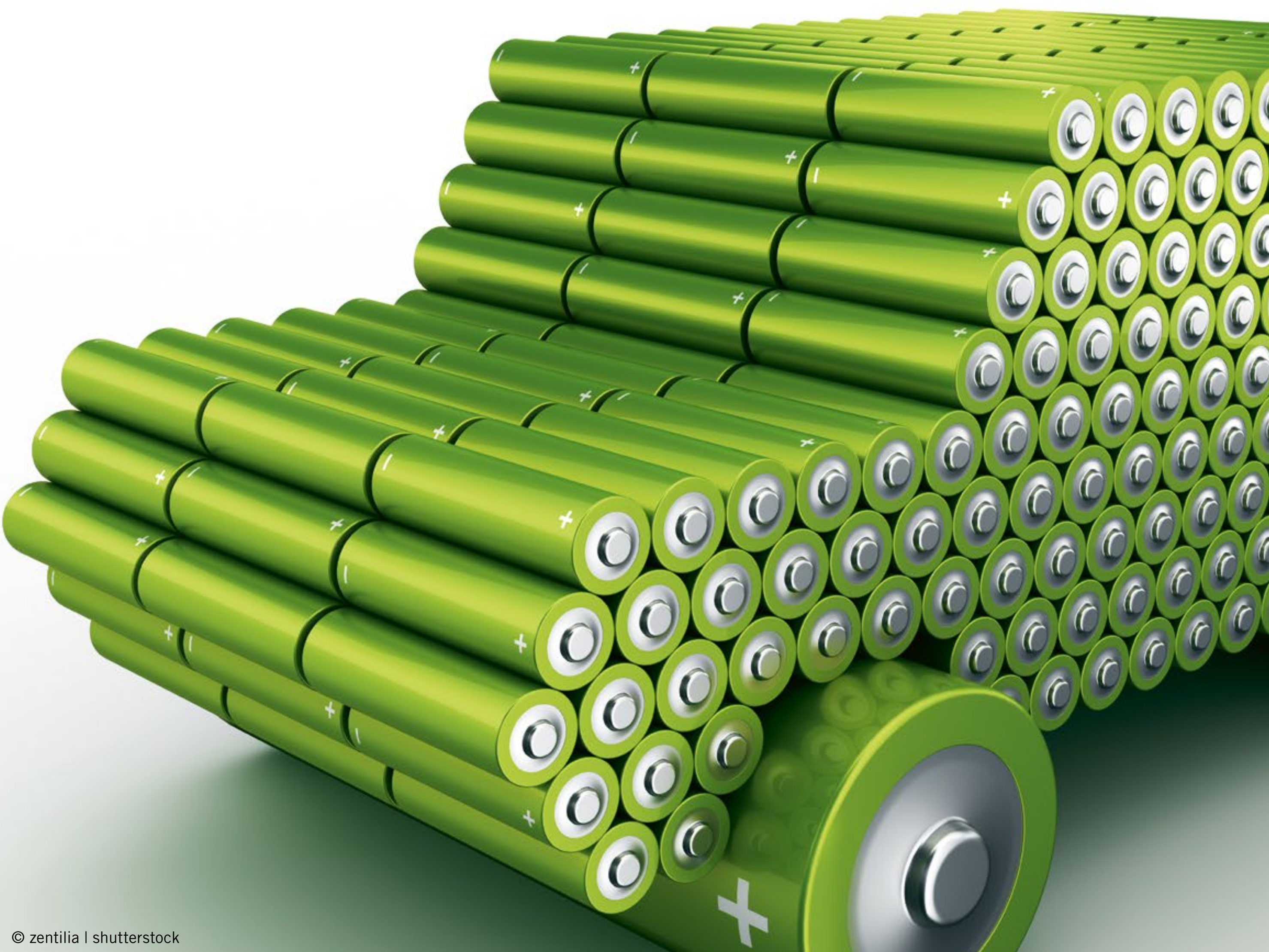

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Energy Management and Hybrid Storage Concept for Electric Vehicles

The progress of electric mobility stands and falls with the performance of the battery. The BMWi hyPowerRange research project aims to enable a modular, more flexible and cost-effective design of the power and capacity of traction batteries in the future. According to Bertrandt, this is to be achieved by developing a modularized, hybrid energy storage system made of high-performance and high-energy lithium-ion cells.

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THE HYBRID BATTERY CONCEPT

In contrast to previous projects, in the hyPowerRange research project the different cell types in the hybrid battery are directly coupled, without an intermediate electronic converter. In this context, the term "hybrid" refers to the combined use of high-performance and high-energy lithium-ion cells in a single battery. Until now, these two cell types were typically installed separately from one another. High-energy cells have a high capacity and can therefore store a large amount of energy, which has a direct influence on the range of a battery electric vehicle. However, they are not dynamic in the way that they store and supply the power.

In this respect, high-performance cells have a clear advantage but this is at the expense of a significantly lower capacity. An electric vehicle with high-performance cells can accelerate faster and recuperate better. Recuperation is a technical process in which kinetic energy can be converted into electric energy in order to recharge the battery. The direct coupling of both cell types has the effect of increasing the performance of the previous batteries with high-energy cells by up to 50 %, while at the same time extending the lifetime of the cells. What is more, there is no longer a need for expensive additional components such as voltage converters, which were required in previous concepts for interaction between the two cell types.

To control this interaction, a novel battery management system is being developed in the project. As part of this research project, Bertrandt has taken on the responsibility for the development and the integration of an intelligent and predictive energy management model. Additional measures to extend the driving range are also being systematically applied in the project. Above all, the hybrid battery in the vehicle is integrated into a higher-level energy and thermal management concept, **FIGURE 1**.

TASKS OF THE ENERGY MANAGEMENT SYSTEM

The energy management is aimed at reducing energy demand. However, this must not be done at the expense of other requirements, such as customer comfort. Legal requirements must also be taken into account. The energy management includes the coordination of different components and the provision of functions according to criteria such as energy demand, component lifetime, and comfort. This applies, for example, to the drive system and current consumers and includes functions such as range extension, charge management, and interfaces to the thermal management system. Due to the complexity of the components and systems in the vehicle, it makes sense to consider them from a complete vehicle perspective.

An intelligent energy management is necessary in order to fulfill all requirements and to support the driver while driving [1, 2]. In this funded project, Bertrandt is developing energy management functions for the battery electric demonstrator vehicle. These are focused on the high-voltage side. Communication between all subsystems of the vehicle data bus and the additional components installed is monitored and analyzed. Conventional message-oriented communication technologies such as CAN are used, and analog and digital signals are transmitted and received. Access to the data takes place in real time. The information is forwarded to the functions, and intermediate values and calculations are stored before being once again written onto the vehicle bus.

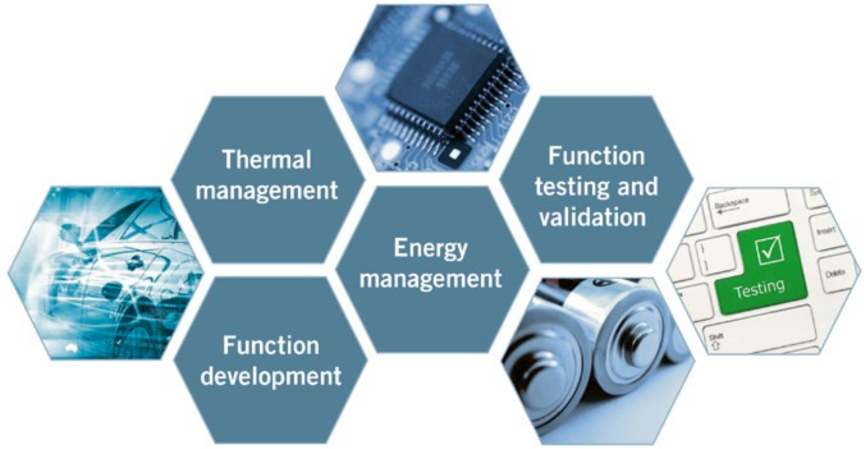
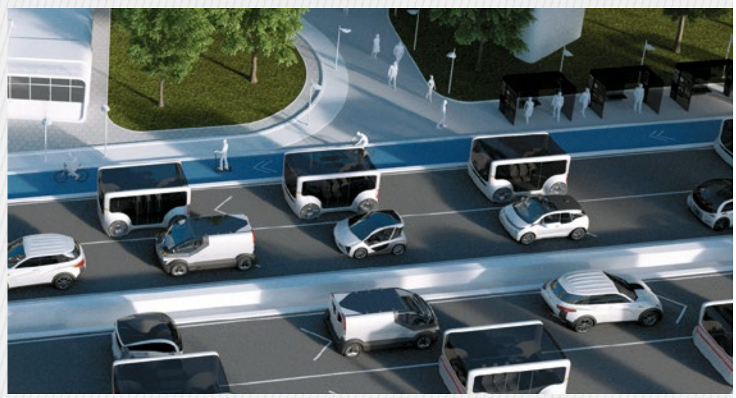


FIGURE 1 Energy management and thermal management are initially independent components that work closely together through defined interfaces; both components begin with function development and lead ultimately to the verification of the functions on the basis of testing and validation (© Bertrandt)

MODEL-BASED APPROACH TO FUNCTION DEVELOPMENT

The project began with the preparation of performance specifications in which each of the project partners were able to include their own requirements, **FIGURE 2**. In the development process of functions, Bertrandt is pursuing a model-based approach. The model is divided into two main modules: energy management and thermal management. The energy management module includes the following functions: operating state recognition, range calculation and extension, recu-

FIGURE 2 Preparation of performance specifications in which each of the project partners were able to include their own requirements (© Jacob Lund | stock.adobe.com)



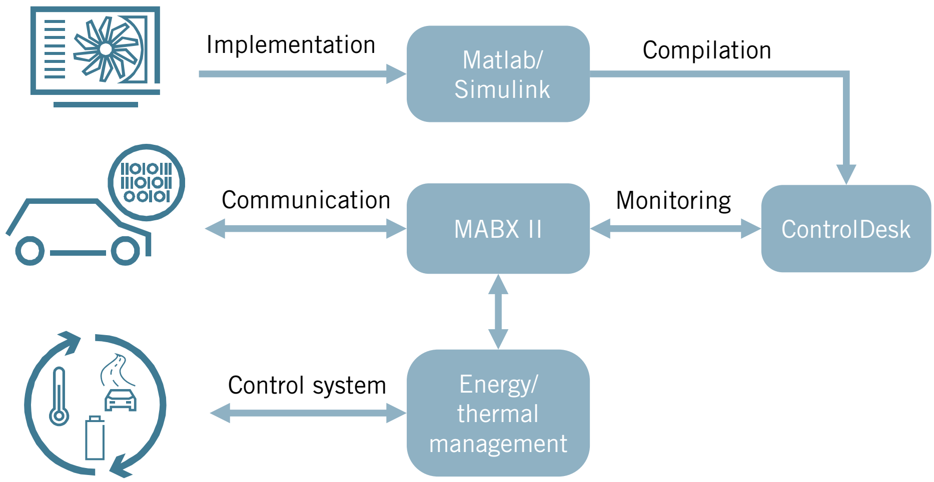


FIGURE 3 This schematic representation shows how the tasks of the different components are distributed within the development process (© Bertrandt)

peration, reduction of the battery load, and charge management to calculate the charging power and the starting time for the charger unit. The thermal management module is responsible for controlling the cooling circuit components of the battery, the drive components, and the vehicle interior.

In a concept, the energy management was initially characterized by function descriptions and the input and output signals (relevant vehicle signals) and supplemented with the addition of flow diagrams. Bertrandt was able to apply its many years of experience in automotive development. For the function model, internal interfaces were defined that make all the necessary information available for the functions. At the output interface, the messages are written onto the vehicle bus and the communication bus, which was specially developed for the additional components.

Driver-dependent route recognition is used to forecast the driving range. This means that the energy demand required to reach a known destination can be calculated before the vehicle sets off, and this can be compared with the amount of energy stored in the battery. If the destination is within the achievable range, no energy-saving measures need to be taken. If driver, traffic, or environmental influences during the journey have the effect of reducing the range to such an extent that the destination can no longer be reached, different measures to extend the range are applied. In the first step, the driver is visually requested to save energy and is supported in doing so. The driver is advised to switch off comfort systems that are activated, for example to reduce the cooling power of the air-conditioning system or to switch off the seat heaters. If these measures alone are not sufficient, the final step is that the Bertrandt energy management system will directly intervene and limit the power draw of the vehicle's drive system.

The driving range calculation described before evaluates information from local map material of the navigation system, such as route sections with road types. The driving styles of different drivers on the various road types are analyzed and, from this, the respective energy demand is determined. These data are linked with the driver profile of each driver. At the beginning of a journey, the data are read out from the long-term memory. After the journey, the energy demand values are assigned to the corresponding driver profile and updated. The more frequently a certain driver takes a particular route, the more precise the forecast for energy demand and achievable range will become.

In parallel, a driver behavior modeling has been worked out. This takes into account not only the acceleration and braking behavior, but also the behavior on bends and when driving at constant speed. The driver's behavior was learned with the aid of linear regression processes. This makes it possible in principle to use predictive route date to determine a speed profile for a driver on the planned route. The aim is to predict the energy required to drive a certain route in the future depending on a particular driver.

TOOLS FOR PROTOTYPE FUNCTION DEVELOPMENT

As part of the prototype development of the vehicle energy management system, the functions are implemented in the MicroAutoBox 2 (MABX2) bus communication hardware from the company dSpace, **FIGURE 3**. MABX2 enables the models created in Matlab/Simulink to be quickly applied in the vehicle.

Many preparatory steps were necessary to reach this point. The first step was to choose the right development tools. The software packages used are CANoe and CANdb++ from Vector Informatik. In order to provide a bus-oriented communication, the databases were created in coordination with the project partners. At the beginning of the concept, communication consisted of individual signals. During the course of the project, new signals and messages were continually added. This led to a continuous increase in the bus load and computing time, due to the fact that some functions were very complex. The models are being expanded with the aid of a special CAN toolbox for vehicle bus communication. The models are flashed onto the MABX2 using the dSpace tool ControlDesk NextGeneration. In addition, settings can be made while driving, and measurements and diagnoses can be carried out.

FIGURE 4 Laboratory workplace with MABX2 hardware and development laptop (© Bertrandt)

In order to perform testing of all functions on a Hardware-in-the-Loop (HiL) test bench, bus communications were recorded on the real vehicle. The communication processes were integrated into use cases and cut into individual trace files. The recordings are sent to the MABX2 bus hardware using the Vector hardware "CAN interface for residual bus simulation." In the laboratory set-up shown in **FIGURE 4**, the existing model can be quickly expanded with the addition of new functions, and already implemented functions can be tested and validated.

For the tests and function validation, Bertrandt is able to apply its many years of experience in standardized testing processes. This made it possible to derive test cycles for the project, in which the functions were first subjected for HiL test benches and then, after being integrated into the vehicle, were verified and optimized for real operation.

OUTLOOK

The Bertrandt energy management model is currently being implemented and tested in the demonstrator vehicle of the hyPowerRange research project. In the future, the model can also be used to simulate and develop further energy-saving measures for electric vehicles and hybrid passenger cars.

In addition, the functions can be adapted to individual customer requirements. In the design of a battery electric vehicle, a cell must fulfill all application requirements today. The aim of hybrid battery modularization is to achieve the target values of performance, capacity, and weight – which differ widely for each electric vehicle – in a better way for the respective application and therefore to provide an application-optimized design. The hybrid battery ("hy") represents the best compromise between "power" and "range."

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THANKS

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