Automotive Technologie in Bavaria

e-Car + Hydrogen

Editorial

Where is the automobile headed?

The future of the car is at stake. The political, business and scientific spheres are facing tremendous challenges in finding ideal and sustainable solutions to mobility problems during the coronavirus crisis.
The need for technically sophisticated, affordable and emission-free cars that are compatible with available fuels is creating confusion throughout the industry. We must find sound answers to the following questions:

- Where can highly competent and vehicle-specific technologies be tapped into and merged?
- What form will the next generation of door electronics take while reducing cost, installation space and weight?
- Are consistent plant engineering and design necessary?
- When must patent claims for injunctive relief be asserted?
- Can plastic materials provide an advantage in conjunction with efficient production methods?
- What is the outlook for the Nuremberg metropolitan area in terms of the transformation of low-emission drives as well as digital products and processes?
- What contribution does laser technology make to the future of mobility?
- Will hydrogen technology play a major role in the future in light of climate change?
- Can energy be stored and transported?

I encourage us to have confidence in the mobility of the future and to take a cue from Galileo in our efforts: And yet mobility still moves.

Walter Fürst, Managing Director

Masthead:

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Integrated engineering in plant design and construction

Necessities, benefits and practical teaching

Integrated engineering

Nowadays, mechanical engineering is characterized by an increasing mechatronization of all components used. This means, that the development and value added of current products is increasingly moving away from the mechanical domain towards the electrical and information technology domain. This is accompanied by an increase of the amount of information required to define, develop, test and commission such products, be they cyber-physical systems or special machines.

By linking all information in a targeted manner, it is possible to react effectively to changing customer and market requirements. This goes hand in hand with the ever-shorter product life cycles on the one hand and the increasing demand for customer individuality on the other. A correspondingly oriented development process, modular products and short commissioning times are indispensable for this and can be made possible by the approach of integrated engineering. This change is particularly noticeable in the automotive industry. New competitors are pushing onto the market and establishing alternative technologies to the point where they are ready for series production, which can only be realized by established suppliers with a considerable delay due to existing processes. These new technologies also lead to new types of customer requirements or even standards and enable the development of new business areas and models. Due to these current and future challenges, manufacturers are forced to increase their efficiency and adapt the development processes accordingly. Here, integrated engineering can be a possible solution.

The integrated engineering pursues the approach of documenting information in a structured way, from the requirements definition to product acceptance, linking it horizontally and vertically and enabling its use in cross-domain development. The integrated engineering is based on the approach of Model-Based Systems Engineering (MBSE) / Model-Based Virtual Product Development. The use of Product Lifecycle Management (PLM)

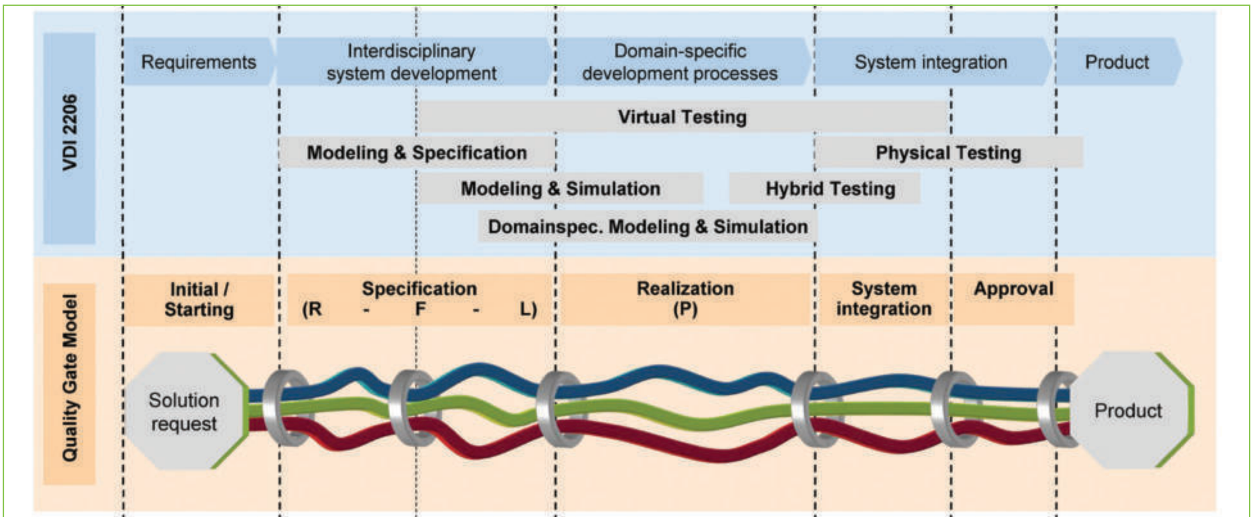

Fig. 1: *Cross-domain collaboration is more than ever the focus of product development; proven process models provide methodical support* ▪

software is an enabler of this approach. In combination with a process methodology, the product development process is supported in a goal-oriented manner *(see Figure 1).*
Depending on the phase of the development process, defined intermediate statuses are coordinated through scheduled synchronization of the domains (quality gates). Between the quality gates, the development work takes place synchronously within the domains "Mechanics", "Electrics" and "IT". PLM systems support the interdisciplinary teams by providing processes, developer role models, document storage and exchange. ■

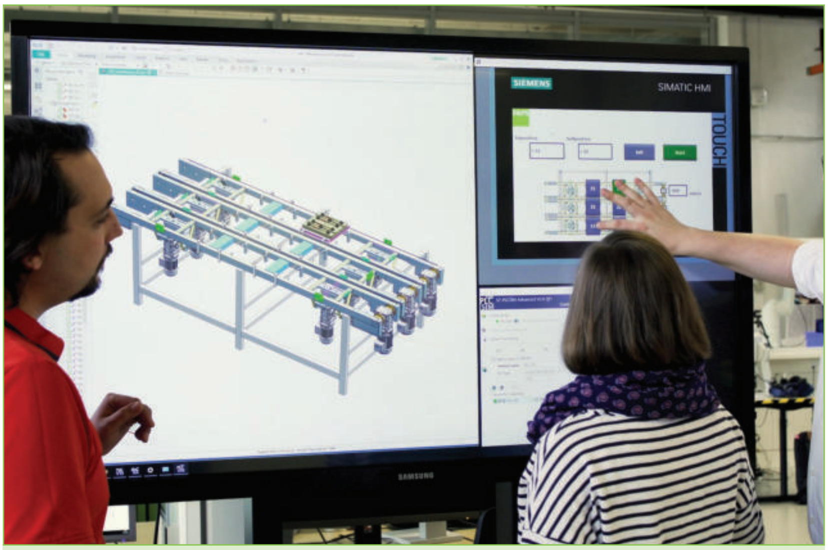

Fig. 3: *Kinematic model and virtual control can be combined to verify the system function* ■

At the beginning, there are the requirements

The process of integrated engineering starts with the structured recording of customer requirements. The properties and boundary conditions to be fulfilled are described, which are structured and hierarchically arranged according to various criteria. These are then integrated into a PLM system for use in the further development process (see Figure 2).
Within the methodical framework, the requirements are transferred into a function structure, from which the logical and physical realization of the product is derived later. All interim results are recorded in the PLM system and related to each other across phases. Quality gates ensure the synchronicity of the domains at defined points in time. Necessary release processes are implemented and documented by the PLM system using stored role models. Likewise, the tests verifying the fulfilment of requirements later on must be defined in early development phases. An appropriately set up process in the PLM system ensures the procedure. ■

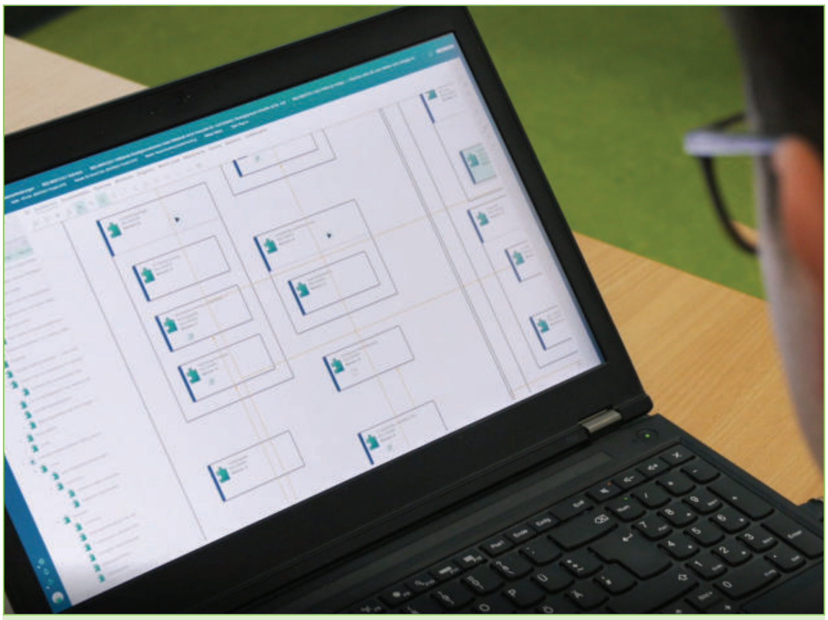
Fig. 2: *Recording of requirements in a PLM system* ■

Domain-specific development data is linked with PLM software

During the realization of the development work in the individual domains of mechanical, electrical and software engineering, documents and data from domain-specific programs are entered into the PLM system in an audit-proof manner. The domain-specific tools used, such as M-CAD, E-CAD or programs for creating software code for controls or HMI, are integrated with the PLM system via appropriate interfaces. This guarantees that all developers work with and build on the most up-to-date data. Furthermore, process steps are released by the persons responsible in the domains, which promotes target-oriented development and reliability. This approach supports collaboration across the boundaries of domains, but also across time zones and workstations. ■

Virtual commissioning forms the bridge from the virtual to the real world

Virtual commissioning is used to ensure the function and quality of the developed system. Sorted according to the degree of concretization, it can be divided into the modes

- Model in the Loop (MiL),
- Software in the Loop (SiL) and
- Hardware in the Loop (HiL).

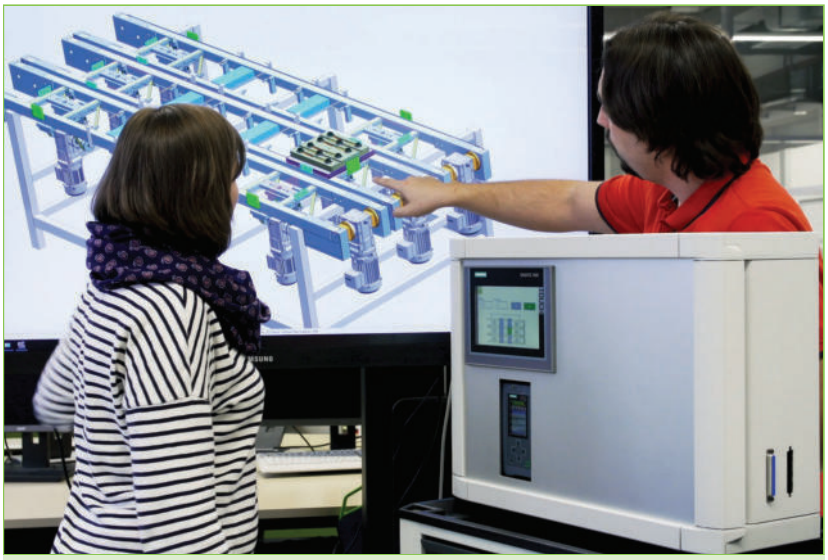

Fig. 4: *Hardware in the Loop (HiL) represents a virtual commissioning mode in which the actual controller interacts with a virtual plant model.* ■

The MiL procedure can be used for testing basic processes without knowledge of the implementation of a PLC. A kinematized plant model in a virtual environment interacts here according to the developer's specifications. SiL can be used for the virtual integration of the associated plant control system. Here, the control code is executed by means of a virtual controller and interacts with the inputs and outputs of the virtual model. The bridge to the physical world is then built using the HiL method, in which the final control code is loaded onto the physical control to be used and coupled with the virtual model. Finally, nothing stands in the way of real commissioning. ■

A block internship brings the concepts closer to prospective engineers

The Chair for Factory Automation and Production Systems (FAPS) at the Friedrich-Alexander University of Erlangen-Nuremberg teaches the methods of continuous engineering to prospective engineers in the block internship of the same name. Once per semester, the participants learn about the advantages of this approach, but also about the effort it implies in practice. Based on a clearly structured project, the steps from requirements definition to commissioning are completed. By connecting the previously tested control system including code with the real plant and starting the implemented process, the practical training ends with a sense of achievement. The software chain used is based on Siemens PLM products, is constantly updated and corresponds to the state of the industry. ■

Annually, the research sector organizes a conference

Every year, the research sector Engineering Systems of the Institute for Factory Automation and Production Systems invites to a two-day conference. The next conference will take place under the motto „Integrated Engineering – from requirement to the finished product“, probably on 24.02.2021 and 25.02.2021 in the premises of the chair in Erlangen. Experts from industry and research are invited to participate. A registration is possible under the following address: https://www.faps.fau.de/veranst/fachtagung-durchgaengiges-engineering/. Last year we were able to welcome around 45 experts on the subject of „digital twins“. We look forward to seeing you again this year.

QR-Code Conference

QR-Code Research sector

FAPS Institute for Factory Automation and Production Systems
Prof. Dr.-Ing. Jörg Franke

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

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Next generation door electronics from Brose

From window regulator anti-trap protection to side camera image processing all the way to active noise canceling for the vehicle interior – a new generation of Brose control units will in future integrate all functions in the vehicle door. This cuts costs, saves space and reduces weight.

Even from a distance the car can recognize and welcome the driver with projections in the vehicle windows. A simple gesture, and the side door opens automatically. A radar sensor scans the environment to prevent any collisions. Monitors in the doors show the image from the side cameras in real time during the drive, while the side windows turn into personal infotainment displays. Passengers inside the vehicle enjoy the quiet ride thanks to speakers with actively controlled noise canceling, which also enhances the sound of the infotainment system.

Brose side door drive with radar-based anti-collision protetion ■

Fewer circuit boards, more features

To make this mobility experience of the future possible, the automotive supplier Brose is driving forward the expansion of its electronics competence. The challenge: Especially the analysis of sensor data or the transmission of image signals overstrains conventional electrical/electronic architectures, as large amounts of data have to be transmitted and processed without any noticeable delay.

At the same time, it makes sense to centralize electronics increasingly: today‘s luxury vehicles contain an average of over 150 control units with microcontrollers. In the future, they will gradually be replaced by central data processing platforms. These control for example smart actuators with integrated (basic) electronics via hardware signals. Smart Brose window regulators are already leading the way in the market – and soon the supplier will also offer drives for side doors and liftgates with integrated electronics.

Software expertise is also gaining importance, because many of the physical control units will be substituted with digital variants on the central platforms. This can only work with the help of so-called hypervisors, which are virtually placed in front of the individual functions. They guide incoming and outgoing data to the right place and orchestrate the functions inside the control unit. In the future, Brose will not only develop individual functions and their interaction with the hypervisor; the supplier will also offer the functional software as a standalone product. Standardized interfaces keep the integration effort for the customer at a minimum.

Low latency and fast processing are key

However, the development towards a central computing unit also has its disadvantages. For example, the future scenario described above will only be possible through the exchange of huge volumes of uncompressed real-time information. The solutions currently used in series vehicles with only one main

At the IAA 2019 Brose demonstrated the applications of glass projections and their interlinking with other functions with a futuristic exhibit. ■

CPU require long cable routes, which translates into high costs and high latencies. This means it takes longer for systems to start and features to be available, resulting in problems in terms of operator comfort and safety – for example when processing images from the side cameras.

This is the reason Brose is developing its next generation of door control units that processes all functions in the door locally. This also includes innovative concepts such as voice recognition in the vicinity of the car, pre-processing of all received antenna signals or variable sun visors thanks to electrified window segments with individually adjustable transparency. A single broadband line connects directly to the central control unit, saving space and costs by eliminating more than 30 cables in the door interface. Thanks to around 35 years of experience in electronics, the family-owned company has the in-house expertise to integrate this into the entire system, thereby reducing the technical and financial expenditure even further for OEMs.

And Brose not only develops the control unit, it also delivers complete solutions. The company assumes responsibility for interlinking the entire mechatronic system – for example by integrating a digital signal processor for active noise cancelling into an existing multimedia architecture, placing sensors and speakers into the door module and fine-tuning all of the individual components. This system approach saves money and enables further benefits. For example, window pane projectors can have much smaller form factors and be positioned more flexibly if their graphics units are located in the door electronics.

The first presentation of the all-in-one door control unit and its features was at the IAA 2019. Brose has already received concrete orders for the development of multiple features such as window projections, variable sun visors and active noise canceling. The next-generation control units could enter series production as early as 2025. ■

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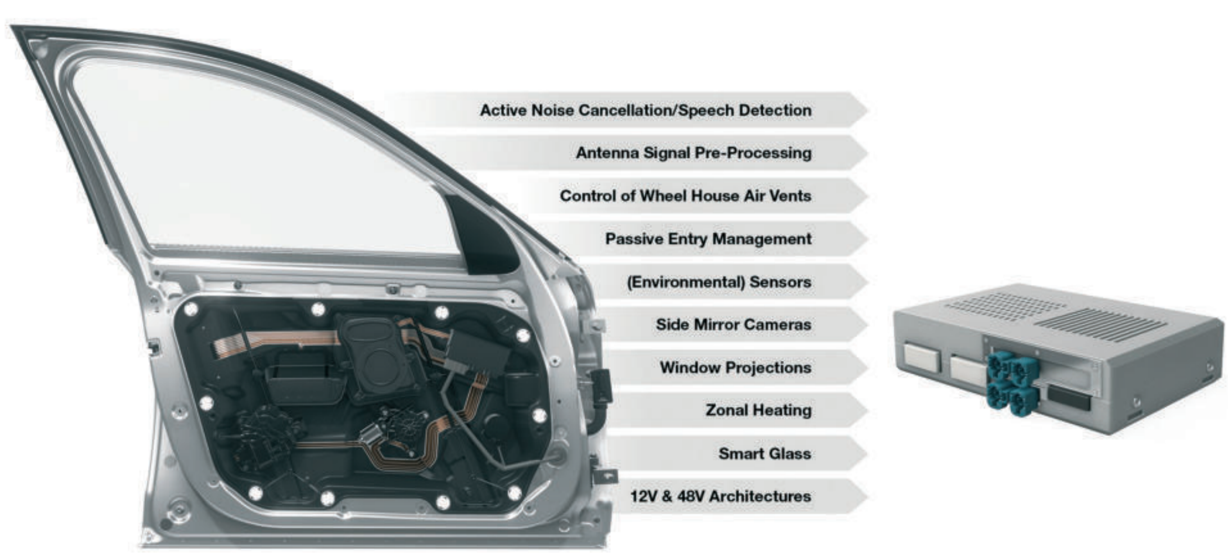

Possible functions of the new generation of Brose door control units ■

Proportionality reservations for patent injuctions

Criticism of automatic injunctions

Unlike in the United States (see 35 U.S.C. 283 - ebay ./. mercexchange), there is no mandatory proportionality test for injunctions in ordinary patent infringement proceedings in German legal practice (§§ 9, 139 (1) PatG). In the event of patent infringement, a cease and desist order is usually issued automatically. In this respect, the patent owner is given a sharp sword against patent infringers.

The increasing emergence of complex products protected by hundreds of patents, related information technologies covered by Standard Essential Patents (SEPs) and, last but not least, the increasing number of "Non-practising entities" (NPEs), i.e. companies which (apart from commercial patent exploitation) do not carry out any operative activities of their own, have triggered a call for proportionality requirements for patent injunctions in Germany in order to avoid "unfair" injunctions. The automotive industry in particular points out that complex products, such as automobiles, and corresponding cost-intensive production processes may be blocked by patents covering only a single part of the whole product and/or process. Therefore, it is required to establish explicit proportionality requirements for injunctive relief in German patent law in order to enable a balance of interests prior to issuing court injunctions.

Legislative initiative of the German Federal Government

In January 2020, the Federal Ministry of Justice and Consumer Protection presented a discussion draft bill (Diskussionsentwurf eines zweiten Gesetzes zur Vereinfachung und Modernisierung des Patentrechts), which contains an amendment of the provision concerning the right to injunctive relief in case of patent infringement.

According to the draft bill, § 139 (1) PatG, which provides that the patentee has a right of injunction against the infringer in the case of patent infringement, is to be supplemented by the following sentence: "The claim is excluded if the enforcement of the right of injunction is disproportionate because it constitutes a hardship not justified by the exclusive right, due to special circumstances, taking into account the patentee's interest vis-à-vis the infringer and the requirements of good faith.

Motives of the legislator

In the explanatory memorandum of the proposed amendment to the law, the legislator emphasises that the supplementary provision is merely a clarification of the legal requirements for the issuance of injunctive relief and points out that German law already allows an examination of the proportionality of the claim for injunctive relief in case of patent infringement. Reference is made to the constitutional guarantee of the principle of proportionality, which is an expression of the requirements of good faith in Article 19 (4) of the German Constitution.

Finally, the explanatory memorandum of the draft bill refers to the possibility of granting use-by periods in the event of patent infringement, as recognised in the case law of the Federal Court of Justice. According to the decision published under the keyword "heat exchanger" (ruling of 10 May 2016, GRUR 2016, 1031), a court injunction with immediate effect may not be issued if the immediate enforcement of the patent holder´s right to injunctive relief would constitute an unreasonable hardship in breach of good faith, for the patent infringer.

The granting of grace periods allows the alleged infringer to continue to use the patent-protected product for a certain period of time after an injunction has been issued and gives time to develop patent free alternatives. In the so-called “heat exchanger” judgement, the patent in dispute protects a system for heating the air flowing around the neck and shoulders of a person in a convertible car. The patentee filed a lawsuit for infringement and claimed injunction against the manufacture and distribution of the cars concerned. The defendant requested that the action be dismissed on the grounds of non-infringement and, as an auxiliary request, that a grace period has to be granted in order to delay the effect of an injunction. Even if the requested period of use was not granted in this decision because the infringing element was not essential for the function of the car, the Federal Supreme Court has provided some guidelines for the granting of grace periods which are to be observed in future court decisions (e.g. Düsseldorf Regional Court GRUR- RS 2017, 106557 - Herzventile; Munich Regional Court, Beck RS 2019, 11305).

Accordingly, grace periods can already be granted under existing law but only upon request and under strict conditions. They are excluded if a changeover to patent-free solutions has already been possible since the knowledge of the infringement allegation. Neither the normal economic harm caused by the enforcement of an injunction nor the public interest can currently justify the granting of such a period. It is also irrelevant whether or not the patent-holder is using the technology.

Only economic consequences of an immediate enforcement of the injunction against the infringer, which go beyond its normal damage, make it possible to limit the effects of the patent by granting a grace period.

In the explanatory memorandum to the discussion draft, the legislator expressly emphasized that the implementation of the principle of proportionality in § 139 PatG must not lead to a devaluation of the patent rights according to applicable legal principles and that the limitation of the injunction order must remain limited to exceptional cases. The injunction should remain a powerful weapon in patent law, which can be issued independent of fault in the event of patent infringement. Therefore, the patentee is in principle not obliged to make representations on proportionality in order to enforce his patent right. This only applies in cases in which the alleged infringer puts forward important arguments in favour of a limitation of the injunction. Such arguments may be based on specific circumstances of the individual case, such as Role of the patent holder as a non-practicing patent exploiter with a limited interest in the enforcement of the injunction adverse economic effects of the injunction for the alleged infringer which are disproportionate to the value of the infringed patent complex products, which are covered by many patents whereas the redesign with regard to the patent-infringing components causes high time and economic efforts.

Degree of fault of the infringer.

Serious doubts as to the validity of the infringed patent do not appear to be an aspect of proportionality, but remain a criterion for suspending the infringement proceedings in the event of parallel revocation proceedings before the Federal Patent Court or the patent offices.

It can be concluded from the intention of the legislator that restrictions of the obligation to cease and desist due to unproportionality should be the absolute exception and may only be granted if unreasonable hardship for the patent infringer cannot be avoided by conversion and use by periods.

It must be concluded from these legislative motives that the mere fact that the patent covers only a minor individual feature of a complex product which might be protected by patents, such as a car, is not in itself sufficient to grant by periods use or to limit the enforcement of the injunction. The same applies in cases in which patents are enforced by NPEs. It remains open how the courts will define the requirements for "hardship not justified by patent law" in case of the implementation of the proposed amendment. It should be noted, however, that the interpretation and application of legal provisions by the courts is not primarily and exclusively based on the motives of the legislator.

Outlook

The draft bill will trigger further controversial discussions before its implementation into valid patent law. The Federal Ministry of Justice has called upon the relevant circles of industry, legal practice and academia to submit their opinions. Practitioners of the legal profession fear a devaluation of the patent system and are concerned about the legal status of Germany as a preferred location for patent cases in Europe. On the other hand, the proponents of the reform even demand a more far-reaching limitation of the right to injunctive relief, which also includes the right to take into account the protection of public interests and third party interests. In case of an implementation of the provisions proposed in the discussion draft bill, the plaintiff should be prepared for the expected objection of disproportionality of an injunction in patent infringement proceedings. The possible necessity of taking evidence regarding disputed factual allegations will lead to delays in proceedings. For defendants from the automotive industry the intended new regulation will in any case provide a platform for avoiding or at least delaying allegedly “unfair” injunctions.

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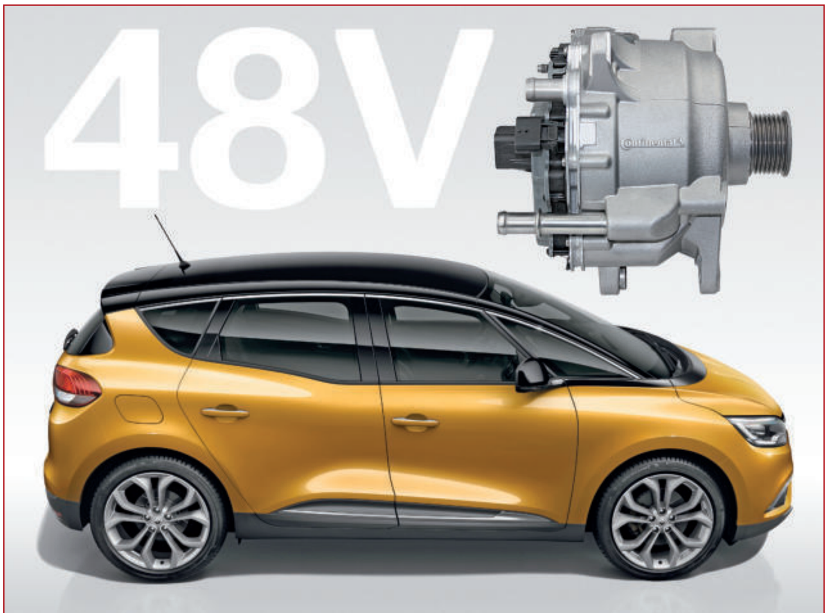
Nuremberg European Metropolitan Region

Low-emission mobility as a strategic trump card

The automotive industry and its suppliers are the leading industry and export motor in Bavaria. The corona crisis is accelerating the transformation to low-emission drives and to digital products and processes. With its broad mix of different suppliers, the Nuremberg Metropolitan Region is excellently positioned to promote and decisively shape these future topics. Particular strengths lie in electrical and mechanical drive technology and mechatronic system solutions.

One example is Vitesco Technologies Germany GmbH (formerly Continental AG), located in Nuremberg, where 500 of the approximately 3,000 employees work on all facets of electrification. Since October 2016, the world's first 48-volt hybrid drive has been in series production at Vitesco. The technology is a particularly cost-efficient solution for significantly reducing fuel consumption and exhaust gas emissions. The 48-volt variant is an alternative to the much more complex high-voltage technology with 300 to 400 volts, which has been commonly used in hybrid vehicles until now. Since 2013, engineers at Continental in Nuremberg have been developing this hybrid drive together with Renault and regional partners such as the Fraunhofer Institute for Integrated Systems and Device Technology (IISB) and the Bayerisches Laserzentrum (blz).



The world's first hybrid drive system that operates at a voltage of 48 volts was developed by Conti in Nuremberg and continues to be series produced there. Source: Continental ▪

Other companies and brands for instance Siemens, Baumüller, Brose, Semikron, Schaeffler, MAN Nutzfahrzeuge and ABM Greiffenberger also stand for considerable global expertise in the field of electric and hybrid drive technology.

A large number of companies offer components and solutions for electronics, cables, on-board networks as well as storage and charging systems. Examples of companies and brands in this sector are Bosch, Leoni, Komax, Aptiv Services, ZF Friedrichhafen, Diehl, Schlenk, Scherdel, E-T-A, ABL Sursum, TÜV Süd and TÜV Rheinland.

The Nuremberg Metropolitan Region is home to several research institutes and university departments specializing in electric mobility. Examples include the above-mentioned Fraunhofer IISB (development of power electronics, design and realization of storage systems and test center for electric vehicles), the Fraunhofer Institute for Integrated Circuits IIS (e.g. information and communication technology for battery management, energy management, connection to smart grids), the Fraunhofer Institute for Silicate Research ISC (material development for high-performance, fast and safe energy storage systems), the E|Drive Center at the Friedrich-Alexander Universität Erlangen-Nürnberg (production-related design, production technologies and application development for electric drives), the Technologie-Transfer-Zentrum Electromobilität (TTZ-EMO) at the Hochschule für angewandte Wissenschaften Würzburg-Schweinfurt (among other things load management with electric vehicles and innovative charging technologies), the Institute for Power Electronic Systems (ELSYS) at the Technische Hochschule Nürnberg Georg Simon Ohm (among other things grid integration of electric vehicles), the Ostbayerische Technische Hochschule Amberg-Weiden (embedded system and real-time software for electric mobility), the Technologietransferzentrum Automotive of the Hochschule Coburg (TAC) and the AutomobilTechnikum Bayern (ATB) in Hof.

Battery-powered electric vehicles are only part of the energy transition but not the entire solution. In the future, hydrogen will play a key role, as it offers a wide range of solutions to bridge the gap between energy, transport and industry. The Center Hydrogen Bavaria (H2.B), based at the Energie Campus Nürnberg, is intended to link industry, science and politics in order to develop the hydrogen economy and to support the transformation process of the Bavarian automotive and supplier industry. Hydrogen is an energy carrier for electric vehicles, which generate the electricity for driving through fuel cells. To activate the market, the state government will promote combined electrolysis facilities and fuel cell vehicles such as buses and commercial vehicles/trucks. On November 18, 2020, the so-called HYDROGEN DIALOGUE will take place in Nuremberg for the first time. This event of the Nürnberg Messe will in future be the central meeting place for experts from politics, industry and science by giving them the support in bringing hydrogen technologies to application.

The Charging Network+ combines the services of around 60 municipal and regional energy suppliers for a regionwide uniform and user-friendly charging infrastructure. Source: N-ERGIE

*The electric engines from the Nuremberg-based Baumüller Group are now also used in battery-powered FRAMO trucks. The 18-ton electric truck has a range of 250 - 270 km and can carry a cargo load of 9.5 tons.
Source: Baumüller*

On September 5, 2019, the Bavarian State Government founded the Center Hydrogen Bavaria (H2.B). The Center intents to accelerate the research and development of hydrogen as a future technology. Solutions for low-emission mobility, especially in the commercial vehicle segment, are a particular focus. Source: Kurt Fuchs/H2.B ■

The Ladeverbund+ has committed itself to promote electric mobility in the Nuremberg Metropolitan Region and neighbouring areas. In order to achieve this goal, the members of Ladeverbund+ are investing in the expansion of a regionwide, uniform charging infrastructure. In 2019, the charging infrastructure was expanded from 280 to 520 charging points, corresponding to a growth rate of 85 percent. The public charging infrastructure throughout Germany increased by around 50 percent in the same period. As a means to create opportunities for cooperation among regional providers, users and developers and simultenously to promote the exchange of knowledge, the Nuremberg Chamber of Commerce and Industry for Central Franconia has been offering the Innovation and User Club eMobility since 2013 in cooperation with the Chambers of Commerce and Industry based in Coburg, Bayreuth and Würzburg-Schweinfurt (http://emobility-nordbayern.de).

The above-mentioned Chambers of Commerce and Industry are planning an additional User Club on the subject of hydrogen technology and infrastructure. Examples of other regional clusters driving forward the topic of hydrogen and electric mobility are Bayern Innovativ GmbH, EnergieRegion e.V., the Center for Transportation and Logistics Neuer Adler e.V.(CNA), the European Center for Power Electronics e.V. (ECPE) and the ofraCar-Automobilnetzwerk e.V. ■

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Laser Technology in Battery Production

How laser technology shapes the mobility of tomorrow.

The need for sustainable and climate-friendly mobility is currently leading to a change of the mentality in the transport sector. As one of Germany's main drivers of innovation, the automotive industry is assigned to the task of pushing ahead with the electrification of the powertrain. One of the key technologies for further market penetration is the traction battery, which accounts for about 40 % of the total value-added costs of an electric vehicle. The demands placed on the currently prevailing battery technology of lithium-ion batteries are correspondingly high in terms of service life, fast charging capability, safety, and energy as well as power density. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) set a fleet target of 6 million electric vehicles in Germany by the year of 2030. This goal only can be achieved by decreasing battery costs and improved performance characteristics, among other things through technological progress in cell production. Assuming that an average electric vehicle is equipped with a battery unit having a capacity of 80 kWh, the production of a total storage energy of 480 GWh will be required until 2030. Supposing a prismatic cell format frequently used in automotive engineering with an energy content of 0.3 kWh per cell, this results in more than 1.6 billion individual battery cells required *(see Figure 1)*. These numbers illustrate the enormous production capacities required and underlines the high standards, which the production of lithium-ion batteries must fulfil. Only highly automated and reliable production processes can meet the demanding targets concerning quantities, cell quality, and costs per kWh storage capacity. The Institute for

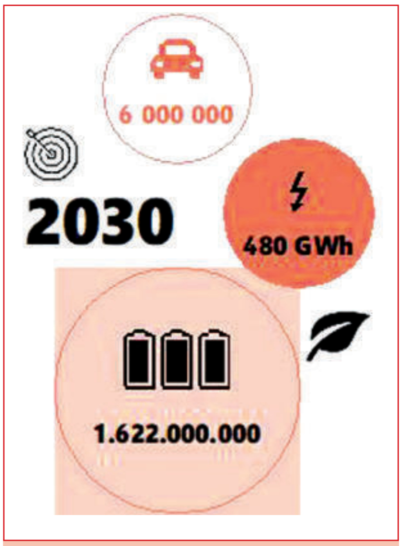

Fig. 1: *Estimated demand for battery cells to achieve the fleet targets of the BMU by 2030.* ■

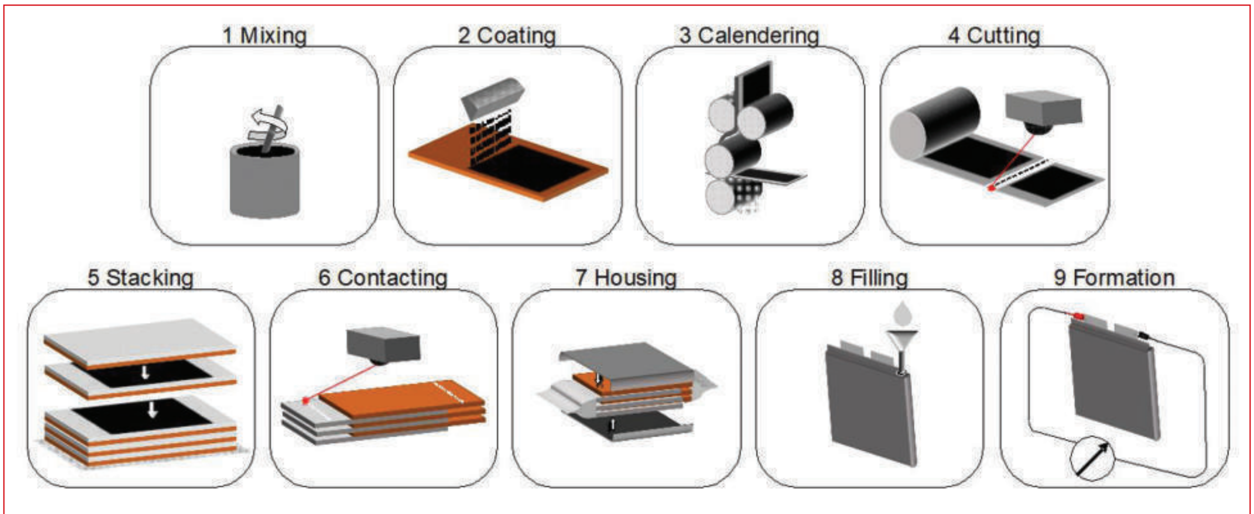

Fig. 2: *The process chain for the production of lithium-ion batteries.* ■

Machine Tools and Industrial Management (iwb) of the Technical University of Munich (TUM) is one of the leading research institutes in the field of battery production in Germany. The operation of an in-house pilot line for the production of lithium-ion batteries facilitates research along the entire value chain, from the manufacturing of electrodes and the subsequent cell assembly up to the integration of batteries into modules. ■

Process chain for the production of lithium-ion batteries

The challenges in the production of large-format lithium-ion batteries lie, among other things, in the complexity of the production chain and the existing dependencies within the individual process steps *(see Figure 2)*. Starting with the electrode manufacturing, the electrochemical active material, conductive additives as well as binding agents and solvents are fed into a mixing process. The homogeneous electrode paste is then continuously coated on thin metal foils. These foils serve both as coating substrate and as current collector in the cell. Within the calendering process, which is a compression step using heated rollers, the porosity of the materials is reduced. Then the anode and cathode layers are wound up on rolls. In the first step of cell assembly, the specified electrode geometry is created by a cutting or blanking process. Subsequently, depending on the desired cell size a certain number of anodes and cathodes are combined to form a cell stack or coil. For electrical insulation within the cell stack, a separator is inserted between the electrode layers. In a following step, the electrodes are electrically connected by welding the collector foils on protruding tabs. After inserting the contacted stack into a cell housing, the cell is filled with a liquid electrolyte. The electrolyte provides the conductivity for the lithium ions within the cell and enables charge balancing when the electric current flows through the cell's current collectors. Finally, each cell is charged and discharged several times in the cell formation to establish the final operability. ■

The potential of laser technology along the production chain

Innovative manufacturing technologies help to achieve the targets in the production of lithium-ion batteries. In this context, product quality has to be increased, the number of rejects reduced, and overall production costs lowered. Laser radiation represents a flexible tool for the processing of the sensitive and thin-layer cell materials. The high process diversity of laser technologies opens up great potential along the entire process chain. The wide range of applications is increasing through innovations in laser system technology and intelligent process control. In comparison to mechanical manufacturing processes, the flexibility in beam guidance simplifies the adaption to new product features, for example to a changed cell format. In the following, three selected examples from cell production are examined in more detail and the potentials of laser technology are shown. ■

Electrode cutting

Depending on the cell dimension, both the anode and the cathode material have to be separated into specific electrode formats *(see Figure 3)*. The roll material is unwound and fed to a cutting device. Currently, the electrode geometries are mostly produced through mechanical fine blanking. The achievable high quality of the cutting edge is counterbalanced by tool wear and, thus, decreasing product quality and regularly necessary maintenance efforts. In a cell production with an annual output of one gigawatt-hour of energy storage quantity, the daily number of tool strokes amounts to several million. Contour cutting by means of laser radiation creates advantages in this context due to the contactless and format-flexible working principle. To meet the high demands on cut edge quality, a suitable process regime must be selected. By employing pulsed laser radiation with pulse durations in the nanosecond range, less heat is introduced into the materials compared to continuous-wave laser radiation. Thus, melt spatters and defects in the area of the cutting edges can be reduced. A further area of interest is the achievable process speeds. To increase the throughput, cutting speeds of significantly more than one meter per second are targeted. One approach is a multi-pass process strategy based on the iterative gui-

Fig. 3: *Stack of anode sheets after laser cutting. Novel laser processes can significantly increase the productivity of the separation process, enabling millions of laser cuts per day.* ■

dance of highly focused laser radiation along the electrode contour at very high speeds. To achieve the desired ablation rates, continuous-wave lasers with a high beam quality and laser scanners capable of moving the laser beam across the workpiece at more than 10 m/s are required. ■

Structuring of electrodes

A possible addition to the process chain in future cell production is electrode structuring, which is currently still on a research scale. After calendaring, a residual porosity remains in the electrodes. During filling, the pore volume is wetted by the electrolyte and the ionic conductivity within the electrode layers is established. To enable charge equalization between the electrodes, the lithium ions must migrate through the complex pore network. A laser can be used to drill microscopic

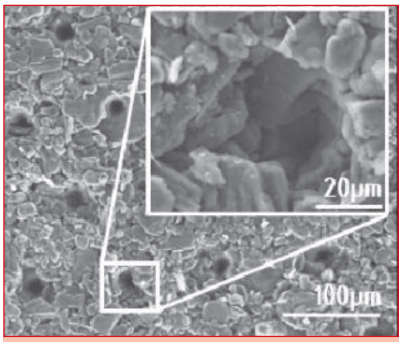

Fig. 4: *Scanning electron microscope image of a laser structured anode surface. Pulsed laser radiation can be used to introduce microscopic structures into battery electrodes to increase their performance.* ■

holes in the material layers *(see Figure 4)*.

Directed channels of the laser structuring supplement the pores, which are randomly arranged after calendering. This facilitates the diffusion of the lithium ions through the electrode material. During operation, the enhanced ionic conductivity not only increases the discharge capacity at high discharging currents but also improves the rapid charging capability of the cell. Depending on the electrode configuration, up to 10000 holes per square centimeter of the electrode can be useful. As a structuring tool, pulsed laser radiation enables thousands of holes with diameters below 50 µm to be drilled within seconds. The short, high-energy laser pulses keep the damaging thermal influence on the material to a minimum. The desired drilling depth can be individually adapted to the electrode thickness by adjusting the number of laser pulses. Scanner technologies with very high deflection speeds offer advantages in scaling-up the structuring process. Polygon scanners, which can pass the workpiece at several hundred meters per second, enable the structuring in a roll-to-roll process and are considered to be highly promising here. ■

Cell-internal Contacting

For cell-internal contacting, the collector foils of the stacked anodes and cathodes are welded together and joined to a tab for further external electrical integration of the cell. To reduce power losses within the cell, joints with minimal electrical resistances are aimed. Currently, the collector foils are usually contacted by ultrasonic welding. In this solid-phase welding process the connection is formed below the melting temperature of the joining partners and the thermal stresses on the heat-sensitive separators are excluded. This contact-based process is limited in the shape of the weld seam by its low geometric flexibility and a high mechanical impact. The vibrations introduced during welding can lead to a deterioration of the thin copper

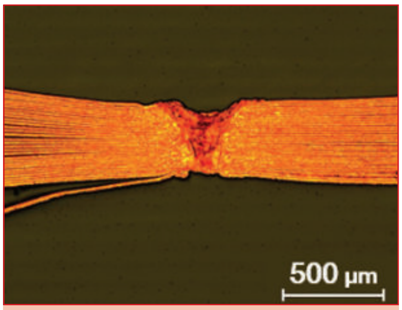

Fig. 5: *Cross-section of a laser-contacted foil stack. Using green laser radiation, a more stable welding process is enabled when joining the battery foils.* ■

and aluminum foils with single-layer thicknesses between 8 µm and 15 µm. Besides, the risk of detaching particles of the electrode materials is involved. As a non-contact joining method, laser beam welding represents a promising, format-flexible process alternative. Novel high-performance beam sources in the visible wavelength range open up possibilities in the area of cell-internal contacting. The collector foils on the anode side are made of copper, which shows a sevenfold increase in the degree of absorption for green laser radiation in comparison to infrared laser radiation. This enables a stable heat conduction welding process with a reduced material ejection *(see Figure 5)*. Safety-critical weld spatter can be significantly reduced. The application of pulsed laser radiation offers the possibility of a decreased heat input into the joining partners and avoids thermal damages of the temperature-sensitive battery components. As a highly flexible tool, the laser process is a promising technology with regard to the design of new cell concepts. The spatial variability of laser beam welding enables a modified design in the cell layout, which allows for a reduction of the dead volume (unused volume within the cell housing) and thereby increases the energy density. ■

Modern battery production in Germany

The use of innovative laser system technology in combination with a well-directed process design offers numerous opportunities for the efficient production of battery cells. Along the entire process chain, this opens up possibilities for improving the production processes the quality of the end products. This is the basic prerequisite for establishing a battery industry that can compete with experienced suppliers from Asia or the USA and helps to maintain Germany as a production location in the long term. ■

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Handling of accident-damaged electric vehicles

Electromobility, specifically passenger car electric vehicles (EVs), will experience a significant increase in near future, due to governmental regulation to reduce CO_2 fleet consumption. The growth would thus occur as a result of an increased number of registered electric vehicles.

Statistically, since there will be more EVs on the roads, more accidents with EVs are expected. At present, there is a natural skepticism and reluctance among the public towards new technologies such as EVs [1]. The occurrence of fires in electric vehicles are making big headlines in the media. For example, at the beginning of October 2019, a Tesla Model S accident in Austria was reported in detail in the media and was controversially discussed [2], [3], [4], [5], [6]. After a collision with a tree, the electric vehicle went up in flames within a few seconds. Nobody was injured, but as the responsibilities and the handling procedure of the vehicle involved in accident was unclear, it was difficult to deal with the situation [4].

The mentioned accident and similar cases illustrate that current legal regulations are still unclear with regard to the handling of an EV accident, and highlight the lack of experience of the population and all involved parties who are responsible for the handling and processing of the vehicles involved in the accident (fire brigade, police, towing service, etc.). This is where the Technische Hochschule Ingolstadt and the CARISSMA technology field Safe Electromobility comes into place in the context of the EU-funded network project SENSE BAY. The aim is to develop recommendations, together with the know-how of the network partners, for the handling of accident-damaged electric vehicles (passenger cars, commercial vehicles) from the scene of the accident to the repair garage or recycling company, and to highlight the differences in regulations between EVs and internal combustion engine vehicles (ICE). ■

High-voltage hazard - intrinsically safe vehicle architecture

Section 323c of the German Criminal Code (StGB) requires everyone in Germany to provide first aid. In road traffic, it doesnot matter whether the vehicle is equipped with an ICE or an electric drive. The fear of suffering an electric shock by touching high-voltages are widespread. Voltages above the range of the protective low voltage, so-called high-voltage ($>$ 60 V and $\leq$ 1500 V (DC) or $>$ 30 V and $\leq$ 1000 V (AC) [7]), represent a considerable danger. In paragraph § 323c of the German Criminal Code (StGB), the importance of self-protection is emphasized and the aid given by the first responder has to be reasonable in order to not endanger him or herself. Since a layperson cannot assess the electrical hazard, vehicles must be designed in such a way

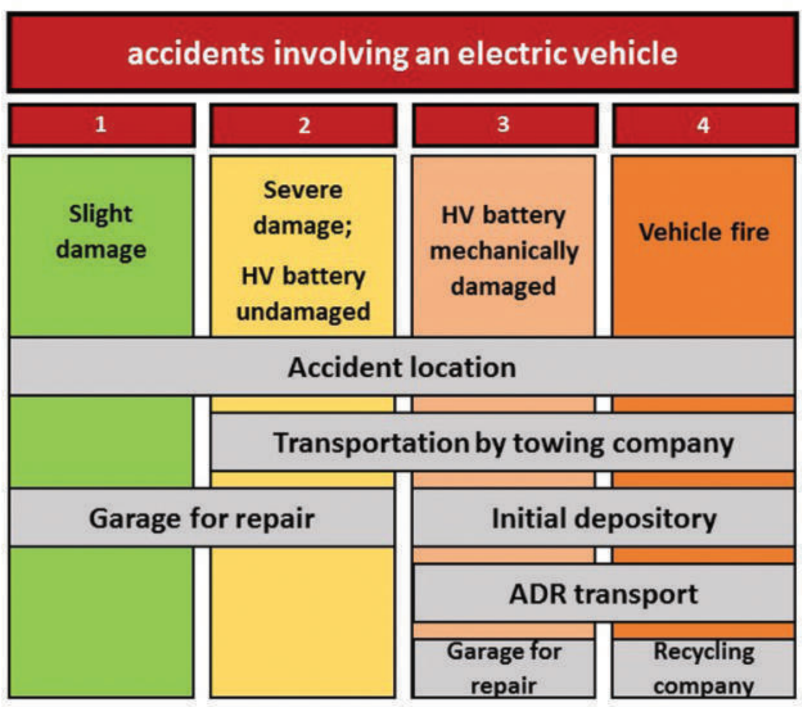

Fig. 1: *Reaction chain of accident scenarios depending on the severity of the accident.*

that complete safety is guaranteed after a serious accident. For this reason, electrical safety is given the highest priority in the development of all vehicles [8]. Technical measures such as the insulation monitor of the energy storage system make electric vehicles intrinsically safe [7]. All high-voltage (HV) components are designed to be safe to touch and are electrically isolated from the 12 V vehicle electrical system and thus from the vehicle body. If an airbag is triggered by an impact, the contactors of the HV circuit are opened immediately and the high-voltage system is deactivated [9]. ■

Accident scenarios and procedure

The manner in which the electric vehicle is to be handled upon the occurrence of an accident is dependent on the severity of the accident. The guide for the handling of accidents involving EVs has been divided into four categories of severity *(Figure 1)*. A detailed presentation of all four cases is not possible within the scope of this article. This article is therefore limited to the description of the fourth case, an accident resulting vehicle fire, as this is where the greatest uncertainty exists. Based on this accident scenario, the consequential recommendation of action for the movement of an electric vehicle from the accident site to the recycling company is laid out and explained in the following section. ■

Accident scenario vehicle fire

Figure 2 illustrates the chronological reaction chain of an accident, which has resulted in a burning electric vehicle. The response steps from the deployment of the emergency staff, fire extinguishing and vehicle towing to the recycling company are explained systematically in the following sections. The roles of the control center, the rescue services, the towing company and the waste disposal company are described in detail.

Reporting the accident - control center

In the event of a serious accident in a newer vehicle, an emergency call (eCall) will automatically be sent to the nearest control center (mandatory from March 2018) [10]. The dispatcher of the control center immediately attempts to contact the vehicle occupants. If the vehicle occupants can successfully be contacted, the dispatcher uses specific questions to determine the location of the accident, the circumstances and the number of people involved. In such scenario time plays a major role as regulations specifies the fix amount of time between the initial call and the arrival of the fire brigade at place of accident. The time limit is dependent on the location of the accident, for example, the maxi-

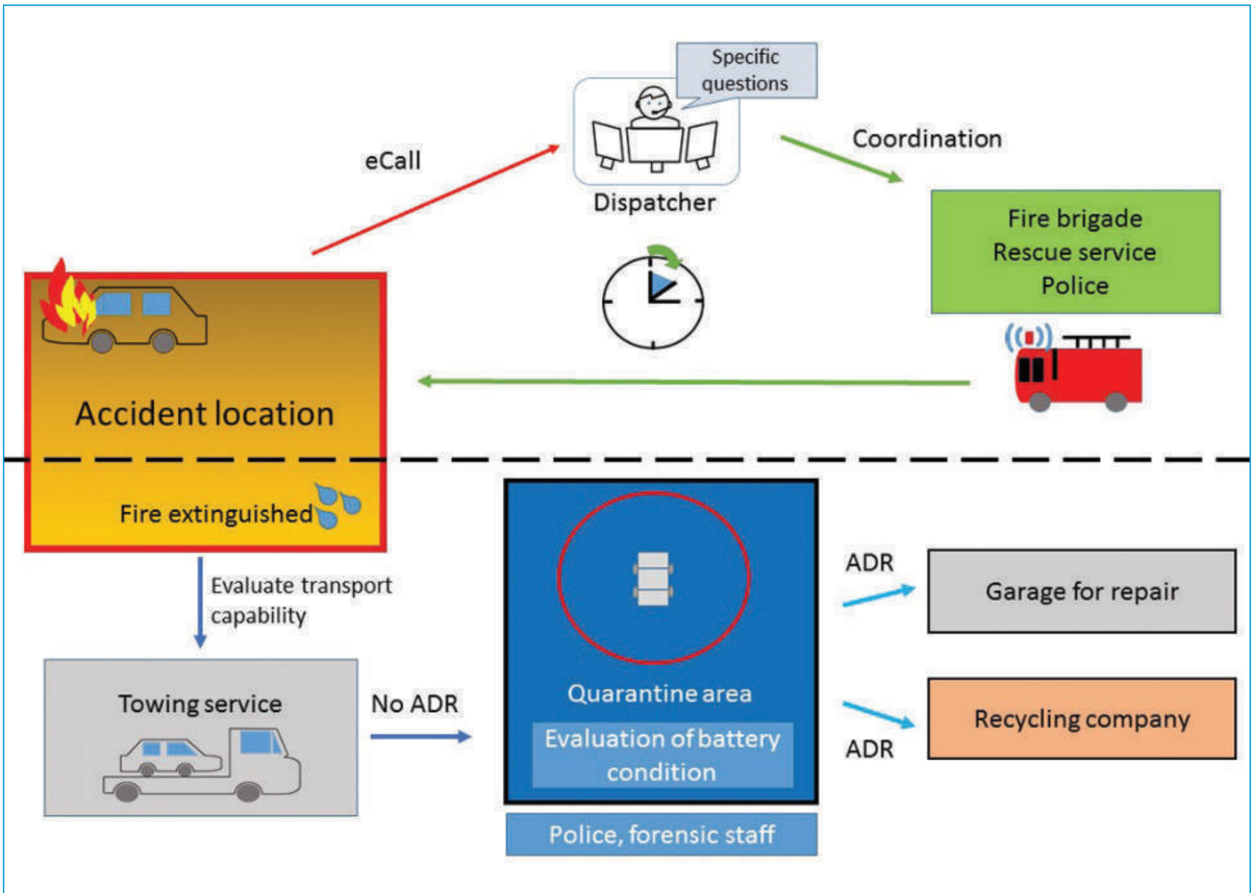

Fig. 2: *Reaction chain and recommended actions in the fourth accident scenario.*

mum time must not exceed 12 minutes in Bavaria [11].

As the airbags are released it would automatically trigger an emergency call (eCall), provides data of the location of the vehicle, the number of occupants and the time of the accident, as well as thedrive system of the vehicle involved [10].

In Germany, the license plate alone does not serve as a clear indicator of an EV, as the vehicle owner can optionally select the E suffix on the license plate. In the case of hybrid electric vehicles, it is possible that the E may not be selected due to limited range (at least 40 km electric range required in Germany [12]) - although a high-voltage system may already be installed here. Clear indications for example would be orange cables of the high-voltage components.

Since 2013, the control center is able to promptly obtain the appropriate rescue data sheet for the correct rescue response via an online license plate query at the "Kraftfahrt Bundesamt" in Germany [9].

Extinguishing the fire - fire brigade

Before the extinguishing measures begin, the control center provides the rescue datasheet of the affected vehicle model to the emergency services at the location of the accident. The data sheet contains information about the location of the HV battery and HV cables in the vehicle as well as instructions for deactivating the high-voltage system.

In general, the electrical hazards for the rescue staff resulting from a fire in an electric vehicle can be classified as low, as the HV system is already switched off. Any residual danger can be avoided by maintaining a safe distance during extinguishing (spray jet 1 m, full jet 5 m [13]).

By using a breathing device with an oxygen tank, the emergency services are able to protect themselves from fumes, soot particles and highly toxic hydrofluoric acid. In vehicles with a conventional drive train, the latter is produced exclusively from a fluorinated component of the air-conditioning agent R1234yf. In a battery-powered vehicle, hydrofluoric acid is also produced by the LiPF6, which is used as a conducting salt. When comparing the amount of hydrofluoric acid released in a fire, an electric vehicle differs from a conventional vehicle by a factor of approximately 2 [14]. Since hydrofluoric acid is extremely reactive, it is quickly converted into more stable compounds. For example, the calcium and magnesium ions present in the extinguishing water can react with HF to form solid CaF_2 or MgF_2.

Once the location of the battery is obtained with the help of the rescue datasheet, the battery can be cooled down in a targeted manner in order to prevent thermal propagation. Real life experiences show, that the amount of water necessary to extinguish or deactivate EVs is significantly higher than that of ICEs (800 - 1,000 l [15]) and even reaches volumes up to 11,000 - 20,000 l. However, the goal is not to only extinguish the fire, but rather to cool down the battery to such an extent that the thermal propagation inside can be dampened [13], [16].

Fig. 3: *Actors involved - fire service and police*

Clearing the accident location - police

The tasks of the police is to divert traffic, record accidents and preserve evidence on site. These measures do not diverge between ICEs and EVs.

The corresponding towing company would be informed by police to clear the accident location. In doing so, the information of the drive train will be forwarded to the company. Therefore, the towing company can send a sufficiently qualified employee to the wrecked vehicle.

Towing of the accident vehicle - towing company

A towing company in Bavaria usually has at least one specialist who is trained to work on vehicles with high-voltage systems [17]. Level 1 (DGUV-I 200-005) is recommended in this case, which only provides non-electrical work [7]. Clearing the accident location is an emergency procedure and thus the vehicle does not have to be transported in accordance with the regulations of the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR 2019 [18]). Nevertheless, it is also not exempted from these regulations (1.1.3.1 d of ADR). Therefore, the acci-

dent-damaged vehicle must be considered transportable. In the case of electric vehicles, this is primarily a matter of evaluating the condition of the battery. However, no data from the battery is available at this stage.
To assess the transportability of the vehicle, a thermal imaging camera can be used to detect existing heat sources [19]. However, since the HV battery is installed deep within the vehicle and is protected by the vehicle, the thermal imaging camera mainly captures the heat response of the surface of the vehicle body. The HV battery as the main heat source is therefore concealed. Consequently, the thermal images of such a camera do not provide accurate information about the actual temperature and can therefore only be used as a rough indicator for the condition assessment of the battery.

Quarantine area - Authorized distributor/service partner

After a vehicle fire has been extinguished, the electric car poses the risk of reignition of the fire within the battery, even after a long period of storage. Therefore, it must be placed outdoors [9]. At present, vehicles are taken from the scene of an accident to a quarantine area, which is provided by an authorized distributor/service partner. However, this area can currently only be accessed during the company's business hours. This is an significant problem if an accident occurs outside business hours and the towing company is unable to find a place to leave the damaged vehicle.
Accident-damaged electric/hybrid vehicles, as well as conventional vehicles, must be stored outdoors at a sufficient distance from other vehicles, buildings, flammable objects and materials [13]. Indoor storage of an electric/hybrid vehicle with a damaged high-voltage system is not recommended [20], as the risk of a building fire is considered too high.
A certified electrician evaluates the battery condition on site using the available data [7]. However, depending on the extent of the fire, it may no longer be possible to obtain the technical data of the battery. In the latter case, another assessment method of the battery is necessary.
After a vehicle fire, the transportation of the vehicle will most likely end at a recycling company. This transportation must be carried out in accordance to the rules of the ADR. For example, the special regulations SV 377 of the ADR apply to non-critical battery waste.

Recycling - Recycling company

The last stop of a burnt-out vehicle will be the recycling company, as the vehicle is beyond a state of being brought to a garage for repair. In contrast to an ICE vehicle, the dismantling process includes the removal of the HV battery by a qualified electrician.
In accordance with the EU End-of-Life Vehicles Directive (Directive 2000/53/EC) [21] and the EU Waste Directive (Directive 2008/98/EC) [22], the recycling process of a residual vehicle is carried out in the same way as for ICE vehicles and undergoes a two-stage recycling process in Germany. Even the burnt-out vehicle still contains some recyclable materials such as steel, copper, light and precious

Fig. 4: *Fire brigade hose distributor with valve shut-off*

metals, glass, tires and plastics [23]. The separated HV battery undergoes a special recycling process. Individual modules do not only contain copper and aluminum but also contain rare metals such as manganese, nickel, cobalt and lithium. From environmental and economical point of view, polluting metals should not be released into the environment, instead they can be reused [24]. Hydro or pyro metallurgical processes can partially recover these metals. In Germany, companies such as Duesenfeld GmbH and Accurec Recycling GmbH specialize in recycling lithium-ion batteries [25], [26]. ■

Recommendations for the future handling of electric vehicles

In the following section, recommendations for the parties involved in optimizing the course of action in the case of EVs involved in accidents are provided.

The incoming emergency call (eCall) will be answered by the control center. In future, the dispatcher should be acquainted with the details of the drivetrain in order to pass on this information to the rescue services.

While the rescue operation is ongoing, information about the traction system of the vehicle should be passed on from the fire brigade to the police, who in turn will inform the notified towing company. It would be advantageous if the employee of the towing company which would tow the vehicle would have a level 2 qualification (training as an EFK) according to DGUV-I 200-005 [7]. This qualification would allow the employee to safely shut down electric vehicles of all manufacturers without further instructions and thus assess the condition of the vehicle.

As soon as a transportable condition of the vehicle is established, the accident site can be cleared. Depending on the assessment of the severity of the accident, if required, the fire brigade can support the removal of the vehicle. It is recommended to create at least one central depository per region, which can be reached independent of the automobile manufacturer at any time by the surrounding towing companies. Due to the potential fire hazard, the vehicle should be placed outside and at a sufficient distance from flammable objects [27]. If the police orders the vehicle to be secured, a locked tent should be set up over the vehicle to prevent manipulation by weather influences or third parties. A tent ensures that a fire, which may occur in the case of a delayed onset of an EV fire, can be contained and the fire will thus be less critical as it will not spread to cause a building fire.

Logistically, the logical operation would be to transport a burnt-out vehicle from the scene of the accident directly to the recycling company. Therefore, the recycling company would act as an initial depository, especially in the event of a fire.

If it is possible to read the battery data via the OBD II interface after the fire, the data set shall contain a „minimum data record“ of the condition and history of the battery. The OBD II standard does not provide the relevant battery data for condition assessment in the current situation. As a result, the legislator needs to define the base for a standardized readout of corresponding data. A qualified electrician [7] can use this data to assess the battery condition and thus decide whether the electric vehicle or HV battery can be transported as a hazardous material according to ADR norms.

The reaction chain with respect to EV accidents differs from that of conventional vehicles in various manners. The hereby-elaborated recommendations are intended to ensure smooth cooperation between the parties involved. The implementation of the recommendation is not exclusively subject to the involved parties, it is especially dependent on the adaptation of the guidelines and regulations mentioned. ■

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Mobility of the future with hydrogen technology

Summary

To reach the ambitious climate targets of the United Nations a systematic decarbonization of traffic is indispensable. As most countries focus on eMobility hydrogen technology offers in the long run a resource-saving alternative. By bonding the explosive hydrogen to an organic carrier substance one created a storage possibility and a transport possibility which allows the use of the existing gas station infrastructure in a nearly unchanged way. Also in national as well as international trade with this safely bonded hydrogen, existing structures in form of container ships or railway can be used with this safely bonded Hydrogen. ■

1. Initial position

The transfer to renewable energy use is the core element of climate policy as decided in the treaty of Paris in November 2015. One determined, that in order to reach the 1.5°target, one has to reduce the greenhouse gases to zero between the years 2045 and 2060.

While one succeeded to expand the renewable energies in the past as to production of electricity, the percentage of emission of green house gases in traffic didn't decrease but has even gone up. Thus the traffic sector has the responsibility to make a substantial contribution to reduce the greenhouse gases. This target can be reached by a massive conversion to battery driven vehicles as well as by fuel cell vehicles.

The pressure to work on environmentally friendly mobility does not only come from the Paris climate conference of November 2015 but recently from the decisions of the European Parliament, the European Council and the European commission of December 2018.

Analysis of the hydrogen carrier oil dibenzyltoluene (c) Hydrogenious LOHC Technologies ■

There demand are put on the car manufacturers to reduce their CO_2 emissions massively namely by 15% by the year 2025 and even by 37.5% by the year 2030 respectively measured at the ambitious targets of 2021. In the current discussion about exceeding the nitrogen oxide limits in 90 German cities there is a strong call that within the framework of "mobility of the future" there should be more and more renewable energies applied.

For several years the topic e-mobility has strongly been propulsed by the federal government. As early as 2011 chancellor Angela Merkel demanded that by 2020 there should be one million e-cars on our roads. But in the beginning of the year 2018 there were not more than 100.000 vehicles, which means this target will not be reached.

So chancellor Merkel announced at the handing over of the management report of the national platform e-mobility (NPE) that the aimed target has to be postponed to the year 2022. Though scepticits of e-mobility ask at what mileage e-mobility is economically and ecologically reasonable. One has to take into account, that e-mobility is more economical and ecological, the higher the mileage is.

This fact also corresponds with the support policy "immediate program clean air" of the German federal government. By this the purchase of those electrically driven vehicles is supported, which are more or less all the time on the road such as busses, delivery vehicles and craftsmen vehicles and recently also municipal vehicles.

Unfortunately there is up to now not enough attention given to the use of fuel cell vehicles.

It is obvious that the use of hydrogen could be an ideal link between "Energiewende" on the one hand and "Verkehrswende" on the other hand. ■

2. Using hydrogen as an alternative

Already to date there are times when more electricity is produced than actually needed due to the systematic expansion of wind energy and photovoltaics in Germany.

This is for example the case, when there is intensive sunshine and at the same time a strong wind blowing. In those cases many wind turbines have to be "taken out of the wind", what is economically and ecologically unreasonable. Paradoxically, this fact is not at the expense of the wind turbine owners, because they get full compensation which is financed by the "energy supply law"(Energieeinspeisegesetz EEG) and has to be born by all consumers, thereby meaning increased electricity costs.

It would be more reasonable do produce hydrogen with that surplus electricity which is not needed in the electrical net at that time.

Though hydrogen has the inconvenient characteristic to be an explosive gas. And in fact hydrogen played a prominent, and at the same time tragic role as to the use of zeppelins which were in operation even for transatlantic flights, The skeptic attitude of many people results from a historic accident

Deployment global LOHC-hydrogen Infrastructure in USA (c) Hydrogeniouis LOHC Technologies ■

on March 4th, 1936 in American Lakehurst in the state of New Jersey. The hydrogen filling of the zeppelin LZ 129 "Hindenburg" caught fire and many people on board and numerous employees of the ground crew lost their lives. Up to today, the storage as well as the transport of hydrogen means increased costs. So, even with the latest transport facilities the Linde AG can only transport 1.1 ton of hydrogen under a pressure of 500 bar in a 40 ton truck. ■

3. Erlangens approach to the problem

In this case, a procedure which was developed at the Friedrich-Alexander University of Erlangen-Nuremberg could most likely help. Developed by the professors Wasserscheidt and Arlt this process makes it possible to bond hydrogen by a catalytic way to an organic hydrocarbon (liquid organic hydrogen carrier, L0HC). Togather with a manager of the company Hydrogenious, Daniel Teichmann, the mentioned team managed to get into the "top three" final group of the "future award" of the federal president Frank-Walther Steinmaier in December 2018 in Berlin. Essential element of the LOHC technology is the chemical bonding of hydrogen to an organic carrier liquid named dibenzyltoluene. The loading of the carrier medium is done by hydrogenation which releases heat and produces Perhydrodibenzyltoluene. The unloading of the carrier medium needs the input of heat and is an endothermic reaction in which dibenzytoluene is produced again. What is so interesting about this innovation is the fact, that the carrier substance can be loaded and unloaded continuously in a closed cycle. The hydrogen bonded to the carrier substance can be transported without any problems with conventional tankers and can be transported to the gas stations and stored in the existing gas station infrastructure. Depending on the demand quantity hydrogen can be separated in a reversible catalytic process from the hydrocarbon (L0HC). However at these hydrogen gas station it could be essential to create the possibility of compression of hydrogen gas. The highly compressed hydrogen can then be filled in the already existing gas station within minutes. In contrary to the long loading processes with eMobility the filling process does not take longer than the filling process for combustion engines with diesel or gasoline.

Similar to the use of hydrogen technology for automobiles there is also the possibility to use hydrogen technology for rail transport. So for example at the end of January 2019 the worldwide first by hydrogen driven train demonstrated its "mountain suitability" after beeing on tour in fall 2018 in the flat Elbe-Weser area in regular service. It bears mentioning that this train has a range of 1000 km and a maximum speed of 140 km/h and that the process of filling does not last longer than the filling with diesel. The researchers at the Helmholtz-Institute at the Friedrich-Alexander-University Erlangen-Nuremberg are already working at a further developed technology: In this latest project hydrogen which is bonded at LOHC should be transported on board and should be released on board of the train only. There it delivers the electricity necessary for driving by a fuel cell during driving operation. The Bavarian government decided to support this technology with a large-scale financial support. The directors of the Helmholtz Institute Erlangen-Nuremberg for renewable energy, Prof. Mayrhofer and Prof. Wasserscheid were granted 29 million € which are meant to be used for the research and de-

LOHC circle with StoragePLANT and ReleasePLANT_(c) Hydrogenious LOHC Technologies ■

velopment of highly emission reduced propulsion systems following the example of rail traffic.
The fact that hydrogen technology has also - independent from the topic of mobility - fields off application was shown in 2016 when the first bonded L0HC hydrogen based electricity storage application was cimissioned. This system offers a long-term storage technology but can also be used as a short term store.
The above described technology can be used not only on a national level, but also across borders: hydrogen can be transported to Germany by tanker ships from those countries , where the production of hydrogen is quite inexpensive as for example Norway, which has extreme reserves of water power.
There electricity is extremely cheap and hydrogen can be produced at low costs in an electrolytical process.
Also on the national level the application of this technology can be used to bond hydrogen which is produced is the north German Laender like Schleswig-Holstein, Lower Saxony, Mecklenburg-Vorpommern, and Brandenburg at LOHC and transporting it on goods wagons or on ships on the waterway from the north of Germany to the industrial clusters in the south. Already 20 years ago BMW, for example, applied the hydrogen technology in vehicles and as early as 1996 the city of Erlangen tested a bus with hydrogen propulsion for half a year without any problems in regular service. ■

4. Advantages of this technology

The enormous advantage of this technology is, that it is absolutely emission free and as only steam is produced as a combustion product. In contrast to e-Mobility where enormous financial costs arise for the production of the batteries - especially when extraction of Lithium is necessary - the production of fuel cells is far more affordable and one does not depend on scarce resources such as Lithium. In the light of this these current discussions in Germany have to be looked at in which one considers to establish a battery production with the expenditure of billions of euro. A further advantage of the application of hydrogen technology compared to e-mobility is the mileage of such driven vehicles can cover. As the weight of the transported hydrogen and the fuel cell which is necessary are significantly lighter than of current combustion engines. E-mobility needs a battery weight of nearly half a ton for a mileage of 400 up to 500 km which has to be transported as a “dead load”.
In the discussion about keeping to the nitrogen oxide limits of 40 µg per cubic meter based on the EU guideline 2008/50 EG (air quality guideline) the federal government published the “immediate program clean air” in fall 2017 which runs to nearly €2 billion euro after the 3rd municipal summit of December 3rd 2018.The federal government intends a quick and sustainable reduction of nitrogen dioxide by means of digitization of municipal traffic systems, by electrification of traffic buses, taxis and delivery vehicles as well as retrofitting of diesel buses with this program.
Presumably these measures will not be sufficient to stick to the necessary limits in the 60 affected cities. For this reason it will be essential to further invest in new propulsion technologies and to incite the application of hydrogen technology with appropriate supporting measures. In this context hopes are set on the announcement at the coalition threaty of the coalition parties CDU/CSU and SPD of March 13th. 2018. It literally reads: “we want to continue the national innovation program hydrogen and fuel cell technology. We want to further develop the mobility and fuel strategy (MKS) technology open and increase the funds for its implementation. We want to promote the link between the energy sector and the traffic sector and amend the legal framework so, that “green hydrogen” and hydrogen as a product from industrial processes can be used as fuel or for the production of conventional fuels (e.g. natural gas). It is stated: “ we want to promote E-mobility in Germany (battery electric, hydrogen and fuel cell) and, wherever necessary, raise the funding by the year 2020. ■

5. Summary

These statements in the coalition treaty give rise to hope that hydrogen technology will herald a totally new era of mobility. This era will not only contribute immensely to the compliance with the climate aims of the UN climate conference of Paris of November 2015, but it is also an important contribution to the implementation of the decisions of the European Parliament and the EU commission of December 2018 to reduce CO_2 emissions.
Finally, the use of hydrogen technology makes us independent from the availability of strategic raw materials, as for example Lithium, which is needed in enormous amounts for the production of Lithium-ion-batteries. ■

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