3rd Newsletter Edition/November 2020

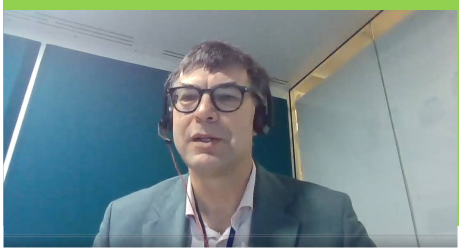
FINAL PUBLIC EVENT

Virtual meeting on September 30th, 2020

Representatives of all 22 partners and interested experts from the industry joined the closing of the project ADVICE. After presentation of the main achievements, four webinars were shown:

1) Dual Battery Systems for High Performance and Range P-HEV
2) High Performance Hybrid Battery for Volvo Cars
3) Advanced Predictive Energy Management in Hybrid Vehicles
4) 48V – Pathway towards Minimum Local Impact

B. Brandstätter and A. Steiner (Vif), above
L.O. Carlsson (Volvo), below



ADVICE FINISHED ITS ACTIVITIES AFTER 3,5 SUSCESSFUL YEARS

Our ambitious goal was to increase the number of hybrid vehicles on the roads and thus contributing to the European CO_2 targets. As requested by the EU-call, conventional Premium class vehicles struggle in reaching the environmental targets of the EC[1] and offer access to well suited customers which made this market segment as the primary target group of the project.

In ADVICE we wanted to cover different widely used hybrid architectures ranging from mild-hybrid over full-hybrid to plug-in hybrid, taking advantage of exploiting the possibility to downsize the internal combustion engines.

The 48V mild-hybrid was set up with a starter-generator machine and an electrical axle in the rear. The full hybrid has an e-axle in the rear as well but the main feature is the high power 400V battery. The plug-in hybrid has a so-called P2 system acting on the rear, while an all-wheel drive has been investigated adding 2 electric motors for each front wheel. An improved and production intent integrated solution based on a single e-motor plus eTwinster transmission has been developed and tested at component bench level.

Another objective of ADVICE was to achieve a **cost premium** of 5% for mild and full hybrid and 15% for P-HEV compared to best in class non-hybrid diesel vehicles available on the market.

Vehicle performance and fun to drive are important selling arguments and were considered for the targeted vehicle class. For this reason, a **cost assessment** procedure was set up to evaluate total cost of ownership as well as a cost benefit analysis to show the economic advantages of the development results of ADVICE.

The **fuel consumption and noxious emissions reduction** are main drivers for hybrid vehicles. To achieve a decrease in fuel consumption engine downsizing, as well as advantages of predictive control strategies and ECO-Routing/ ECO-driving functionalities were used. These results can be seen in our **project video and in the streaming of our final event on our webpage.**

[1] https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32009R0443

HIGHLIGHTS OF DISSEMINATION IN THE LAST 12 MONTHS

AVL International Simulation Conference, October 2019**:** Conference paper on Heat storage by ViF, AVL and other project members

International Vienna Motor Symposium, April 2020: Conference paper on High Performance Battery for Premium Class Hybrid Vehicles by FEV and RWTH Aachen

Final Public Event, September 2020: Project goals and achievements, webinars and Q&A organized by whole consortium; **Streaming of the whole event** under www.project-advice.eu

Automotive Thermal Management Online Conference 2020, November 2020: Conference paper on Predictive Thermal & Powertrain Energy-Management in a mild-HEV Application to Reduce Energy Consumption, by ViF, Siemens and FEV

HIGH PERFORMANCE BATTERY FOR VOLVO CARS

The design of high-performance batteries is a real technical challenge, but it can be mastered very well with suitable measures. By analyzing the different necessary functions of the parts inside a module, a morphological box was created to support the design process. The concept design was based on a multifunctional central structural element with a T-shape, which represented a central structure of strength and at the same time takes over the cooling. This concept was very well suited for series production, as the production of such a T-beam as an extruded profile was ideal. Cooling was primarily indirect via cooling channels placed inside the extrusion element and secondarily via a guided airflow. The aim of this cooling concept was to achieve the most efficient cooling possible while maintaining a low-temperature distribution across the cells and the module. We have fully achieved this goal in the project.

The cells were fixed on both sides of the T-beam with a thermally conductive adhesive. The T-beam was electrically insulated with a powder coating to guarantee the electrical insulation of the cells. The powder coating guarantees continuous electrical insulation over the full length of the T-beam, even over corners and edges.

With the given design of the cooling system, the distribution was analyzed and optimized to have a low deviation to the optimal flow distribution and to have high velocities in the small channels for a high heat transfer coefficient. The temperature of one battery pack was simulated for steady state simulation and transient conditions. A filling simulation was done to avoid air in the running system.

The finite element analysis with consideration of static crash accelerations has been conducted for the given assembly. Stresses and deformations obtained in the simulation were uncritical, i.e. they were in an acceptable range.

The target installation solution for the Volvo S90 T8 had two stacked modules. The second level was required to integrate the necessary 168 cells in the given space.

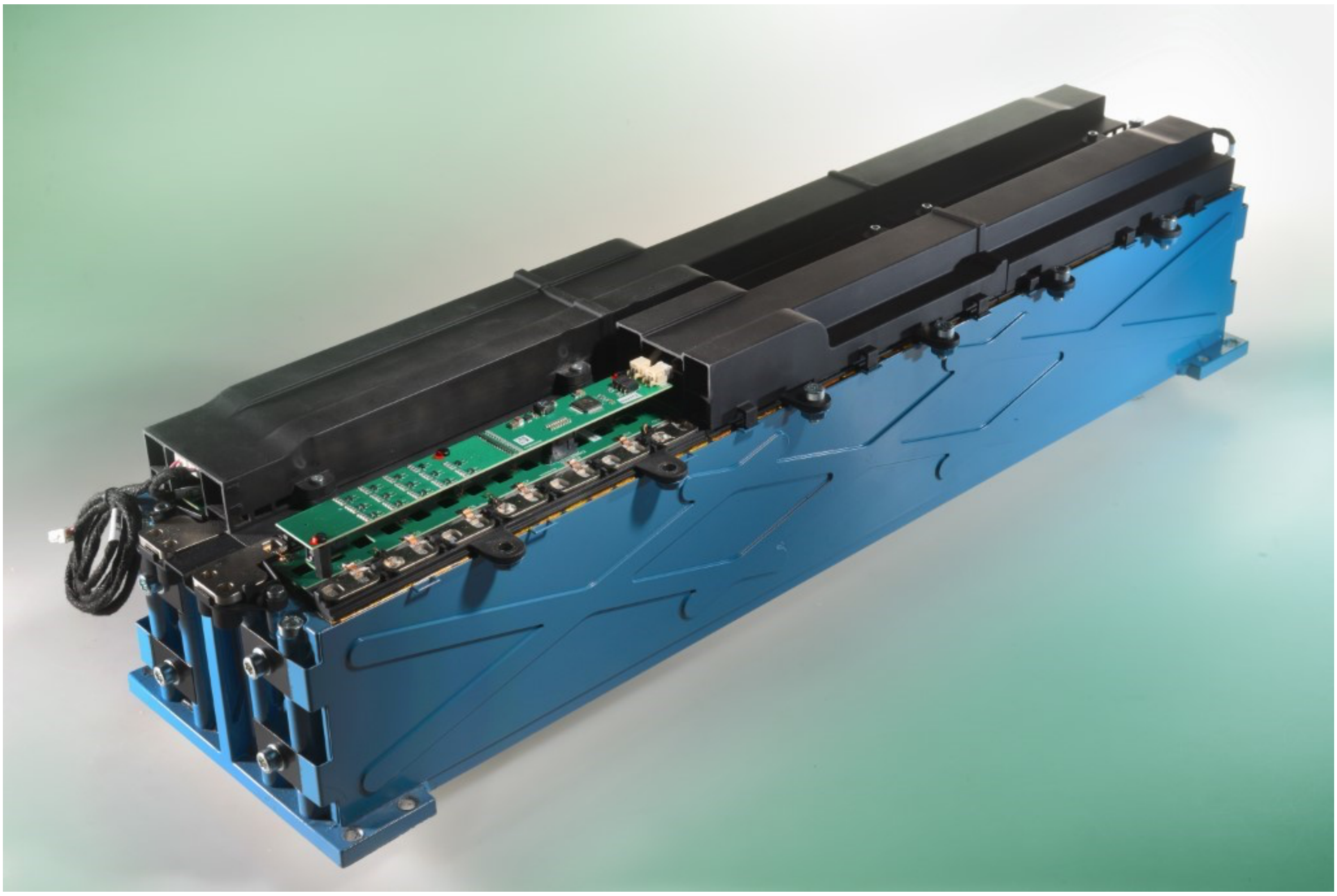


Figure 1: High performance battery

48V- PATHWAY TOWARDS MINIMUM LOCAL IMPACT

After evaluating the 48V e-axle with integrated inverter the functionality was proven. The 48V system implemented in ADVICE showed significant improvement in emissions. The demo vehicle was designed to enable pure electric driving in inner cities. The project partner AVL plans mass production of the optimized e-axle system in the upcoming years.

Figure 2: Pathway of e-axle exploitation

BATTERY TECHNOLOGIES FOR PLUG-IN HYBRID VEHICLES

In ADVICE, the project partners FEV and CRF explored the potentialities of hybrid battery systems for high-performance premium segment plug-in hybrid electric vehicles.

The basic idea was to explore the possibilities of so-called hybrid battery with two different cells, one sized for the energy demand and one for the power demand. The complete battery system architecture consisted of a high specific energy pack and a high specific power pack, coupled via a bidirectional DC/DC converter. However, a simple coupling of these parts would require the doubling of a lot of components with a relevant impact to the overall cost.

An important achievement of the ADVICE project was to understand how these components could be more effectively integrated and hence save cos, weight and volume. This goal was reached with a highly integrated solution which consisted of only one housing and one power electronic converter able at the same time to couple the two packs, manage the energy/power flow and act as battery manager master. The thermal parts as well as the power distribution have been integrated, too.

Moreover, FEV carried out research regarding longer term post lithium ion cell technologies for automotive high energy battery packs. Lithium sulfur and solid-state cell technologies have been promising mainly from the theoretical energy densities. Only few manufacturers of lithium sulfur and solid-state sales existed in 2018. Even fewer were willing to give away their cells, and if so, only under strict confidentiality. Real life lithium sulfur and solid-state tested cells fell short for about 50% from these theoretical values for gravimetric energy density. They also fell short by 50% in volumetric energy density compared to state of the art Li-ion NMC cathode technology. Cycle life was still a major issue for lithium sulfur but already very promising for solid-state technology. Issues like price or safety were not investigated.

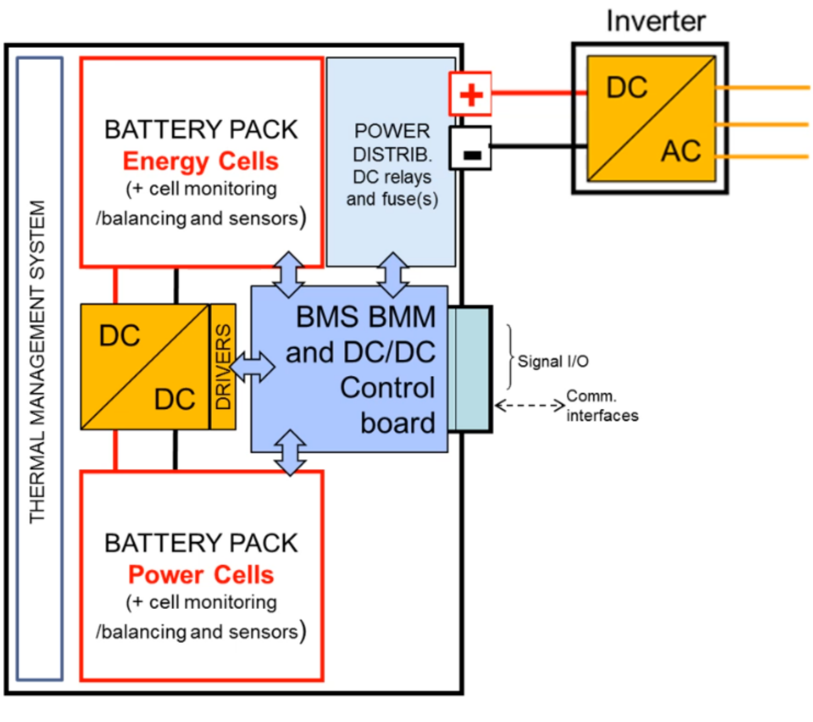


Figure 3: Innovative Integrated Dual Battery System

CRF P-HEV DEMO VEHICLE

The goal for this demo vehicle was to reduce emissions and fuel consumption having at the same time improved performance.

The longitudinal P2-P4 plug-in hybrid architecture was developed including eTorque vectoring functionalities. Additional features have been a downsized gasoline engine and a relevant pure EV range for the urban usage able, in this operational mode, to reduce to zero the noxious emissions and the Tank to Wheel CO_2 ones.

Figure 4: Fiat demo vehicle

VOLVO DEMO VEHICLE

The powertrain technology can be found in the diagram. The front axle was driven a by four-cylinder combustion engine with a power output of 235 kW, the rear axle was driven by an electric axle. The battery had to be designed within the right power range. Charging power was around 90 kW.

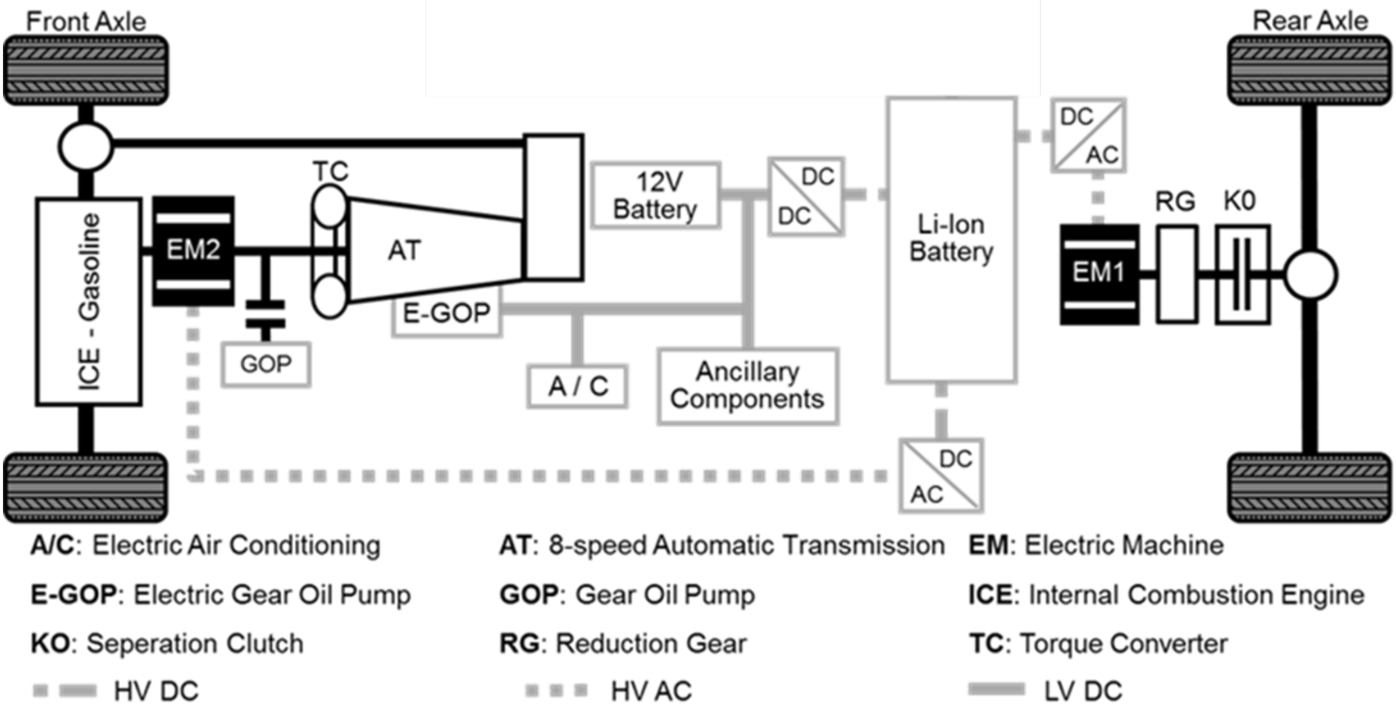


Figure 5: Volvo Demo Vehicle

OPEL INSIGNIA DEMO VEHICLE

Figure 6: Opel Insignia Demo Vehicle

ADVANCED PREDICTIVE ENERGY MANAGEMENT

In the project Advice, a predictive strategy was pursued.

By obtaining future information of the route and the heat input, an optimization was calculated in advance to reduce energy consumption. Therefore, at each time step, a fast running cooling circuit model was calculated for the whole future time vector and the obtained optimization values were applied to the real vehicle.

Several prediction horizons were evaluated leading to the result that 300 to 500s were a good compromise between accuracy and calculation effort. This advanced strategy was then compared to a simple state of the art control.

In Figure 7, several components of the vehicle are shown that were considered in the optimization process. There are heat inputs via the High Temperature circuit, the Low Temperature Circuit and HVAC system. The auxiliaries that are controlling the heat rejection are mainly operated by electric motors (colored in blue), that are optimized in energy consumption. Furthermore, a Heat Storage and a Chiller are considered to obtain a higher degree of freedom for heat shifting and the reduction of energy consumption.

The results we obtained are applicable for a WLTC as shown in the diagram. Applying the optimized strategy (red lines), the power consumption could be lowered, but there was no positive effect on the coolant temperatures, see first diagram. Knowing the future heat input, the auxiliaries can be operated less conservative, which means at lower speed.

In other experiments we also increased the coolant set temperatures by 5 kelvins resulting in acceptable reduced thermal safety margins.

Considering all these findings, a reduction potential of around 15% is realistic when applying a predictive strategy.

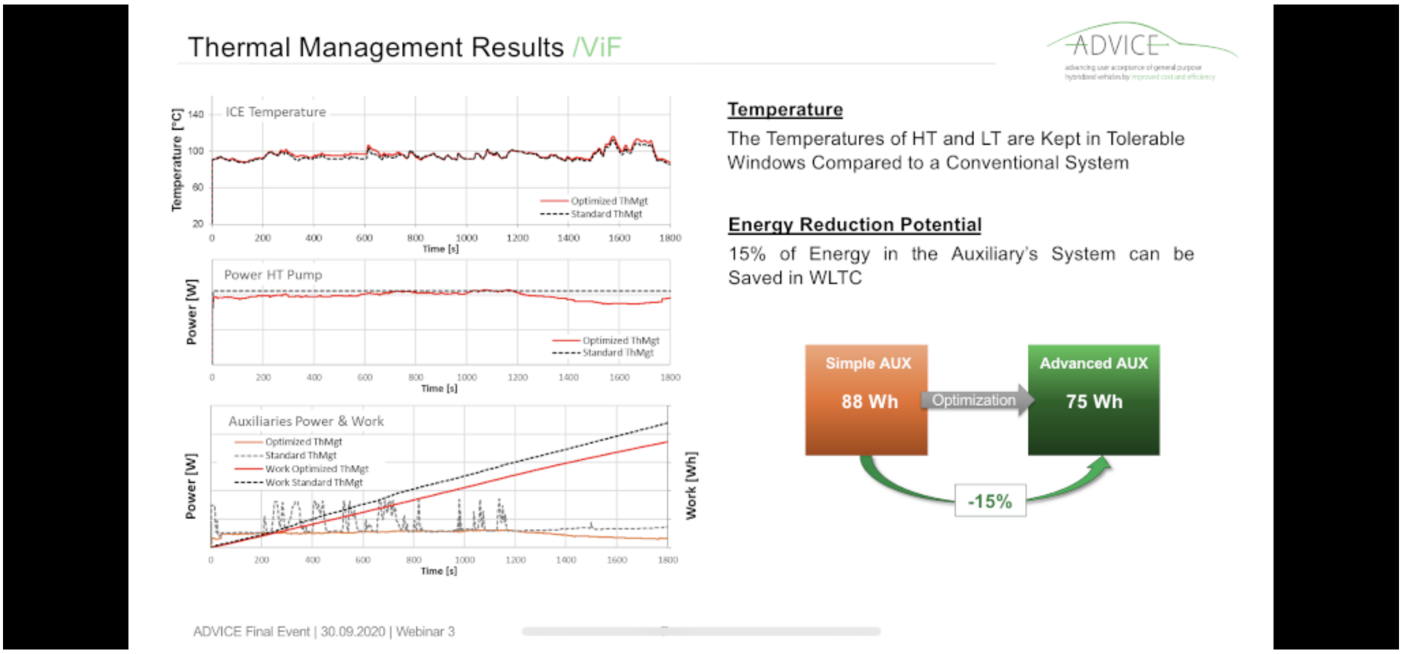


Figure 7: Advanced Predictive Energy Management