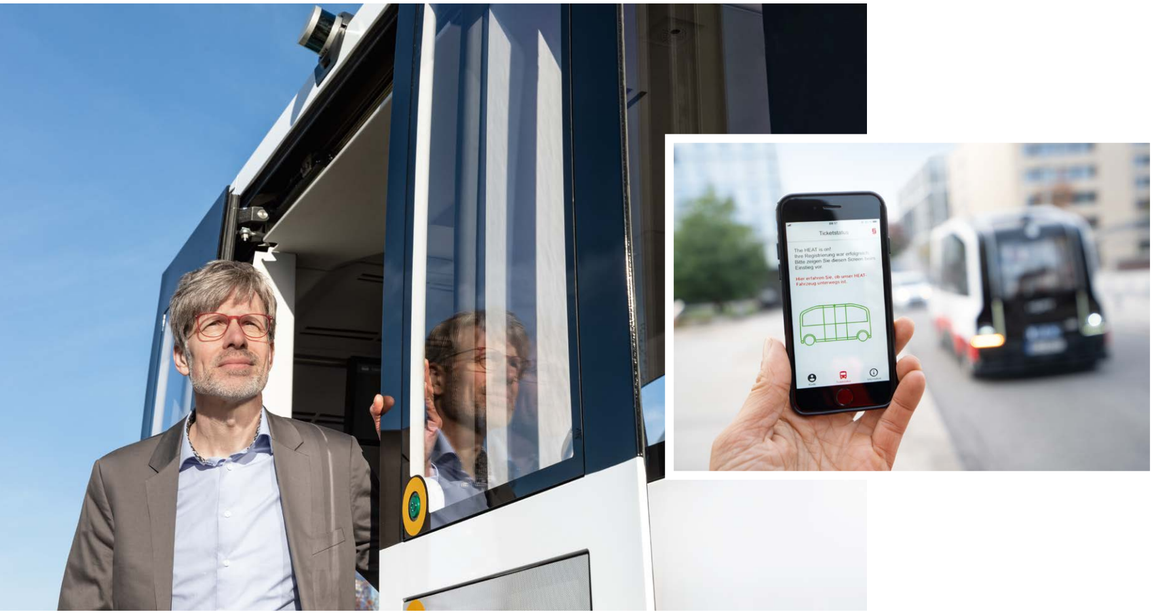
Since the end of April, the autonomous HEAT shuttle has been back in the port city of Hamburg. In the third and final series of tests, IAV and the project partners are making the e-bus and the route infrastructure fit for autonomous shuttle use at the ITS World Congress in the fall. In an interview, IAV project manager Veit Lemke talks about technical improvements to the shuttle, feedback from the inhabitants during test drives in the autonomous bus and the pitfalls of a sweeper.

Farewell to the winter training camp: In Gifhorn, the engineers made the HEAT Shuttle fit for the summer with a number of innovations and upgrades.



"The goal is as many successful hours of operation as possible."

automotion: Mr. Lemke, a look back: HEAT was last in Hamburg in the fall of last year. How did the test drives go?

Veit Lemke: The tests with the speed now increased to 25 km/h were a success. The shuttle mastered the traffic situation on this extremely challenging course, with the vehicle attendants only having to intervene in a few situations. However, the test operation also repeatedly held surprises for us that we had not considered in this way in the simulation. Here's an example: Sweepers. They sometimes drive on the street, sometimes for a moment on the sidewalk. For the shuttle, this is a strange situation at first. In short: We learned tremendously and were able to further optimize infrastructure and shuttle sensor technology over the winter thanks to the test data.

automotion: For the first time, citizens were also able to test the shuttle. What was the feedback like?

Lemke: We are making autonomous driving a tangible experience. The interest was correspondingly high across all age groups. The feedback from passengers was overwhelmingly very positive.

They felt safe in the shuttle and gave us helpful feedback on seat comfort, the interior concept and the ease of use of the app programmed by IAV for registration.

automotion: Were there any points of criticism?

Lemke: Some passengers complained about the somewhat abrupt braking behavior of the shuttle. As a precautionary measure, the system braked a little earlier during the test drives than experienced bus drivers would do. With the knowledge gained in the fall and the test drives that are now pending, we want to further optimize the braking behavior.

automotion: What are the targets?

Lemke: The goal, of course, is to have as many successful hours of operation as possible. At 1.8 kilometers, the new test track in the port city is twice as long as before. Siemens recently expanded its infrastructure sensor technology for this purpose. We will now incorporate these data to an even greater extent in order to increase speed at intersections. We're also turning left for the first time. The route now also includes a longer multi-lane section where we are testing autonomous lane changing. To ensure that HEAT can keep an eye on the traffic behind it at all times, we have consistently developed our AD system in the winter, among other things. Other innovations include an improved operating and display instrument for the vehicle attendants.

automotion: The shuttle is to be in continuous operation for the trade show in the fall. How do you assess the operational capability for ITS?

Lemke: Because we have already been back in Hamburg since the end of April, we have a very extensive testing period with the shuttle and for the overall system consisting of the shuttle, infrastructure sensors and control center. In this phase, we are also already running extensive trial operations with passengers six days a week, virtually in continuous operation. Knowledge gained from this flows directly back into development and pays dividends in terms of performance and availability with ITS (World Congress "Intelligent Transport Systems") as a goal. You can never rule out the possibility that a component will cause problems and the shuttle service will have to be interrupted. But with the test kilometers and daily on-site checks of the shuttle, we are confident that we will be able to offer visitors an exhilarating experience, both during the test phase and later at ITS.

Race AI

increases pace of autonomous driving development

The development of automated driving functions from Level 2 to Level 5 is keeping the automotive industry busy. The higher the automation level, the more artificial intelligence is used. IAV offers developers two new software modules to expand functions for autonomous driving.

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They look like a hybrid of a racing car and Bruce Wayne's Batmobile: Roborace cars that do at top speed on racetracks what is currently still strictly forbidden on our roads - driven solely by algorithms. Artificial intelligence (AI) decides all the vehicle's maneuvers.

To date, the use of AI processes for the majority of vehicle functions is largely unexplored. In the cooperative project "rAIcing - autonomous driving on the race track" as part of the "Roborace" competition, IAV has joined forces with the Technical University of Munich and industrial partners to develop two innovative algorithms for making automatic maneuvering decisions.

"With the help of our mechanical learning method, vehicles learn new traffic situations and consequently develop their own criteria for a maneuvering decision. The rule-based approach, on the other hand, works deterministically, with all criteria predefined for all situations - we know exactly what the car will do," says Thorsten Scheibe, Head of AD Validation & Automation at IAV.

A TECHNOLOGY NOT ONLY FOR AUTOMOBILES

IAV has developed and tested two approaches: one based on clearly predefined rules, the Decision Manager (DM), and a second based on neural networks. IAV offers these approaches to customers who want to make maneuvering decisions for autonomous motion, for example in driver assistance systems, to a new level or develop these further. The IAV engineers validated both modules in a simulation environment (software-in-the-loop) The SiL results were then reproduced on the HiL (hardware-in-the-loop) at the Technical University of Munich. The algorithms underwent tests on hardware that will later be used in racing cars.

These innovations are scalable: "Our research results are technology-related and can also be used, for example, in small robots for transporting goods or in flying drones," Scheibe explains.

To get an understanding of how the Decision Manager works, it helps to look at the current common work processes of such functions. Mostly the usual if-then-else logic is used.

"If a single vehicle is driving slowly in front of me, the current logic can initiate an overtaking maneuver. But if the situation becomes more complex, for example due to a high number of road users, different vehicle types or different driving behavior, the if-then-else logic reaches its limits," explains the IAV expert.

DIRECTIVES GUIDE THE VEHICLE

"At the DM, we define directives that give the vehicle principles of behavior," Scheibe explains. For the rAIcing project, that means specifically: The algorithm lets the race car avoid collisions with other race cars and stay on the track while minimizing lap time. If the DM is further developed for a production vehicle, new directives can be integrated - without having to adapt the entire software.

The second approach developed by IAV is based on a self-learning neural network that makes decisions based on learned knowledge. Here, a supervised-learning algorithm is used to learn a specific driving style based on labeled training data. "In our case, that means understanding the environment around the vehicle and deciding on a driving maneuver," Scheibe explains. This way, serial production vehicles or more advanced driving assistance systems could benefit from the findings of the rAIcing project in the future, in addition to racing vehicles.

"We have to grab the ten seconds"

Harvesting fruit and vegetables fully automatically: A bold dream for farmers plagued by a shortage of skilled labor. But close to Rostock, a team of IAV engineers is now sending the prototype of a harvesting robot out into the field.

Mr. Pannek, the "harvesting robot team" has built a prototype in just four months. What was the biggest challenge?

Jürgen Pannek: Our first model of the harvesting robot was not designed for a specific fruit. Starting in January, we adapted all components, from the simple motor to the complex system architecture, to strawberries. The most challenging part was probably to get the required parts delivered and software and hardware integrated within a few weeks. Colleagues across all maintenance groups worked on this under high pressure.

What do you particular pay attention to in the strawberry field?

Pannek: We have to catch up the ten seconds. This refers to the time the robot needs to target a strawberry with its camera, determine its degree of ripeness as well as harvest and deposit it. The crux is the approach process, since the strawberries are very closely next to each other. After all, we don't operate, but in an industrial like under glass. As a human being, you already have problems to keep the stems of the strawberries apart - and the robot is supposed to harvest the fruit precisely at the stem, which now works due to the software improvements by our colleagues. Our customer demands high quality standards here, so one wrong touch can make difference between premium goods and usable for jam only.

What knowledge do you expect to gain from the first practical field test?

Pannek: The team tests how the robot fits into the farm. We learn this together with the farmers and also adapt to each other Is our palletizing correct, how many arms do we need, how much does the tonnage vary, how time-consuming is it to change from one planting aisle to the next, and how does the operation change on the farm? As one thing is clear to everyon: Robots will not replace humans. We will then use these findings to design software and hardware even more efficiently and eliminate teething problems that occur in the field by the time the harvesting robot is launched on the market next year.

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Transformation at IAV

The automotive industry is undergoing profound change. And not just since yesterday. As far as is known. Stricter environmental targets on the one hand and fast digitalization on the other hand are fueling the technological transformation toward cleaner powertrains and a shift in expertise toward software, AI and Big Data. This has far-reaching consequences.

"Increasing employees' skills must become a matter of course in companies to master the transformation."

MARTIN ACKERMANN,
Head of Human Resources at IAV

More alternative drives such as electro-mobility means fewer conventional drives in the medium-term. More digitization in the car means new, different fields of activity for employees and, at the same time, less "classical" automotive engineering at one point or another - keyword powertrain development in the area of gasoline and diesel.

On the one hand, this has an impact on the self-image of development service providers, which increasingly see themselves as technology providers. But it also has an impact on the relocation and development of new expertise among the workforce. This cannot be done overnight and costs a lot of money. Money that IAV is making available and thus pressing ahead with qualification and transformation at full speed. To this end, the company also reached a collective agreement with IG Metall in April.

"Technological change can only succeed if it goes hand in hand with employee training in future technology fields. In close cooperation with IG Metall, we will now systematically pursue this path and make a mid-double-digit million euro amount available annually for employee training," says Mark Bäcker, Chairman of the General Works Council at IAV. This way, we are pressing ahead with the company's reorganization and, at the same time, providing security for the workforce as it undergoes this change."

With the agreement, IAV is setting the course to enable employees to develop quickly and professionally into a new role. Employees will have access to a diverse, future-oriented range of qualifications, and an interdisciplinary committee with equal representation from the company and IG Metall will decide on the use of funds for measures and manage the speedy drawdown of the budget. In addition to the qualification budget, IAV has established an additional research pot in the form of an innovation fund to support ideas from the workforce that pay into the company's future.

"Employee qualification must become a matter of course in companies in order to master the transformation. But also, to keep pace with the changes in our industry in the future. The wheel will continue to turn quickly. We have to adjust to this," says Martin Ackermann, Head of Human Resources at IAV.

In the short term, the industry's shift to more environmentally friendly drive systems is a driving force for retraining employees. Ultimately, transformation at IAV means lifelong learning, which will be a natural part of working life.

"In close cooperation with IG Metall, we will now consistently pursue this path."

MARK BÄCKER,
IAV General Works Council Chairman

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