LÜNENDONK

Technical Services for Battery Production in Europe

Operational Excellence for the Automotive Industry

Lünendonk®-White paper 2021

A publication by Lünendonk & Hossenfelder GmbH in cooperation with Leadec

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Content

Foreword

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The transformation of the automotive industry away from the internal combustion engine towards battery electric vehicles is bringing about major changes for companies: On the one hand, legislators are setting the framework conditions, up to and including pending sales bans for combustion engine vehicles. On the other hand, sales figures have only recently started to rise. Europe has now overtaken China in growth rates with battery-powered vehicles. While more than 3.2 million electric vehicles were already newly registered in Europe in 2020, more than 4.6 million new electric vehicles are already expected for 2021, although many end customers are apparently still reluctant. This applies not only to passenger cars, but also to commercial vehicles such as buses and agricultural machinery. Companies are therefore faced with the difficult decision of when to develop battery-electric vehicles and to what extent, as well as converting their value-added processes and thus their production plants. Uncertainty about the market success of competitive technologies such as hydrogen and also the rapidly advancing technical progress in battery technology are challenges whose risk can be reduced with the support of external service providers. There are already many successful examples of this.

Technical Services for Battery Production in Europe
Operational Excellence for the Automotive Industry

External technical services are ubiquitous in manufacturing: Service companies provide production companies with specialist skills, help to manage workload peaks, increase plant availability, take over support processes, and increase their customers' flexibility.

Flexibility in production is particularly important in times of fluctuating demand and rapid technical progress. Specialized industrial service providers assume responsibility for complex process chains on behalf of their clients, from planning and installation to the qualification and operational management of the necessary employees.

Lünendonk & Hossenfelder GmbH has been analyzing B2B service markets since 1983 and focused on the market for industrial services in Germany in particular since 2008. Leadec is one of the leading technical service providers for industries worldwide and is one of the few companies to not only provide non-core business related services, but also take on production logistics and automation services in addition to traditional maintenance.

In this white paper, we look at the role of external service providers in the transformation of the automotive industry towards battery-electric drive systems. After an overview of the central challenges in Part I, these are fleshed out while possible solutions are provided in the subsequent interview.

We hope you will find points of departure for overcoming your challenges in this white paper, and we look forward to sharing them with you!

Christoph Jaschinski

Thomas Ball

Introduction: moving on from combustion engines changes production processes

The automotive industry is moving from the combustion engine to electromobility with great strides. After many years of only a few new models and low sales figures being announced, demand has been rising significantly since the fall of 2020. At short intervals, companies announce the construction of production capacities for electromobility: Volkswagen is building six factories for battery production in Europe.[1] The Volkswagen subsidiary Audi announces that it will no longer develop new combustion engines, but only further develop existing engines.[2]

In Europe, and especially in Germany, new factories for the production of electric vehicles are being built or existing ones are being converted. More and more "giga factories" for the production of cells, modules, and packs are being planned and built in Europe - both by European vehicle manufacturers and by third-party companies. The signal is clear: electromobility has established itself and is here to stay.

Evidently, the automotive industry is undergoing the greatest transformation since the introduction of assembly line production more than 100 years ago. This is having a significant impact, in turn, on the demands on external industrial service providers, who are taking on a wide range of services, from technical services such as production support to quality inspections and maintenance of production machines to inplant logistics.

COME TO STAY: STRATEGIES FOR THE CONVERSION TO BATTERY ELECTRIC VEHICLES OF SELECTED MANUFACTURERS

BMW GROUP	DAIMLER	VOLKSWAGEN
From **the end of 2022**: produce at least one fully electric model in all German plants. By **2030** seven million electrified cars on the roads, two-thirds of them battery-electric, and more than 50 percent of sales from electrified cars.	By **the end of 2030**: reduce the supply of combustion engines by 70 percent. Half of all new cars sold should then be electrically powered. There is currently no communicated exit strategy.	**2030**: E-cars should account for more than 30 percent of the Group's total sales, and at least 40 percent in Europe and China. There is currently no communicated exit strategy. From 2030, all Bentleys sold are to be electric. The company is already launching an electric offensive this year.
Japan's auto industry already decided in 2018 to phase out the internal combustion engine for the year **2050**, with one important exception: hybrid drives. Official plans for an actual phase-out of the internal combustion engine have not yet been announced by the car giant Toyota.	From **2024**, every vehicle from the brand will be offered at least as a hybrid. From **2030** Ford wants to sell only purely electric cars.	By **2025** the group aims to sell one million battery-electric cars, covering ten percent of global demand for electric cars. In Europe, Hyundai produces in the Czech Republic. There is currently no communicated exit strategy.

Fig. 1: Exit strategies from the internal combustion engine of selected car manufacturers producing in Europe. Source: separate compilation

This transformation of the automotive industry has been made possible by technological progress in battery technology. Battery-electric cars and buses are just beginning to make inroads into the mass market, but they are not the only area of application. Modern lawnmowers need a powerful battery just as much as drones, e-bikes, battery storage solutions for the home, large construction, and agricultural machinery - as well the air taxis currently under development.

ELECTROMOBILITY OFF THE ROAD SYSTEM

With its numerous plants and jobs at manufacturer and supplier sites, but also as a taxpayer, the automotive industry is of great importance to European economies. Public attention is therefore particularly high. However, its importance for Europe as a production location, and Germany in particular, goes far beyond this. Vehicles that, in contrast to cars and trucks, usually travel off the highway grid, are also expected to be electrically powered in the medium term. Today, scooters are often battery-powered. In industrial settings and warehousing, forklifts have always been battery-powered, as have the autonomous industrial trucks that have become increasingly widespread in recent years. Concrete mixers and road rollers can also be battery-powered today.

Scooters, Motorcycles	Etergo, Ola Electric Harley Davidson "Livewire" KTM "Freeride E Regent Motorcycles "No.1" Energica (several models on offer) Zero (also several models on offer)
Wheel loader	Kramer: Kramer 5055e Schäffer: Schäffer 23e
Excavator	Liebherr: R 9200E excavator for mining operations. However, the 232-tonne large machine with 850 KW and 1,369 hp is suspended from a cable up to 300 metres long. Liebherr: Type LH 150 C Industry Litronic - Excavator for handling, e.g. in the port. In order to obtain the longest possible range with the electric excavator, a new winding system with roller deflection bend for the electric cable was installed. With this device, the E-excavator can move up to 100 meters away from the "socket." Caterpillar: Swiss company ecovolta supplies the battery.
Road roller	BAM: The conversion from diesel to electric drive was carried out in-house and took approx. 1.5 years. The operating time of the roller with one battery charge is approx. 8 hours. The charging time is given as 3 to 5 hours.
Concrete mixer	Liebherr: Concrete mixer ETM 905
Milling	Wacker Neuson: BC 40 diaphragm wall trencher

BATTERY-POWERED DUMP TRUCKS

Has been in the quarry since 2018 Péry BE from Ciments Vigier an electric dump truck in action. It is powered by a 4.5-ton lithium-ion battery. Because the path of the loaded machine with a total weight of 110 tons runs downwards from the broken edge to the processing and the 590-kilowatt electric motor as a generator delivers more energy to the 4.5-ton battery than the dumper on the way back up with an empty weight of 45 tons consumed, the large dumper is 96 percent self-sufficient in terms of energy. Of the " eMining "-Dumper is supposed to transport over 300,000 tons of rock annually within ten years, saving 1,300 tons of CO_2 and 1 million liters of diesel. Together with the Swiss battery manufacturer Lithium Storage GmbH, Kuhn Switzerland has founded the company " eMining "Founded and sells the electric dumper.[3] Less technically demanding and with greater potential for mass distribution are, for example, tractors for agriculture. With the e100 Vario, Fendt already has a fully battery-electric tractor on offer.

EUROPEAN BATTERY ALLIANCE: INDUSTRY, THE POLITICAL SECTOR, AND RESEARCH EFFORTS PROMOTE BATTERY DEVELOPMENT AND PRODUCTION IN EUROPE

The European nation states and the European Commission recognized the central importance of battery production in Europe years ago. In Germany, there is the Battery Cell Production in Germany initiative; at the European level, the EU Commission, nation states, and industry and science have joined forces in the European Battery Alliance since 2017. In the meantime, more than 500 participants along the entire battery value chain identify as members of the initiative. This is an indicator that the high relevance of the topic for industries as well as countries has been recognized. The investments will have a significant impact on production capacities.

The European Battery Alliance aims to develop and build an innovative, competitive, and sustainable battery value chain in Europe. These are the six focus activities:

- Securing access to raw materials for batteries
- Support for European battery cell production and other investments
- Strengthening industrial leadership through accelerated research and innovation programs
- Securing a highly qualified workforce along the entire value chain
- Supporting a sustainable EU battery cell manufacturing industry
- Ensuring consistency with broader frameworks

Numerous regulations and subsidy programs of the European nation states and the European Commission are currently affecting the cost-benefit calculation for vehicles with combustion engines. With the pricing of carbon emissions, gasoline and diesel will become noticeably more expensive in the coming years. This applies to cars and trucks as well as to all other vehicles previously powered by combustion engines, and thus affects the economic efficiency of dump trucks, concrete mixers, and many other vehicles. The generally higher acquisition costs will be amortized more quickly given the new levy than was previously the case with internal combustion engines. It can be assumed that further regulations will be introduced in the coming years in order to achieve climate protection targets.

If these regulations (ban on the sale of combustion engines, financial incentives for electromobility, etc.) are introduced, they are likely to further increase demand for electrically powered vehicles at the expense of those with combustion engines. This will also increase the demand for battery cells and the assembly steps up to packs, thus requiring additional production facilities.

The production of cells and their assembly into modules and battery packs in Europe is more cost effective than importing them from South America, Africa, or Asia. But safety aspects also influence the choice of production location: if, for example, a battery catches fire in a cargo ship, there is a risk that the entire load and possibly the ship could be lost.[4]

The German Federal Ministry for Economic Affairs and Energy estimates the market potential for automotive batteries produced in Europe at up to 250 billion euros by the mid-2020s. The ministry currently also assumes that the production of battery cells in Germany based on ministry-funded projects will start in 2022, with production on a larger industrial scale expected for the mid-2020s.

By 2030, the ministry expects a tenfold increase in the output of lithium-ion batteries produced in Germany, from an annual output of 200 gigawatt hours today to more than 2,000 gigawatt hours.

ARE LITHIUM-ION BATTERIES JUST A TRANSITIONAL TECHNOLOGY?

The technological progress of research and development for batteries is rapid. Solid-state batteries could become the standard energy storage device in a few years. Unlike lithium-ion batteries they are based on a solid electrolyte and have a higher energy density, are more environmentally friendly, and less hazardous. If the current technological challenges are solved to the point where solid-state batteries are market ready, they could again require different production and assembly processes. At the same time, experts attribute to solid-state batteries the potential to enable new areas of application, such as intermediate storage for renewable energies and much more.

Some carmakers expect to be able to launch models with solid-state batteries from 2025 on. The Chinese start-up Chengdu has announced plans

The next technology step?

Solid-state batteries have a higher energy density, are more environmentally friendly and less dangerous.

to mass-produce and sell a sedan with a solid-state battery and a range of up to 1,000 kilometers from 2022.[5]

FOCUS OF THE WHITE PAPER

Modern factories are organized according to a strict division of labor: materials and components, suppliers and various production processes, as well as logistics must be closely coordinated. A large number of external service providers are involved in the assembly, logistics, and maintenance of production facilities. In the course of the shift in production to a high degree of automation and digitalization, the requirements are changing not only for the production process, but also for the service providers involved.

This white paper presents the essential requirements for external technical service providers involved in the production of components and vehicles with high-voltage batteries. In particular, the effects of technical progress, the economic cycle of high-voltage batteries, the changed requirements for employees, and the quality requirements are addressed. The paper is designed as a position paper that may serve as an orientation for companies and observers for a more in-depth examination of the topic.

Battery production in Germany and Europe: an overview

The conversion of factories and the build-up of battery production capacities are in full swing. Tesla is known to be one of the pioneers in this field, but German manufacturers are also in the process of conversion. To date, most vehicle manufacturers have limited themselves to battery pack assembly. Most cell production sites are located in Southeast Asia. In Europe, and Germany in particular, numerous production facilities are currently being planned, built, and commissioned along the entire value chain of batteries for cars.

VALUE-ADDED STEPS IN BATTERY PRODUCTION

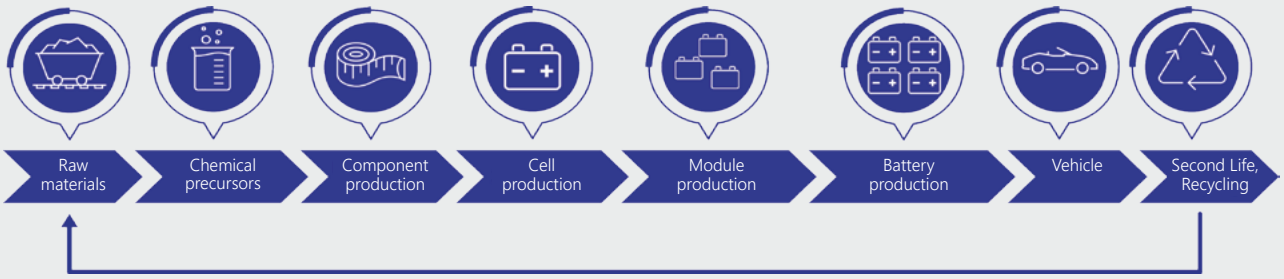


Fig. 2: Value-added steps in battery production, Illustration according to: National Platform for the Future of Mobility, 1st Interim Report on Value Creation

The boom in battery-electric mobility is having an impact on value chains and is also generating increased demand at numerous other companies, encouraging efforts to establish and convert production capacities, and creating a need for external services such as maintenance, among other things.

Along the battery manufacturing value chain, production machines are required that are also built by European manufacturers, including Dürr, Grob, Manz, and Trumpf. Europe is also becoming an important manufacturing location for Chinese mechanical engineering companies.

Every battery cell is based on chemical process technology for the production of anodes, cathodes, and electrolytes, for example. The starting materials are produced both by established European manufacturers, who are building up production capacities for this purpose, and in particular by Southeast Asian companies, which are setting up new plants in Europe.

In cell production, too, established European vehicle manufacturers are building up their own capacities — either in-house or in cooperation with partners — on the one hand, and cell production plants are being set up by Southeast Asian companies that are establishing themselves in Europe on the other.

The assembly of cells into modules and modules into finished battery packs usually takes place in close coordination with or in the vehicle manufacturers' own facilities. The various vehicle manufacturers are pursuing different strategies here: BMW and VW are building new halls in existing plants, others are converting existing component plants or building completely new plants for the assembly of battery cells into modules and packs.

COMPONENTS AND MANUFACTURING DIFFERENCES OF AUTOMOTIVE BATTERIES

Batteries for electromobility are produced in different manufacturing steps. Comprehensive quality tests are carried out at all levels of the production steps. The individual steps usually take place in different plants.

Battery cells

The first production step is the largely automated manufacture of battery cells, which in simplified form consist of anodes, cathodes, separators, and electrolyte. Chemicals are only processed during cell production. Battery cells are currently manufactured either as pouch cells, round cells, or prismatic cells.

Modules

Modules consist of several cells. Depending on the cell technology used, sufficient space must be provided for the expansion of the cells (pouch) and the cooling of the cells must be ensured. The cells must be mounted in a frame and interconnected. Before assembly, they are checked for quality, cleaned or activated, and then mounted in the frames or glued together. The modules are then insulated with heat-dissipating foils, which also interrupt the flow of current to neighboring modules and thus act as fire protection. The boards of the battery management system are then connected and mounted. Before several modules are assembled into a pack, cables are attached, and the module is sealed via cover plates.

Battery packs

Several modules are assembled in a tub to form a battery pack. Before the modules are assembled, cooling plates for operation and a heater for winter use are mounted in the tub. The cell modules are fixed in the frame and interconnected. At the pack level, the modules are controlled by a central high-voltage module, the battery management system master, and the central cooling module. Only suitably qualified personnel are permitted to assemble the high-voltage connection. The pack must then be prepared and sealed for installation in the vehicle. Before mounting, the desired uniform charge level must be established and the respective current battery management software must be loaded.[6]

CELL PLANTS PLANNED AND UNDER CONSTRUCTION

The battery modules for cars are large and bulky. As a rule, they weigh several hundred kilos per vehicle. That makes global supply chains difficult to operate. In addition to the existing factories in Poland, Hungary, and Scandinavia, numerous battery factories are being built near the manufacturing plants. There are no indications that production sites in Germany or in Europe in general will be relocated to Asia, the US, or South America in the course of the transformation of the automotive industry in the near

future. On the contrary: Tesla has decided to serve the European market from Grünheide near Berlin and is building its own battery cell production plant there in addition to a vehicle assembly plant.

At the beginning of March, the German daily newspaper FAZ reported on 22 large factories for the production of battery cells currently planned in Europe, some of which are already under construction. This would create around 100,000 new jobs by 2030. The most important location within Europe is Germany with its high density of vehicle manufacturers.[7]

BATTERY FACTORIES IN EUROPE: 22 GIGAFACTORIES WITH UP TO 460 GWH PLANNED BY 2025

Fig. 3: Planned battery cell manufacturing plants in Europe, Source: Transport & Environment, p. 16

However, it is not only European companies that want to catch up in terms of manufacturing capacity, especially compared to Southeast Asia, but also Asian companies such as CATL, LG Chem, Samsung, or SVolt are building production capacity in Europe.

Various battery cell manufacturers are currently planning and building production capacities in Germany and neighboring European countries. As of March 2021, 24 locations for battery cell production in Europe were concretely planned or in operation. Regional focal points in Germany are emerging in Berlin-Brandenburg, the Wolfsburg-Hanover region, and in the southwest (Kaiserslautern/Stuttgart); Hungary is another focal point. In operation at the time were a Customcells manufacturing facility in Itzehoe, a Varta factory in Ellwangen, and one run by EAS in Nordhausen. Four companies are planning to start up a production facility in 2022.

BATTERY PROJECTS: MARCH 2021

Fig. 4: Overview of factories for the production of battery cells in Europe that are currently planned or under construction. Own representation according to Source: https://battery-news.de/index.php/2021/03/12/batterieprojekte-europa-maerz-2021/ (retrieved 03/18/2021)

Operators have different reasons for their choice of location and regional clusters. Among the most publicly cited are the following:

- Existing infrastructures (motorways, railway connections) to ensure the delivery of raw materials and shipment of manufactured components
- Proximity to existing plants (including VW Salzgitter, PSA Kaiserslautern)
- Proximity to assembly plants (especially for Southeast Asian third-party manufacturers)
- Adequate availability of skilled workforce
- Availability of land for very large factory buildings
- Availability of renewable electricity

OUTLOOK

The production of battery cells, modules, and packs remains highly dynamic due to the rapid pace of technological development. If the emerging solid-state battery cells are here to stay, production processes will be changed in the coming years. This will impact factories, market players, and processes. As recently as 2020, several vehicle manufacturers have publicly announced that they will not enter their own cell production until solid-state cells are ready for the market. This is at least an indication that a second boom in the development of manufacturing capacities is to be expected in the coming years.

High-voltage batteries change production requirements in the factory

The production of battery cells is largely automated today. However, in contrast to the assembly of the cells into modules and packs, it is essentially based on chemical process engineering. The production of high-voltage batteries and their assembly into vehicles differ greatly from the assembly of vehicles with combustion engines. This requires new production processes and quality assurance measures, which many manufacturers are using to completely renew production.

ELECTRIC VEHICLE PRODUCTION — THE EXAMPLE OF THE PORSCHE TAYCAN

Porsche has built a completely new factory in Leipzig for the Taycan Turbo model on its existing site. Production takes place over three floors using elevators. Autonomous, driverless transportation systems replace the traditional assembly line. Battery-powered autonomous robots move the vehicle in production along the assembly stations and transport the components required for the respective steps just in time. They are guided by QR code strips on the floor.

The driverless transport systems are connected to the logistics software via Wi-Fi and partly also to the assembly platform. The body is glued, welded, and bolted fully autonomously by the robots and then inspected. Painting is also carried out by robots.

The powertrain is manufactured on a pre-assembly line and consists of electric motors in the rear and front, the battery, and the axles. The battery pack consists of 396 cells, which together weigh 650 kilograms. The high-voltage components have to be connected after the battery has been inserted.

Production is networked to the greatest possible extent: an electronic car escort card enables communication between the factory, the vehicle, and the employees and releases the equipment features selected by the end customer in the system. For Porsche, this means significantly greater flexibility in the event of subsequent changes to production processes and in the manufacture of new models.

Assembly

Battery modules and packs are heavy, sensitive to impact and must be sealed against foreign objects.

BATTERY MOUNTING REQUIREMENTS

There are a number of aspects to consider when mounting the battery modules and packs: The components are very sensitive to impact. To avoid short circuits, a high level of cleanliness must also be ensured, and the battery housing must be precisely sealed against external influences such as water and dust. To provide the necessary power for the vehicle, the DC voltage is up to 1,000 volts. Vehicles with combustion engines are usually designed with a safe on-board voltage of just 48 volts.

THE UN-TEST 38.3

For a lithium battery (cell) to be transported from A to B at all, it must have successfully passed UN test 38.3. Most logistics service providers now require proof of this. This is to ensure a minimum safety standard.

In the series of examinations that make up UN Test 38.3, eight different tests are carried out to simulate conditions which occur as loads during regular carriage or which must be avoided in order to prevent damage. This includes checking short-circuit protection as well as pressure differences, temperature differences, and also mechanical loads. If all these tests are passed successfully, the manufacturer receives the certificate for exactly this type (battery/cell/assembly). Many people are not aware that the test has to be repeated in the event of reconfiguration - even if it is only changes to the control electronics.

In principle, therefore, the following applies: Lithium batteries may only be transported with proof of a successfully completed UN test 38.3. Exceptions are only made for prototypes and pre-production series or with special official approval.
https://www.sifa-sibe.de/sicherheit/gefaehrdungsbeurteilung/sicherer-umgang-mit-lithiumbatterien/

Errors during installation by insufficiently qualified employees can have serious consequences: If a battery is not mounted correctly, it can be damaged while driving and catch fire or explode. If the employees involved in production are not in a position to assess the necessary electrotechnical work, identify possible hazards, and consistently comply with suitable protective measures, there is a risk of occupational accidents with serious health consequences. For this reason, there are obligations to ensure that employees involved in production are adequately qualified, which go well beyond the requirements for the production of vehicles with internal combustion engines only. The three-level model described below describes the necessary qualifications for all employees involved in the production of high-voltage environments.

EMERGENCY CONCEPTS

In view of the high risk potential, a comprehensive emergency concept is necessary when high-voltage batteries are produced, moved, stored, and assembled. The concept must take into account all conceivable risks and define processes in order to exclude hazards for employees or reduce them as far as possible. It must include the following components:

- Risk analysis
- Binding work instructions and documentation of processes and concepts
- Consideration of possible production errors by man and machine at all stages

In the event of an accident, employees of the company and external service providers must take predefined actions to prevent an acute hazard or a hazard that may occur later. This includes informing all necessary agencies such as the plant fire brigade and medical personnel.[8]

Due to the special hazard situation, special emergency concepts are necessary for high-voltage batteries that are adapted to the uncontrolled heating of the cells and, for example, use water immersion baths as a fire protection measure. Structural safety measures and appropriate employee training are also required in storage, among other areas.

EMPLOYEE QUALIFICATIONS

With the conversion of production, requirements are also changing for employees. McKinsey write in their "Boost" study that the skills profile for automotive powertrains will shift from mechanics to me-chem-tronics, i.e., it will expand to include chemical skills. McKinsey expects that by 2030 the proportion of employees in traditional mechanical jobs will fall from 80 to 60 percent worldwide. According to McKinsey, the remaining 40 percent will be accounted for by electronics engineers and chemists.

Although in all likelihood significantly fewer employees will be needed overall, the requirements will increase due to the greater complexity. Depending on the area of application, knowledge of different machines and production processes and the resulting sources of danger is an important prerequisite.

Specializations and corresponding training programs in the automotive industry have therefore already changed in recent years in light of increasing automation, the transformation to battery-electric mobility, and the steadily increasing proportion of electronic components, particularly in car and truck production. Both in powertrain production and in assembly plants, there has been a shift from purely metal occupations to mechatronic occupations such as (automotive) mechatronics technician and industrial electrical occupations such as electronics technician for automation, machine, and drive technology and so on.

THE THREE-STAGE MODEL FOR WORKING ON HIGH-VOLTAGE SYSTEMS

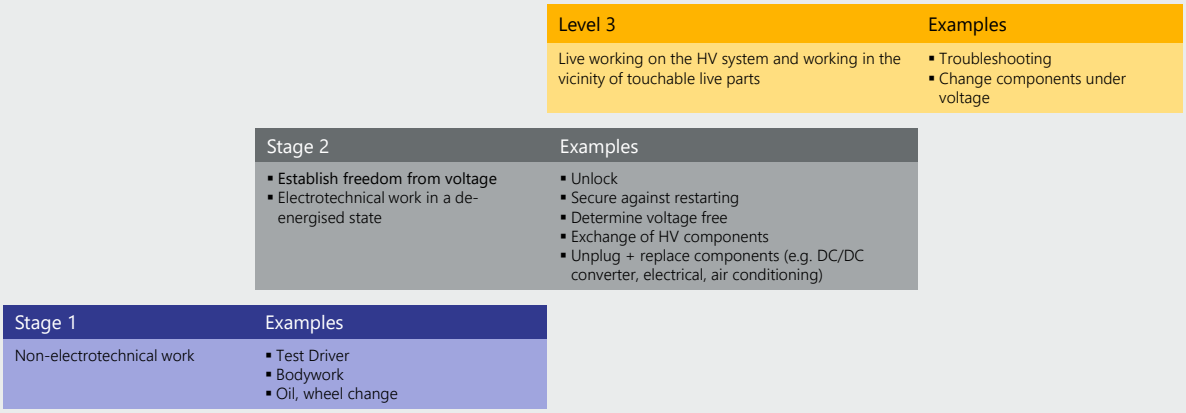


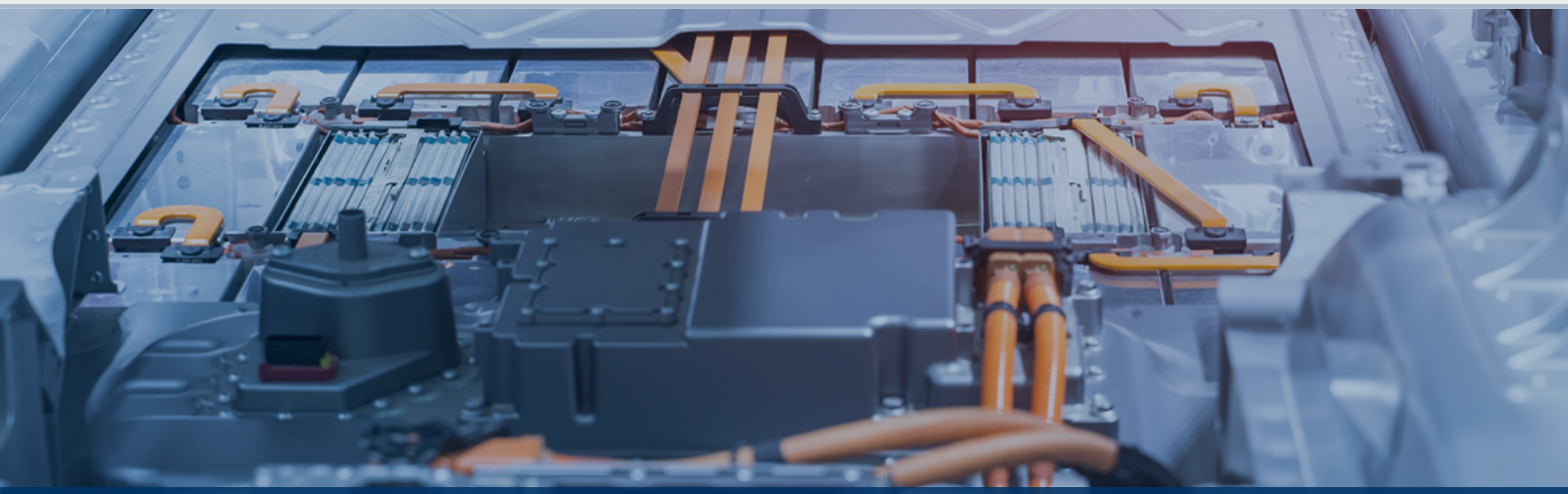
Fig. 5: Employees working at level 1 require at least one training class on possible hazards. For levels 2 and 3 At least proven technical knowledge or a qualification for live working is required. Source: DGUV Information 8686, April 2012.

Persons who carry out work on vehicles with high-voltage systems and their components must provide evidence of a qualification comprising several training units, depending on their previous training. The responsibility for this lies with the company but can also extend to commissioned service providers.

STANDARDS AND GUIDELINES FOR ELECTROTECHNICAL WORK

The technical requirements for persons carrying out electrotechnical work are specified in various regulations and VDE provisions, in particular the following:

- Occupational Health and Safety Act
- Accident prevention regulation "Electrical installations and equipment" (BGV/GUV-V A3)
- DIN VDE 0105-100 "Operation of electrical installations“
- DIN VDE 1000-10 "Requirements for people working in the field of electrical engineering"



Technical services for battery production and assembly

Battery technology currently accounts for the largest share of value creation in electric vehicles, at around 40 percent. In all likelihood, electromobility will only be able to establish itself if the costs of batteries fall significantly.

In 2020, the costs per kilowatt hour of storage capacity averaged around 160 US dollars, according to an analysis by the Fraunhofer Institute. For the cheapest manufacturers, they were around 90 dollars. By 2030, Fraunhofer expects costs to drop to 80 to 60 percent compared to 2020 due to technical progress, industrialization, and experience. With increasing technological maturity and higher unit numbers, costs for variables that cannot be influenced by external service providers will decrease. Among these are depreciation on equipment that is in operation for longer, raw material prices, and the cost of research and development. Optimized production processes and, if necessary, the outsourcing of partial services offer additional savings potential in terms of costs for maintenance, warranty services, and production scrap. Costs for cell production, but also the costs along the entire value chain up to the assembly of the battery packs into the vehicles, are expected to decrease.

COST STRUCTURE OF BATTERY CELLS IN DOLLARS PER KILOWATT HOUR OF STORAGE CAPACITY MINIMUM AND AVERAGE

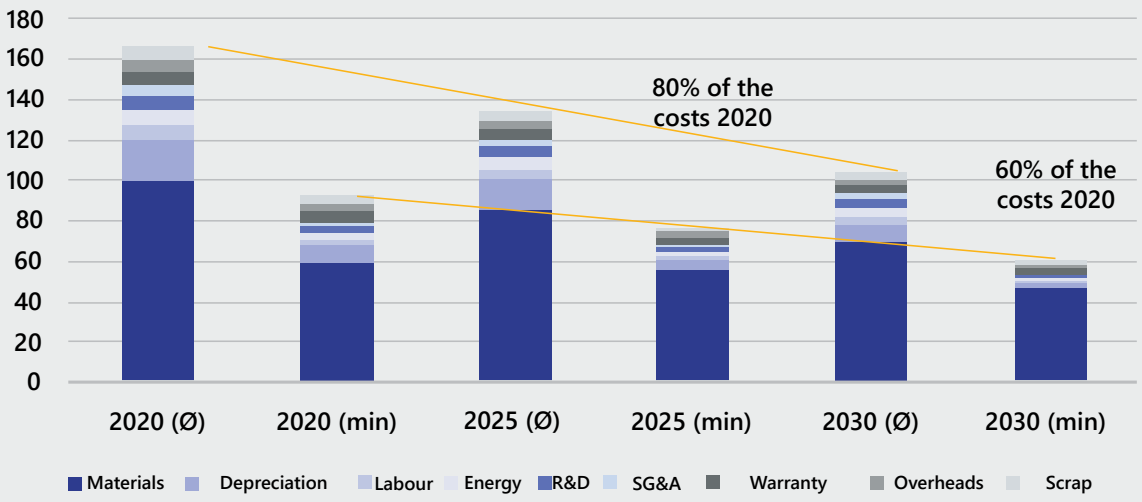


Fig. 6: Forecast battery cell cost structure in dollars per kWh, source: Fraunhofer ISI

In the competition between manufacturers, the technological lead is currently of great importance. External service providers for the maintenance of production machines or even for battery assembly must therefore not only have the comparatively new and thus demanding technological expertise, but also meet the highest requirements for occupational safety, production quality, and protection against industrial espionage.

External service providers traditionally undertake a wide range of production-related services in the automotive industry, including the following:

- Planning of production lines and manufacturing processes including quality assurance
- Contract manufacturing from partial components to complete batteries
- Assembly of the individual battery components up to the assembly of the complete battery system in the vehicles
- Quality assurance measures in production through analyses, tests and, if necessary, rework

- Maintenance of production facilities including maintenance analysis and process optimization
- Planning and implementation of supporting processes such as safety/hazard concepts, logistics, storage, and recycling of production rejects
- Planning, construction, operation, and maintenance of charging station concepts

A company's make-or-buy strategy is usually influenced by a variety of factors, which include the company's own technical expertise, the available resources, the importance of the batteries for the vehicle to be manufactured, as well as the planned number of units. Companies with their own research and development capability, which have a technological lead over competitors and produce and sell large numbers of units, may be more likely to rely on in-house production than suppliers of special vehicles with low unit numbers. The latter must assume that in-house research and development would lead to significantly higher prices than if they purchased the corresponding services on the external market.

Not to be underestimated, especially for companies that are not yet represented in Germany and other European countries and want to build up cell production capacities, are the applicable legal conditions and the numerous regulations that have to be observed, for example:

- Required employee qualifications
- Documentation requirements
- Labor law, including co-determination and information duties
- Personnel recruitment
- Insurances
- Import and export regulations
- Depending on the country, funding programs from the EU, national states, regions, and municipalities

Involving service providers with experience in the local markets reduces the time between the planning of the plant and the start of operations by incorporating regulations to be observed and country-specific experience at an early stage. In view of the highly dynamic market, the so-called time-to-market is crucial for success.

In order to keep the administrative effort and the legal risks low at the same time, it can make sense to contract out support services close to and far from the core business to external service providers. Particularly in the start-up phase, manufacturing companies reduce their economic risk in this way: If demand does not develop as planned, the contract with external partners is not extended or is extended only with altered terms.

EXPECTED INVESTMENTS IN PRODUCTION FACILITIES

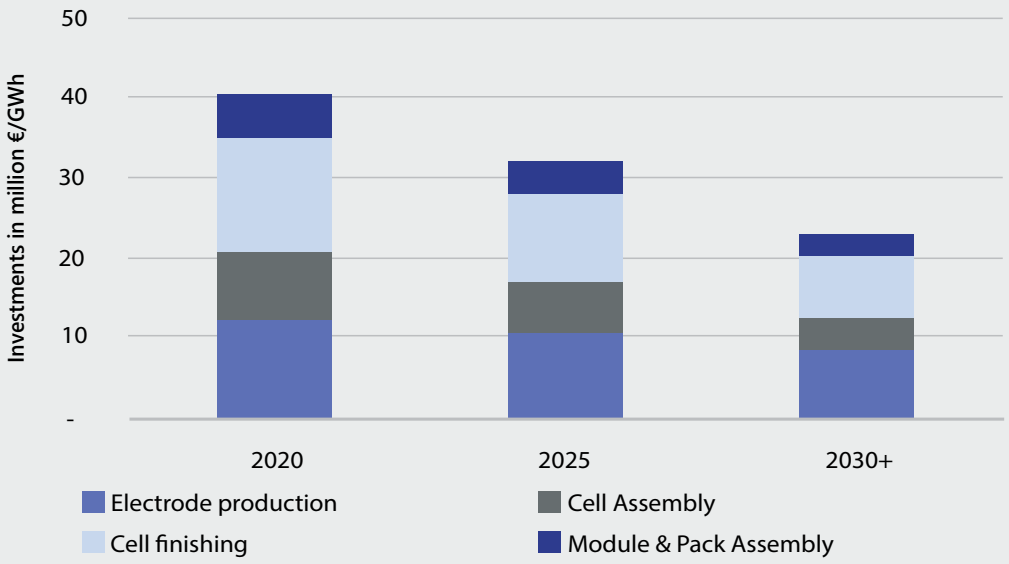


Fig. 7: Investments in production facilities in € million / GWh, Source: Fraunhofer ISI

THE SPECIAL IMPORTANCE OF QUALITY MANAGEMENT

Compared to vehicles with combustion engines, battery-electric vehicles are expensive to produce. The comparatively high retail price is a major reason why market penetration is currently still low. Lithium-ion batteries are the main price drivers. Lower production costs can increase acceptance in the market.

As with all new technologies, there is still a lack of experience in cell production and assembly into modules and battery packs. Not all processes are yet fully industrialized. This lack of experience and the missing process adjustments must be compensated for by comprehensive quality management, especially in view of the hazard potential and the high costs for recalls and exchange/replacement of low-quality batteries.

In view of the successive production steps, cost effective battery production is only possible if faults are detected at an early stage and the faulty components are sorted out. This reduces material waste and costs.

As an example, common production errors occur in chemical production due to deviations in surface dimensions, edge protrusions, positioning errors, or foreign particles. Components such as controllers, cooling elements, or cables are also sources of error. In addition to cooling failure, leaks are a hazard that must be taken seriously. Inferior parts can also be detected and sorted out by camera technology in the production of intermediate products such as electrode manufacturing.[9] These quality assurance measures are now regularly performed by external service providers.

Quality

Quality management is essential for economical production when there is a potential high risk and expensive components

REQUIREMENTS FOR EXTERNAL SERVICE PROVIDERS

External service providers are active in a wide variety of functions along the electromobility value chain. This includes plant planning as well as contract manufacturing, assembly, and maintenance. In view of the high sensitivity of the components of battery-electric powertrains, a high quality of work must be demonstrated and documented. This is difficult to achieve without (highly) qualified employees. It is not enough to recruit employees once; fluctuations must be compensated for regularly. At the same time, the service provider must keep up with the rapid changes in the market and technological developments. Therefore, it is not enough to reach the technical state of the art once; regular and detailed market observation as well as continuous further development of personal competencies are imperative.

The requirements profile for external service providers varies depending on whether they are integrated into existing production processes (brownfield) or directly involved in the construction of the plant (greenfield). In the greenfield, external service companies can contribute experience and support their customers in planning as well as in setting up sub-processes. This is particularly relevant when foreign companies have to implement the specifications and local requirements quickly and in a legally compliant manner.

External technical services reduce transformation risks

Uncertainties regarding the market potential and sales of battery electric vehicles, as well as the rapidly advancing technical development, particularly in battery technology and the associated manufacturing processes, make it difficult to plan in an economically reliable manner and thus to invest and build up development and production capacities. In these times, companies need a high degree of flexibility in order to be able to react quickly to changes.

It is not only the large and well-known automotive groups that rely on external service providers for many processes and services in view of the investment risk. This increases flexibility in the event of a change in demand due to changes in purchase quantities. Costly negotiations with social partners and financial risks can thus be significantly reduced.

EXTERNAL SERVICES OFFER FLEXIBILITY

External industrial service providers are essential for Germany as an industrial hub. The companies provide a wide range of services: from site services such as plant security, maintenance of green areas, and plant fire brigades, to technical cleaning, maintenance of production facilities, engineering and improvement, logistics, and the taking over of component production, quality assurance, and pre-assembly.

Technical service providers act as a flexibility instrument by providing contractually defined services for a limited period of time. At the end of the term, it is comparatively easy to adjust to changes in plant utilization. External service providers cover performance peaks and provide competencies that are rarely needed. They also provide specialized services that go beyond the client's core business. They bring in process know-how and contribute to an economical production in which the client concentrates on their core business.

Especially in times of demographic change and a shortage of skilled workers, external companies are indispensable for many clients. Employee recruitment as well as training and further education becomes more costly with fewer applicants and a possibly declining applicant quality. The client's HR department concentrates its resources on those employees who are most relevant to the core business: research and development, IT, dales, plant and production Management, administration, and managers and specialists. The outsourcing of supporting processes also means reducing expenses for personnel recruitment, qualification, and administration. If different qualifications are required at the end of the contract with the external service provider due to a different production policy or technological development, the social obligations and thus the cost risk for the client are eliminated.

Technical service companies provide added value for industrial companies in many situations in terms of expertise, experience, and cost-effectiveness. They are often also willing and able to support them in the complete set-up of production capacities: from planning, to the construction and monitoring of production lines, to pre-assembly and assembly on the vehicle.

The core competence of many industrial service providers is the economic maintenance of production facilities. In the early stages of technical product development and industrial production there is a lack of experience, which leads to higher initial maintenance expenses. Reducing these with the support of external service providers, who have different cost structures than the plant manufacturers and the operator's personnel, is a key task to reduce production costs in general.

This white paper has addressed the key challenges posed by the transformation of vehicle manufacturing towards high-voltage battery drives, insofar as they are relevant for cooperating with external service providers. The high level of complexity and the potential for danger are a major challenge, especially for companies whose core business is not the research and production of batteries; this applies in particular to storage, logistics, production, and assembly for production lines with different models and low volumes. For these companies and others, cooperation with experienced and highly competent external service providers is often a sensible option in terms of content and economics. If, in addition, sub-processes are outsourced to external service providers over a fixed term and the service provider assumes initial investments that are refinanced over the term of the contract through regular remuneration for the provision of services, this supports the often desired strategy of shifting the necessary capital expenditure (CapEx) in favor of expenditure on business operations (OpEx), thus shortening the period between expenditure and income.

The outsourcing of partial services reduces the administrative effort and the economic risk.

Interview: the added value of services in the battery manufacturing ecosystem

Thomas Ball
Lünendonk & Hossenfelder

Dr. Christoph Jaschinski
Leadec

Thomas Ball, Partner Lünendonk & Hossenfelder GmbH:

Dr. Jaschinski: Lithium-ion battery, fuel cell or biogas - which is the technology of the future?

Dr. Christoph Jaschinski, Head of Global Business Development, Leadec Group:

"Batteries, especially optimized lithium-ion batteries, are now seen worldwide as a key technology for electric vehicles. Many manufacturers and suppliers are also experimenting with other fuels and drive technologies, such as hydrogen in combination with fuel cells or synthetic fuels. But it is becoming clear that, at least in the medium term, the focus for passenger cars will be on vehicles with lithium-ion batteries. By 2030, for example, more than 4.5 million electric vehicles are expected to be produced annually in Germany alone. Recent estimates suggest that over 4.6 million battery-powered vehicles will be sold in Europe as early as this year. This growing demand continues to pose major challenges for the industry. It

starts with the planning and ramp-up of new plants, continues with the transformation of existing plants, on to efficient and cost-effective service models and ends with the supply chain. This is where specialized technical service specialists are needed - with expertise in all aspects of modern factory organization.

Lünendonk: What does such a service specialist have to bring along?

The requirements differ depending on the stage of the value chain. In the case of vehicle assembly, i.e., the "marriage" of battery and the car body, it is primarily a matter of implementation know-how or planning and operating expertise for the complete intralogistics of the electric vehicle batteries. The situation is different for battery pack assembly plants. Here, special planning competencies are needed in assembly technology, automation, and analysis methods, but also in quality assurance and control. The actual production of battery cells is particularly demanding. Europe lacks process knowledge in this area, and manufacturing technologies are still changing very rapidly. For example, the industry demands knowledge about smart factory analytics, agile working or plant technologies that can often only be developed together with plant manufacturers.

In addition, however, competencies that are generally common in the automotive industry today are also required: operational excellence, special knowledge of production systems, and the management of ancillary processes in global automotive production. This ranges from factory planning, installation, factory automation, operation, and maintenance to facility management and inplant supply logistics. Thanks to our range of services and many years of cooperation with leading automotive manufacturers and suppliers, both in vehicle assembly and in component plants, Leadec is involved at an early stage in special issues relating to the production of battery-powered vehicles.

Our declared goal is to prove ourselves as the leading technical service specialist for factories assembling batteries and manufacturing electric vehicles. Regardless of the manufacturer, our services can cover the various phases of the value chain from the battery cell, to the battery pack system, to the final assembly of a battery-powered vehicle.

What experience does Leadec have?

We have references for testing and in large-scale production through projects in Germany, Poland, and the US. They have shown that manufacturers are primarily interested in technical services. Engineering, maintenance of new assembly lines, services for pre-assembly, and supply logistics are at the top of the list. One example:

Among others, Leadec cooperates with a subsidiary of Daimler AG. Sophisticated lithium-ion batteries for plug-in hybrids or all-electric vehicles are built in Kamenz near Dresden. Within a few months, Leadec planned and implemented a service model for the pre-assembly of different battery pack cases here at its own site outside the factory premises. The innovative supply concept includes just-in-sequence delivery as well as empties and quality management. The customer was able to concentrate entirely on setting up its assembly lines for the electric vehicle batteries. We took over the upstream component assembly and were thus able to make an important contribution to shortening the time to market.

At the same location, we are responsible for the maintenance work in the battery assembly line. At a second plant, we were able to contribute our experience already during construction. The two orders for battery line maintenance activities are the first of their kind in Europe to be taken on by a technical service specialist. Today, we are already looking after eight battery lines.

How does the plant management benefit from the cooperation with industrial service specialist?

Increasingly, new plants for battery cell production are being built, more and more also in Western Europe, both by Asian and American manufacturers and more and more by European companies. And they have clear criteria: sustainability in the supply chain, proximity to vehicle assembly plants, carbon neutral production, access to qualified personnel, knowledge of local legislation, and a fast ramp-up curve. Many of these companies are new to countries such as Germany or France. They then not only have to set up production facilities in a short time, but also train 1,000 to 2,000 employees and introduce manufacturing and testing processes. Time to market is everything! Experienced industrial service specialists such as

Leadec, who already have their own systems and tools for setting up technical service units in greenfield plants, take on many of the tasks.

And what does outsourcing mean on the cost side?

Today, the media often still focus on topics such as fast-charging capability, energy density, and range. In order to further increase the demand for battery-powered vehicles, the vehicle costs and thus, above all, the production costs of electric vehicle batteries are coming under pressure. This is where automation and maintenance come into focus. It is true that material and equipment costs account for the largest share of the manufacturing costs of a battery cell, about 70 - 80 percent in combination. However, this proportion will continue to fall significantly over the next few years due to the further development of materials technologies, irrespective of the location of the plant. Significant cost components will then remain in the shape of wage and maintenance costs. Innovative automation solutions and maintenance concepts for the new manufacturing and

PRODUCTION PROCESS OF ELECTRIC CARS

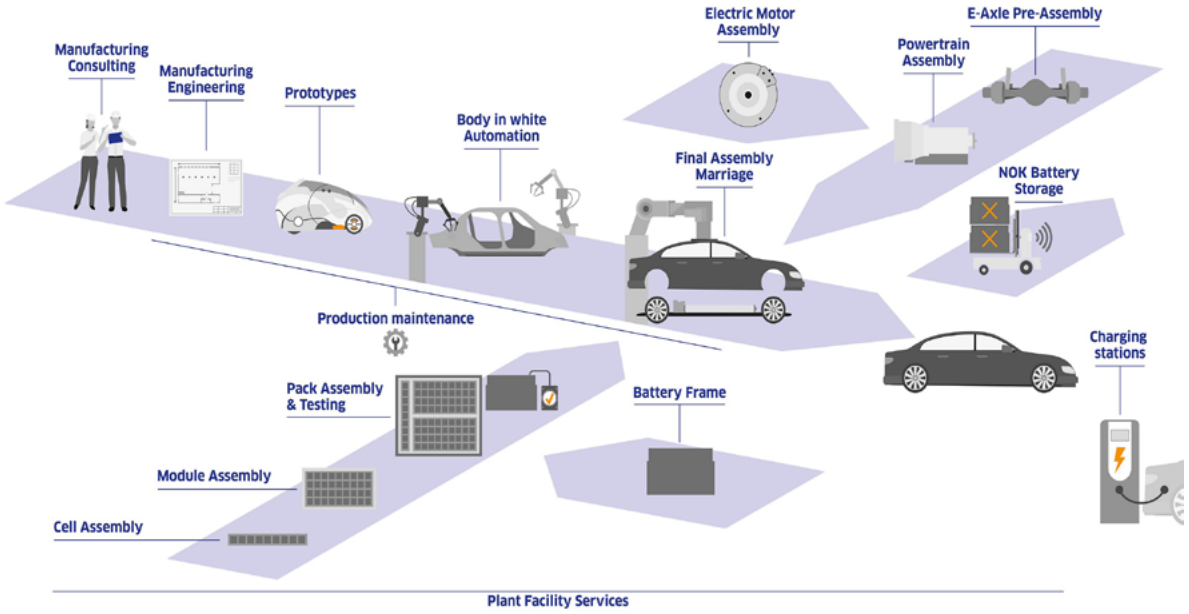


Fig. 8: Production process for electric vehicles, source: Leadec

assembly technologies, such as the use of smart factory analytics, should significantly improve the competitiveness of European battery cell plants.

Which skills are currently in particular demand at your company?

Most of our current projects entail series planning of assembly processes, the planning and implementation of special fire protection and emergency concepts, and quality assurance activities. The latter relate to the module delivery area, the individual assembly steps as part of corrosion protection, the professional discharge or the removal of NOK battery systems from the plant.

For the past two years, competencies in the supply logistics of the plants with battery systems and drive components have also become increasingly important. Today, specialized industrial service providers are already taking over inbound logistics, layout planning and operation of the actual battery warehouse, pre-assembly of components, and outbound logistics to the actual battery production. And all this in a demanding high-voltage environment. That is why we rely on specific training concepts for employees, both at management and shop floor level.

How do you see the future of Europe as a battery production location?

In battery cell production, Asian companies with their Asian production facilities have so far been much further ahead in the industrialization of manufacturing technologies. However, it is now becoming apparent that the geographical proximity to the automobile manufacturers' European production plants is increasingly outweighing possible disadvantages in production efficiency.

In the past year in particular, the political discussion about Western Europe as battery production location, especially Germany and France, has once again become much more intense. Initially, Asian manufacturers had announced that they would build new capacities for battery cell production in Europe. In the meantime, European and American companies have also begun to build new plants in Europe. New battery cell production capacities of over 250 GW h/a are expected by 2025 alone, and this figure is expected to more than double by 2030. At the same time, European chemical companies are building capacity in Germany. There is a lot going on.

However, none of this will work without skilled workers. In addition to the enormous financial and technical challenges, not only for the companies but also for the state, it will therefore be essential for Germany in the coming years to get people excited about these new opportunities in automotive production and to quickly qualify them for the new challenges.

Is the golden age of industrial services dawning?

Indeed, industrial service specialists like Leadec now have a special opportunity to contribute their experience from the various waves of automotive production development and support the transformation process. Industrial service will continue to professionalize. With the new manufacturing, assembly, and testing technologies, the trend towards smart manufacturing and thus also smart services will continue to intensify, especially in the production of battery cells and modules. Our strategy of an integrated technical service chain from engineering to automation, from production maintenance to production logistics, and facility management now gives us advantages in offering our customers special solutions for a fast time to market. Leadec considers itself to be in an excellent position to deliver on this count.

COMPANY PROFILES

Leadec

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ABOUT THE LEADEC GROUP

Leadec is the leading global service specialist for factories across their entire life cycle and related infrastructure. The company, which is headquartered in Stuttgart, employs about 18,000 people worldwide. In 2020 Leadec earned sales of around EUR 830 million. For almost 60 years, Leadec has been supporting its customers along the entire production supply chain. The service provider is based at more than 300 sites, often directly at the customers' plants and facilities.

Leadec's global services comprise: Engineer (Production Planning & Optimization, Automation and Production IT), Install (Electrical Installation, Mechanical Installation and Relocation), Maintain (Production Equipment Maintenance and Technical Cleaning), Support (Technical Facility Management, Infrastructural Facility Management and Logistics) as well as other local services. Customers include companies from the manufacturing industries such as automotive, aerospace and consumer goods.

In the area of digitalization, Leadec is a pioneer in its market environment.

The Leadec.os digital business platform is used to record all processes end-to-end and integrate further digital services. This allows transparent planning and provision of all services as well as their seamless integration into the customer's systems and reveals optimization potential in the factory. The data obtained forms the basis for further transformational processes within and related to production towards the "factory of the future."

Lünendonk & Hossenfelder GmbH

LÜNENDONK

Lünendonk & Hossenfelder, based in Mindelheim (Bavaria), has been analyzing the European business-to-business service markets (B2B) since 1983. The market researchers focus on the sectors management and IT consulting, auditing, tax and legal advice, facility management and maintenance, as well as personnel services (temporary work, staffing).

The portfolio includes studies, publications, benchmarks, and advice on trends, pricing, positioning, and award procedures. The large amount of data enables Lünendonk to derive knowledge for recommendations for action. For decades, the market research and consulting company has published the "Lünendonk® lists and studies", which are considered a market barometer.

Many years of experience, in-depth know-how, an excellent network and, last but not least, a passion for market research and people make the company and its consultants sought-after experts for service providers, their customers, and journalists. Every year, Lünendonk, together with a media jury, honors deserving companies and entrepreneurs with the Lünendonk Service Awards.

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ENDNOTES

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