

Automotive fluids for e-mobility applications

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E-mobility – lubricants of the future

New drive concepts require adapted and specialised solutions



With regard to CO_2 neutrality and Europe's current target of only registering climate-neutral cars by 2035, the automotive industry is undergoing change – and with it, vehicle technology. Car manufacturers are facing new requirements in the area of powertrains, which is leading to new developments in the field of electric vehicles.

The components that are relevant in electric vehicles and the requirements that the corresponding fluids must meet are explained in the following.

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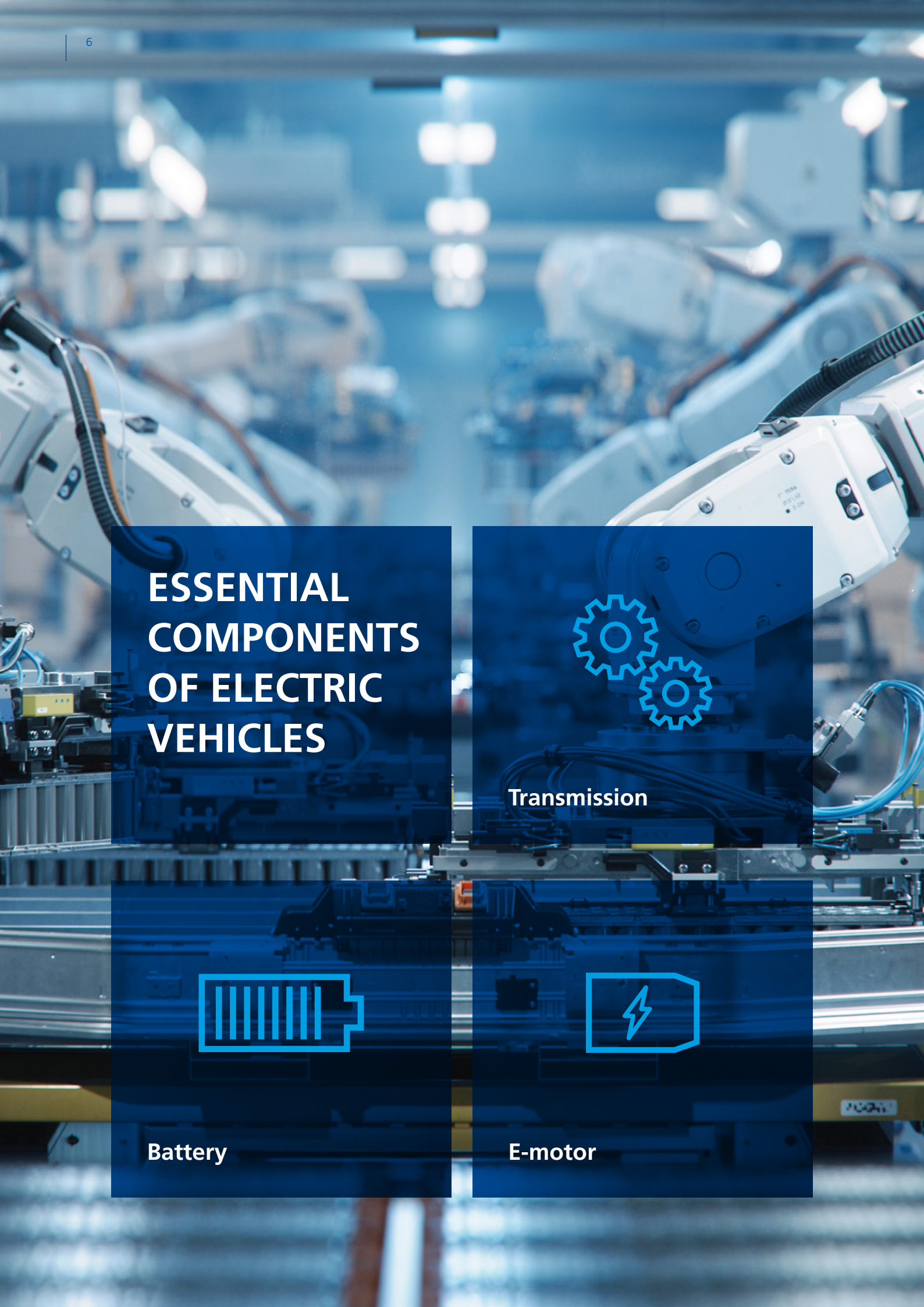
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ESSENTIAL COMPONENTS OF ELECTRIC VEHICLES

Transmission

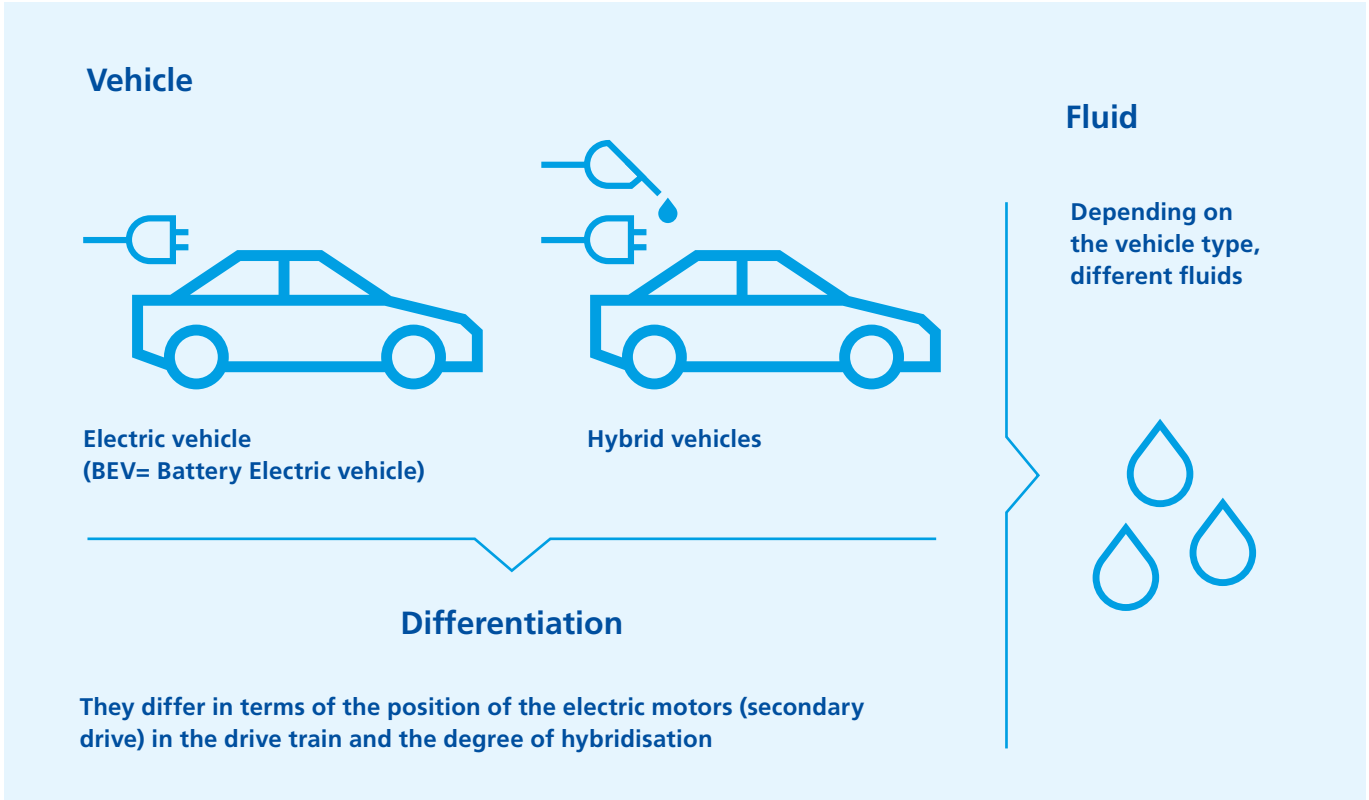
Battery

E-motor

Basics and definitions

In addition to the transmission, other components such as the battery and the electric motor are essential components of a pure electric vehicle (EV). The electric drive is often implemented by an electrified axle (e-axle).

In addition to pure electric vehicles (BEV = battery electric vehicle), there are also hybrid vehicles. These differ in terms of the position of the electric motors (secondary drive) in the powertrain and the degree of hybridisation. Depending on the vehicle type, different fluids are required as they have different properties. These include material compatibility with polymers and elastomers, but also metals such as copper, thermal and electrical properties, wear protection and many more.



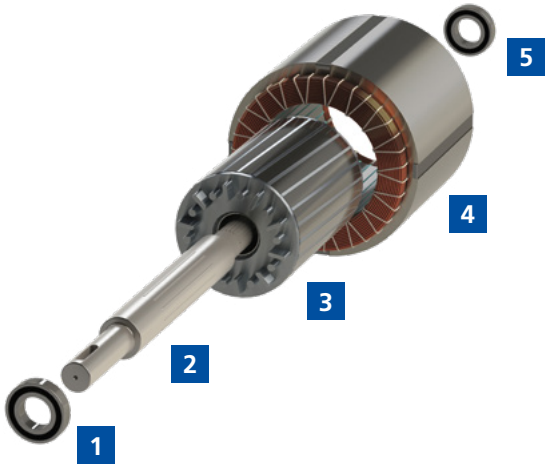
When charging an electric or hybrid vehicle, as much electrical energy as possible should be supplied in as little time as possible (= charging power). The more electrical energy is fed into or drawn from the system (traction, electric motor drive), the more thermal energy is generated. This applies not only to the charging station, charging cable, and vehicle battery during charging, but also the battery, power electronics (inverter primarily) and e-motor during operation.

E-motor

As a central component of a pure electric vehicle (BEV) and in contrast to a pure combustion engine vehicle, the electric motor takes on the task of driving the vehicle. The main components of the electric motor consist of the rotor (3) and the stator (4).

The example shown here is a permanently excited rotor (permanent magnetic field) and a wound stator. The type of winding and the packing pattern used may vary depending on the manufacturer. The inverter converts the direct current from the battery for the electric motor into alternating current, which then flows through the copper winding. This generates a rotating electromagnetic field with changing polarity of the north and south poles.

The principle of attraction between opposite poles and repulsion between like poles causes the rotor to move and transmit the resulting torque to the drive via the shaft (2), which is held in position by bearings (1+5).



E-motor

1 + **5** Bearing

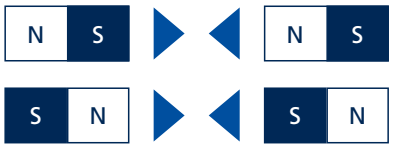
2 Shaft

3 Rotor

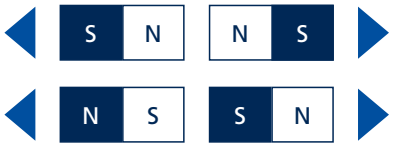
4 Stator

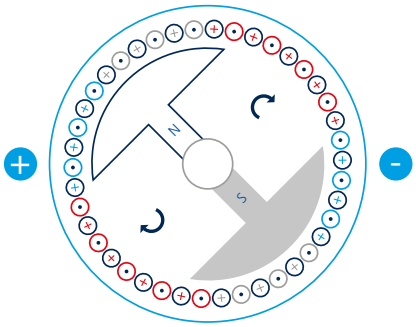
Principle of polarity

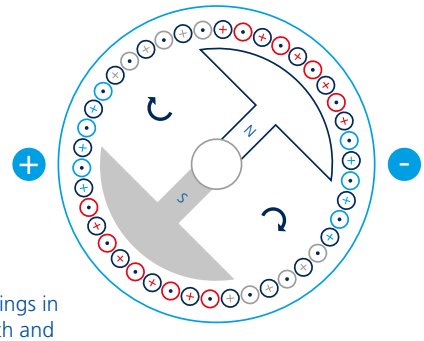
Opposite poles attract each other



Like poles repel each other







Functionality of electric motor with 3 windings in blue, grey and red, rotating rotor with north and south poles

E-axle

The term e-axle refers to the combination of an electric motor and (axle) gearbox, which are located in the same gearbox housing. A distinction can be made between a wet e-axle and a dry e-axle. In a wet e-axle, the electric motor and (axle) gearbox are located without any physical separation. This means that both the electric motor and the gearbox are lubricated and cooled with the same (oil-containing) fluid, known as EDF wet (p. 13).

In a dry electric axle, the electric motor and (axle) gearbox are located in the same housing, but are spatially separated from each other. This means that there are two separate circuits. The (axle) gearbox section is lubricated by means of immersion or splash lubrication. EDF dry is used for this purpose, as there are no requirements for the oil with regard to the electric motor (p. 13). The electric motor is cooled in a separate circuit and can be cooled either directly or indirectly (p. 15).The principle of attraction between opposite poles and repulsion between like poles causes the rotor to move and transmit the resulting torque to the drive via the shaft (2), which is held in position by bearings (1+5).

Hybrid vehicle models

In addition to pure combustion engine and electric vehicles, there are also vehicles that use a combination of an electric motor and a combustion engine for propulsion. These vehicles are referred to as hybrid vehicles. The energy sources consist of an electrical storage device (battery) on the one hand and fuels such as gasoline or diesel on the other. Hydrogen and LPG (liquefied petroleum gas) are also possible options for this.

Depending on the design, different vehicle models can be distinguished. Hybrid models can be subdivided according to the type of power distribution. Here, the degree of hybridisation is determined by the proportion of the total power generated by the electric motor.

Another distinction can be made based on the spatial placement of the electric motor in the powertrain (parallel hybrid drives). The vehicle type is designated based on these two distinguishing criteria. In particular, MHEV vehicles (MHEV = mild hybrid electric vehicle) are built with P0 or P1 hybrid drives, as these enable a compact design of individual components.

Classification according to degree of hybridisation:

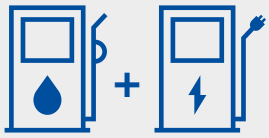


ICE
(Internal Combustion Engine)

MHEV
(Mild Hybrid Electric Vehicle)



BEV *
(Battery Electric Vehicle)
electric drive: full

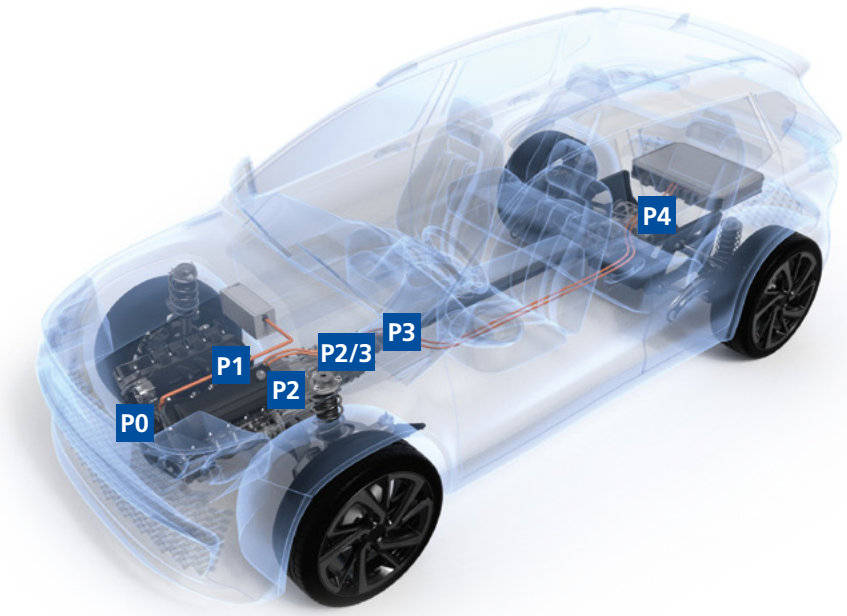


HEV **
(Hybrid Electric Vehicle)
electric drive: short distance

PHEV ***
(Plug-In Hybrid Electric Vehicle)
electric drive: longer distances

Degree of hybridisation

low =* medium =** high =***



Parallel hybrid drives
Position in the powertrain

P0
Electric motor permanently installed in front of the combustion engine

P1
Electric motor connected to crankshaft

P2
Electric motor on input shaft installed

P2/3
Electric motor and generator integrated into transmission (power split or series-parallel type)

P3
Electric motor installed on output shaft

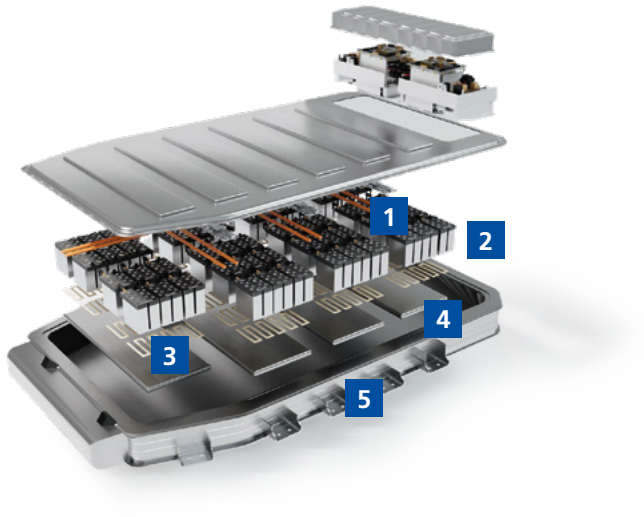
P4
Electric motor installed in separate

Additional temperature control of the electric motor is necessary, particularly for variants P2 to P5.
This is carried out as described on pages 20–22.

Battery

The battery is used to store the electricity required to power the electric motor. The battery is charged via the charging station (see below), in-home charging, brake regeneration, and for hybrids specifically, by the internal combustion engine. All components of the battery are housed in a casing.

The cells are the core components of the battery, in which the redox reaction for the chemical storage of electricity takes place. During the start-up and driving process, the discharge reaction converts the chemically stored energy back into electricity and passes it on to the inverter in the form of direct current. Several cells are combined within the battery housing to form individual cell modules. The number of cell modules depends on the respective battery and manufacturer. The module units are connected to the control system for controlling and monitoring the cell sand to the inverter for transmitting electricity to the electric motor.

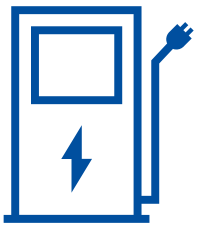


Battery structure

1. High voltage busbar
2. Cells
3. Thermal Interface Material (TIM)
4. Cooling plate
5. Battery case

Charging station

The charging station plays a central role in the regular use of electric and/or hybrid vehicles (BEV and plug-in hybrid). The electric charging process of a vehicle can be regarded as equivalent to refueling a conventional combustion engine vehicle at a petrol station.



Charging mechanisms and functionality

There are several ways to charge a BEV or plug-in hybrid. The fastest method is to completely replace the battery at a suitable exchange station. This avoids the battery charging time. However, the most common method is to charge the existing battery in the vehicle via a charging station. A distinction can be made here between manual power transfer using a charging cable and automated charging via inductive coupling between the vehicle and the charging station.

In inductive coupling, a copper coil (1) is traversed by alternating current (2), generating a magnetic field (3). The directional change of the alternating current causes the magnetic field to change regularly. For the charging process ,another copper coil (4) must be present in the vehicle, which now enters the magnetic field generated by the above-mentioned copper coil. This causes the magnetic field to oscillate , thus also generating an alternating current in the second coil. This alternating current can then be converted into direct current using a rectifier (5), thereby charging the battery (6).

In manual power transfer, the power source (6) is found in the conventional power grid (alternating current). The mains power is distributed to the individual charging stations (2) via a central module (7). If direct current is required, it can be generated by the rectifier installed in the central unit. The current is transmitted from the central unit to the individual charging stations (8). During the charging process, the current flows through the charging cable and plug (4 and 5) into the vehicle. The charging cable can be cooled directly or indirectly (see p. 16). For private charging options, elements of the central unit can be installed directly in the wall box. Charging the electric vehicle in a public area takes place at a car park (3) at a corresponding charging station (1).

Technical connection between charging station and battery

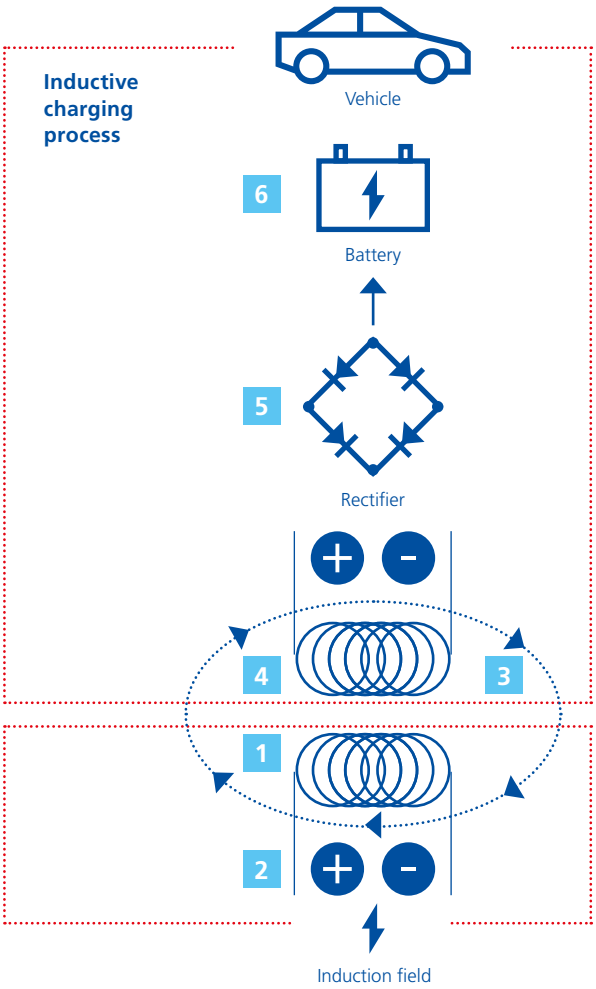
The terms charging power, current and voltage are often used in connection with batteries and charging. Depending on the voltage and current which is available, different charging powers and charging times are possible. The following physical formula explains this relationship:

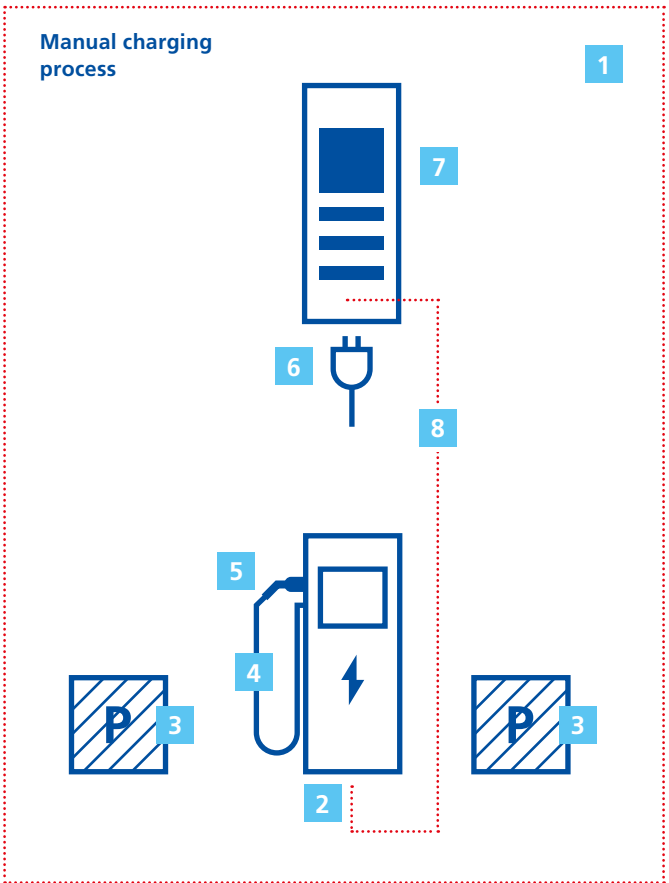
$$P = U*I \quad [W = V* \frac{W}{V} = V*A]$$

P = charging power, Watt [W], U = voltage, Volt [V], I = current, Ampére [A]

The charging power (P) is composed of the applied voltage (U) and the available current (I). Current and voltage are interdependent in this case. In Europe, the standard mains voltage for private households is 230V. The charging capacity and onboard voltage of the vehicle depend on the respective manufacturer and must therefore always be determined individually. In principle, however, the vehicle always draws the maximum possible charging capacity, depending on the temperature, the charging conditions and the initial state of charge of the battery. If a charging station has a charging capacity of 110 kW, but the vehicle only has 22 kW, then only a maximum of 22 kW can be charged. The charging capacity of the vehicle is always the decisive factor for charging the battery, not the capacity of the charging station itself.

If the battery becomes too warm during charging, the battery management system (BMS) can reduce the charging power to prevent overheating. This in turn results in longer charging times, as less charging power is available for the same period of time. Overheating can occur particularly during fast charging, as this involves a particularly high charging power in a short period of time, resulting in a greater amount of thermal energy being released during the charging process. In these cases, proper thermal management is essential.





Technical fluid requirements

Use of special fluids for lubrication and cooling required



In order to lubricate or cool certain components, it is necessary to use appropriate fluids. Depending on the application, both water-based and oil-based fluids can be used. In the case of oil-based fluids, which are composed of base oils and additives, the base oils have a significant influence on the viscosity of the fluid, among other things. Water-based fluids, on the other hand, consist largely of water, with appropriate inhibitors added as additives.

Electric Driveline Fluids (EDF)

Electric driveline fluids (EDF) are used in electric axles. The requirements for the respective fluid vary depending on the application, for example, the type of electric axle. A distinction can be made between EDF dry and EDF wet.

EDF dry

In a dry electric axle, requirements are placed on the cooling of the gearbox, among other things, in order to minimise thermal influences on the components in the gearbox. In addition, wear protection is an important requirement for EDFs, as this protects the gear and thus ensures the functionality of the gearbox. In this context, appropriate protection of the bearings is also necessary, as without this, performance can be significantly impaired and friction and wear can occur. The focus of EDFs is particularly on increasing efficiency, which is achieved by optimising the coefficient of friction.

For dry electric axles, so-called EDF dry can therefore be used. Due to new additive technologies and low-viscosity fluids, specially developed EDF dry are more suitable for dry e-axles than conventional gear oils that are not specifically designed for this purpose. The new developments also offer significant advantages over conventional fluids in terms of material compatibility.

The following requirements should be observed for EDF dry :

- Friction coefficient optimisation
- Thermal properties
- Viscosity
- Compatibility with materials
- Bearing protection
- Wear protection
- Oxidation stability
- Evaporation losses
- High speed aeration

EDF wet

In the case of a wet electric axle, the EDF (EDF wet) must also meet the cooling requirements of the electric motor in order to ensure its optimum operating temperature and prevent overheating. Due to direct contact with copper windings and their coating, a major focus in the development of the EDF wet is on the material compatibility of the components. Another important property of EDF wet is its compatibility with current-carrying components. The electrical properties of the fluid are specially adjusted for this purpose. The fluids are usually equipped with the latest additive technology and suitable base oils.

For EDF wet, the following requirements must be observed in addition to those for EDF dry:

- Material compatibility with copper and its coating
- Electrical insulation
- Corrosion protection

In both dry and wet applications, additional components can be installed that require more advanced friction performance requirements (FC = Friction Control). Components can be used to control torque (torque vectoring) or to shift gears, which require outstanding friction performance. To achieve this, technologies that go beyond the regular properties of EDF wet/dry are required. In these cases, the terms EDF dry FC or EDF wet FC are used.

Dedicated Hybrid Transmission Fluid (DHTF)

Dedicated Hybrid Transmission Fluids (DHTF) are designed for hybrid vehicles that have an electric motor installed in the housing, for example next to a dual-clutch transmission (wet running). This means that the fluids must meet the regular requirements for a dual-clutch transmission oil, such as material compatibility of the synchronisation materials, friction value behaviour and wear protection (see also FTI: Transmission oils). In addition, the electric motor used places additional requirements on the electrical properties.

A distinction can be made between the fluids, analogous to the electric axle in terms of a common or separate fluid sump for the transmission and electric motor. The requirements described above refer to a DHTF that is used in a common fluid sump.

The following requirements should be observed for this type of fluid:

- Friction coefficient behaviour
- Copper compatibility
- Foaming behaviour
- Conductivity
- Oxidation stability
- Electrical properties
- Wear and bearing protection

The requirements for the individual fluids in the transmission area can be found in the following overview. Axle, automatic and dual-clutch fluids are explained in detail in the transmission FTI.

Overview of requirements for gearbox fluids

Fluid requirements	**AXF** Axle Fluid	**ATF** Automatic Transmission Fluid	**DCTF** Double Clutch Fluid	**DHTF** Dedicated Hybrid Transmission Fluid	**EDF dry** Electric Driveline Fluid dry	**EDF wet** Electric Driveline Fluid wet	**EDF (wet/dry) FC** Electric Driveline Fluid with Friction control
Wear protection	+ + + +	+ + ₊	+ + ₊	+ + ₊	+ + +	+ + ₊	comparable to EDF dry EDF wet
Friction	n.A.	+ +	+ + + +	+ + + +	n.A.	n.A.	+ +
Aeration	+	+ +	+ + +	+ + +	+ +	+ + +	comparable to EDF dry EDF wet
Electrical properties	n.A.	+	+ +	+ + ₊	n.A.	+ + +	comparable to EDF dry EDF wet
Material compatibility	+	+	+ +	+ + +	+	+ + +	comparable to EDF dry EDF wet

+ = 1unit | ₊ = 0.5 unit



Thermal management and cooling circuits

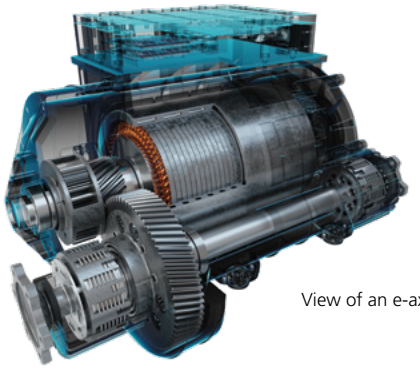
Individual vehicle components can only function optimally at the correct operating temperature. Thermal management is an important component in vehicles for ensuring that components such as electric motors, internal combustion engines, transmissions, batteries, cells, power electronics and charging stations are operating at their ideal temperatures.

In thermal management, a distinction can be made between oil-based fluids (dielectric fluids) and water-based fluids (EV coolants, EV = electric vehicle)

Cooling circuit of the electric motor:

In addition to batteries, thermal management is also very important for the electric motor. On the one hand, this can contribute to lower noise levels from the electric motor at high engine speeds. On the other hand, it enables a more compact design and improved motor and power electronics efficiency. Thanks to thermal management, cooling can also take place when the vehicle is stationary.

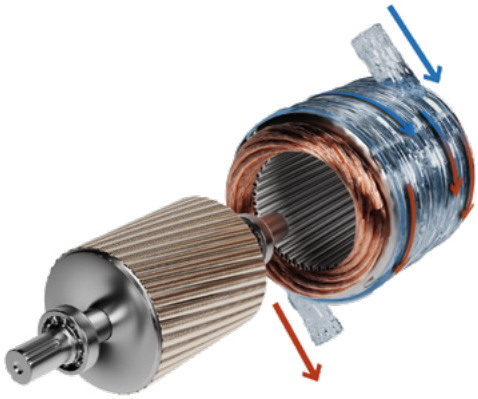
The electric motor can be cooled either directly, through direct contact with live components (or copper windings), or indirectly, if there is a separating surface between the components to be cooled and the cooling lubricant.



View of an e-axle

In **direct electric motor cooling**, the lubricant is added in different ways, either passively or actively. In direct active cooling, the cooling medium is sprayed directly onto the winding heads of the copper windings via suitable nozzles. In direct passive cooling, the rotating movement of the rotor causes the cooling medium to be thrown onto the copper windings by centrifugal force, thereby producing cooling. Due to the electric motor and the copper windings used herein, the lubricant must be compatible with copper and its coating, the sealing materials and the power electronics.

The **electric motor is cooled indirectly** by air or jacket cooling (e.g. water). In this case, the electric motor is surrounded by a cooling jacket and the heat is dissipated via the interface between the electric motor and the cooling channel with the aid of the coolant. Due to the high thermal conductivity of water, water-based coolants are ideal choices for indirect cooling of e-motors and power electronics. Corrosion protection plays an important role here. This must be taken into account when selecting the coolant.



View of an electric motor with jacket cooling

Battery cooling circuit:

Thermal management helps to increase the service life of batteries in particular. The thermal fluid is used to ensure a constant ideal temperature for the battery. In addition, the battery's charging and discharging processes can be carried out more quickly and gently, as the heat generated during these processes is dissipated more quickly via the fluid, thus maintaining constant functionality. The right fluid can also contribute to safety by preventing short circuits in battery cells and their chain reaction to other cells, thus avoiding cell burn-up (thermal runaway).

To keep the battery in optimal working order, an operating temperature of 25°C is required, depending on the manufacturer and battery design. The thermal fluid provides cooling in summer and heating to the desired temperature in winter. Cold temperatures (e.g. 0°C / 32°F or below) require the battery to be preheated before charging and operation to ensure its functionality and effectiveness. Cold temperatures in winter (e.g. 0°C / 32°F or below) in particular require the battery to be pre-heated for charging

Cooling circuit at the charging station:

In the charging station area, proper and adequate thermal management allows for higher charging power by dissipating heat, which results in faster charging speeds and increased efficiency. In addition, the use of thermal management makes it possible to optimize the cable routing (wire thickness) when connecting the car to the charging cable.

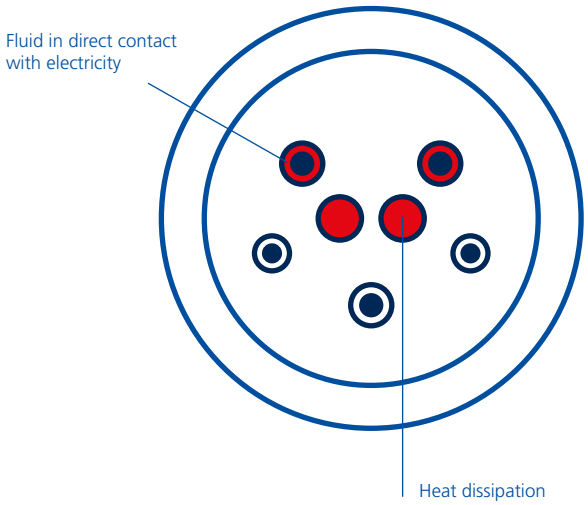
In directly cooled charging cables, the current-carrying conductors are immersed directly in the oil. To dissipate the heat, two additional cable guides are installed in the charging cable itself, through which the coolant is transported back to the heat exchanger (known as a chiller). This creates a closed cooling circuit for the coolant. Direct cooling enables high heat dissipation.

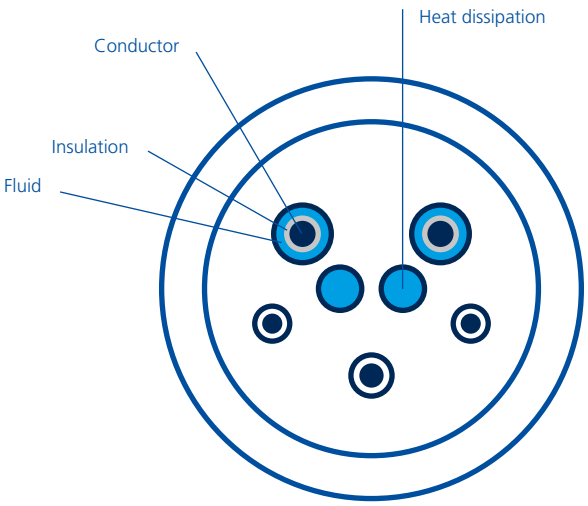
In water-based indirect cooling, the conductors are surrounded by tubes in which the cooling fluid is ready to dissipate the heat. The properties of the tubes enable them to actively absorb the heat from the conductors and transfer it to the cooling fluid. Due to their electrical conductivity, direct cooling is not possible with water-based fluids.

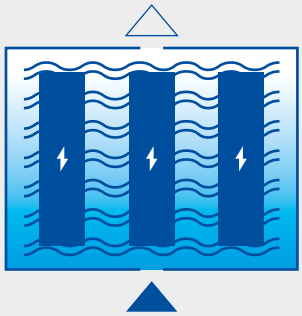
Heat dissipation from current-carrying cables can also be achieved via the air. However, this does not provide the same cooling effect as direct/indirect liquid cooling. For cooling with air, larger gaps between the insulation and the cable are also necessary to enable heat dissipation through the air in the first place. This increases the weight and volume of the cable, which can impair user-friendliness.

The design of the charging cable may vary depending on the manufacturer. However, the concepts all include the same core elements.

Type 1: plug with cooling channels

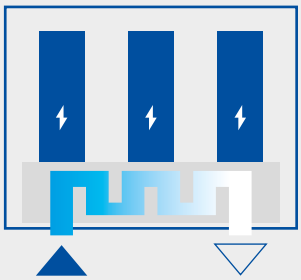






Direct cooling circuit for the battery

If the cells are temperature-controlled directly, they are immersed in a suitable thermal fluid in the battery housing. The thermal fluid must meet specific requirements in terms of electrical conductivity and material compatibility with regard to the electrical components. Direct battery cooling is also known as battery immersion cooling.



Indirect cooling circuit of the battery

In the case of indirect cooling, thermal interface materials (TIMs) and potting compounds are used to transfer heat from the battery cells to a cooling plate. The cooling plate then moves the heat to a coolant, which transfers the heat to a heat exchanger, where it is ultimately dissipated.

Dielectric Fluids – Thermal Fluids (TF)

Dielectric fluids are in direct contact with the components to be temperature-controlled, whereby the components are immersed in the fluid (immersion or immersion cooling). The fluid acts as an electrical insulator and must have a low, but properly designed conductivity that simultaneously prevents both unwanted current flow and static charge buildup. These fluids are used, among other things, for direct battery cooling and are generally referred to as thermal fluids (TF).

The following requirements should be observed for this type of fluid:

- Thermal conductivity
- Viscosity
- Density
- Specific heat capacity
- Material compatibility
- Bearing protection (electric motor)
- Sealing materials
- Electrical conductivity

EV Coolants

As a counterpart to dielectric fluids, EV coolants are available for indirect cooling (jacket cooling). In contrast to thermal fluids, EV coolants contain water. The fluids have a higher specific heat capacity and are therefore excellent heat conductors. This enables them to contribute to optimal thermal management. (Further information on water-based fluids can be found in the FTI on radiator antifreeze).

The following requirements should be observed for this type of fluid:

- Corrosion protection
- Material compatibility, especially with aluminium alloys
- Compatibility with sealing materials
- Thermal conductivity
- Viscosity
- Density
- Specific heat capacity
- Electrical properties

Specifications

Fluid requirements in e-mobility

The focus on electric mobility has only increased in recent years in Europe. Unlike in a firmly established specification environment (API, ACEA), which is familiar from the field of conventional drives, there is currently no uniform understanding of specifications for fluids in e-applications. Due to this, individual specifications for fluids are specified depending on the manufacturer. Often, only limited information on the requirements for the fluid is publicly available. However, the corresponding standard norms are in the development phase and may come to fruition over the next few years.

It is also apparent that established vehicle manufacturers are often relying on known specifications that were not originally developed for electric or hybrid applications which may result in use of fluids that are not optimized for the application.

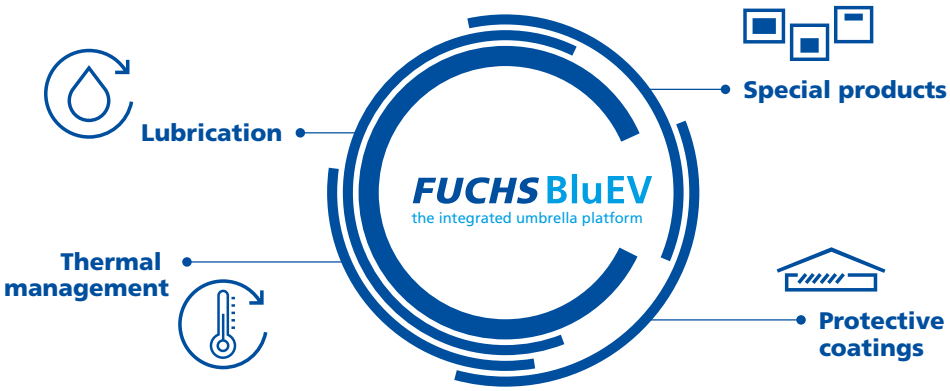




FUCHS products for e-mobility

FUCHS BluEV

FUCHS BluEV is the platform for sustainable drive technologies, such as those found in electric and hybrid vehicles. The formulations are based on the latest additive technologies, which have been specially developed for these applications. As a comprehensive product line, FUCHS BluEV products can be used not only directly in vehicles, but also in their manufacturing process or in individual components.



BluEV Technology

In addition to the FUCHS BluEV product line, FUCHS also introduced BluEV Technology. BluEV Technology bridges the gap between existing and new lubricant applications. This designation identifies existing products developed for conventional use that are also suitable for use in hybrid applications and electric vehicles. The products suitable for this purpose are labelled with BluEV Technology.

BluEV
TECHNOLOGY

The available FUCHS products for the e-mobility sector can be found in the current delivery programme or on the website.

Discover our product program

FUCHS LUBRICANTS GERMANY

Automotive fluids for e-mobility applications



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