



Electrified Mobility

System Expertise for Electrically Driven Commercial Vehicles



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Efficient and Climate-Friendly

Fuel efficiency and greenhouse gas reduction are hot topics for industry and governments. It's all about reducing fleet consumption of fossil fuels as well as cutting CO₂ and NO_x emissions in city centers and high-density zones. To achieve this, we need locally emission-free drives that use regenerative energy sources.

ZF, drawing on its decades of experience in modern vehicle drive systems, also offers electric and hybrid system solutions for commercial vehicles. They enable efficient, low-emission operation of buses, trucks and light commercial vehicles. Because battery packs make vehicles heavier, weight has to be saved elsewhere. With our expertise in lightweight construction, electronics and system integration as well as energy management, ZF is a strong partner for vehicle manufacturers.

Electromobility From ZF

Electric battery or hybrid technology – ZF has been supplying both drive types for passenger cars and commercial vehicles for years. These two variants benefit from each other, and customers benefit even more. That's because electric drives and hybrid transmissions are ready for everyday use.

As a leading technology company offering comprehensive system solutions, ZF's clear objective is making intelligent mobility possible. Quality, technology leadership and innovative strength have shaped ZF's identity for more than 100 years. As we look to the future in our Corporate Strategy 2025, we have defined our motivation and obligation to shape mobility safely, efficiently and sustainably with trendsetting technologies.

ZF's concept is Vision Zero – a world without accidents and emissions. That means electric drives for all applications that also benefit economically from all-electric vehicles. Today, electric motors can already be used in long-distance traffic to supplement conventional drives in hybrid vehicles. ZF supplies the corresponding hybrid transmissions for this.

With its extensive portfolio, ZF covers all types of commercial vehicle – from small light commercial vehicles to heavy trucks and city buses. Axle-based electric solutions and central drives meet different customer needs. While wheel-hub and electric axle drives offer installation space advantages, central drives are ideal for converting a conventional vehicle layout to electric drive at a minimum of cost and effort.

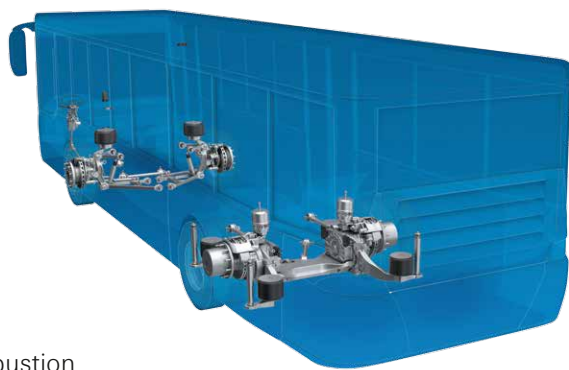
ZF can engineer entire drive systems. They come with all components optimally fine-tuned to each other in terms of performance, cost-effectiveness and service life. That means the vehicle manufacturer saves costs and effort. Our systems expertise covers converters and electronic control units just as much as the associated chassis technology, steering systems, axles, dampers and cooling systems. And of course we support you with the integration of our systems into your vehicles.

For a Better Climate

Today, there are extensive efforts under way to free urban centers from all types of emissions; whether noise, exhaust gas, or others. Legislators such as municipalities impose maximum permissible values to prevent damage to health and the environment. What's more, operators like public utilities and forwarding companies also have an eye on costs.

Driveline technology in modern vehicles plays a leading role here. Stakeholders want vehicles that drive as far as possible without exhaust gas emissions as well as quietly and economically. So that life remains liveable and attractive for people even in megacity centers.

When it comes to buses, the focus is on local public transport which takes people to their destinations all over the city. In addition to conventional drives, locally emission-free electric drives have become established in recent years, and they continue to gain ground. They offer advantages not only in terms of emissions. Operators also benefit. That's because electric motors are easier to install in vehicles than conventional drives with internal

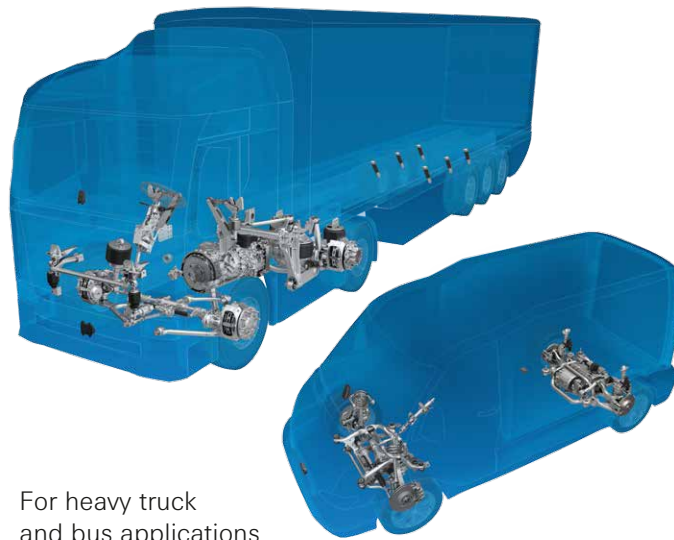


combustion engines and transmissions.

The result is space for more seats or standing room in buses, additional doors, plus step-free, low floors.

The vehicles can transport more passengers, who board and exit faster, for ultimately more effective bus routes. The energy storage units (e.g. batteries) need space, but they can easily be accommodated in the floor or roof areas.

Also in the truck sector there are lots of new developments in drives. Emission-free driving is an important goal here as well. Increasingly, electric-drive specialists are looking at distribution vehicles for all-electric driving in cities. From lightweight to medium-weight vehicles.



For heavy truck and bus applications, electric motors supplement conventional drives in hybrid vehicles – particularly for the last mile in urban areas.

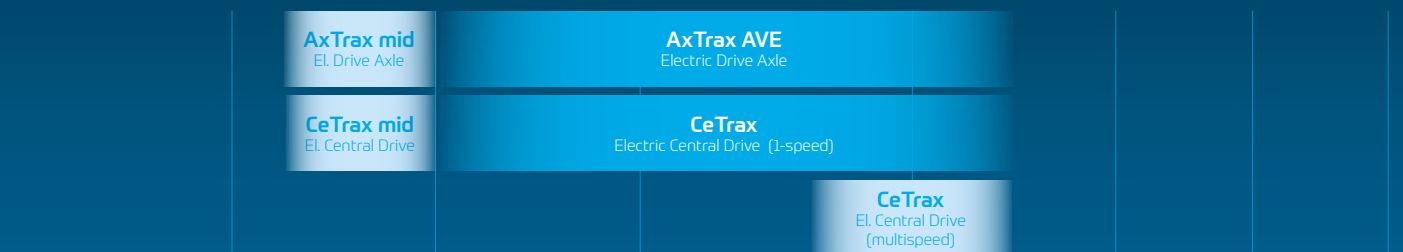
There are no traffic bans for these vehicles, and they can achieve significant fuel savings. For all these use cases, ZF develops perfectly coordinated systems from a single source, created by experts with long-standing experience in electric drives. Vehicle manufacturers can rely on our company that has been developing, producing and selling highly successful drives for motor vehicles for more than 100 years.

Electric Drive Solutions ZF Product Portfolio

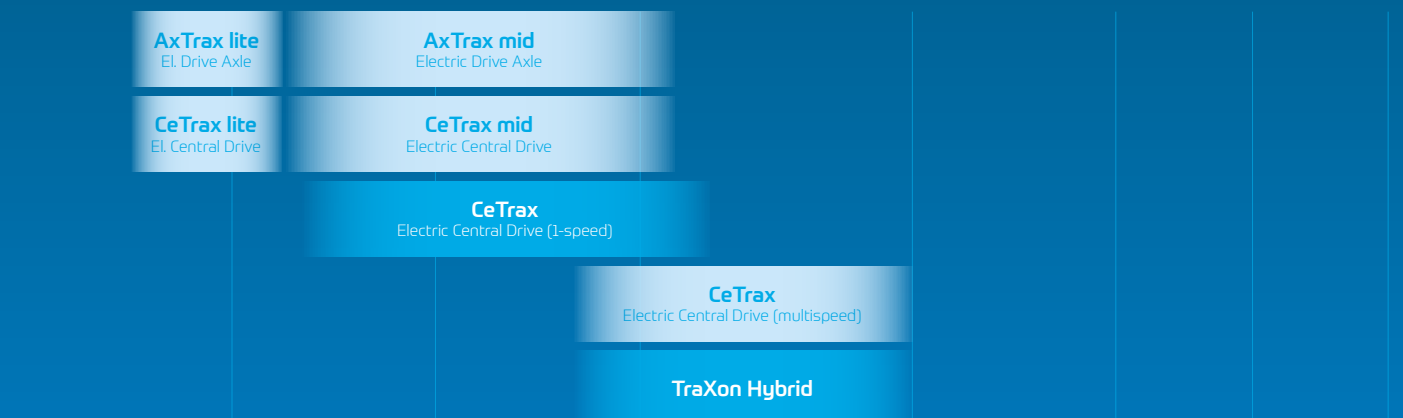
Vans and Trucks



City Bus



Intercity Bus and Coach



○ Current Portfolio ● Under Development

AxTrax

For Clean Cities

The greatest possible elimination of emissions and noise – this is what AxTrax offers for all alternatives to traditional combustion engines.

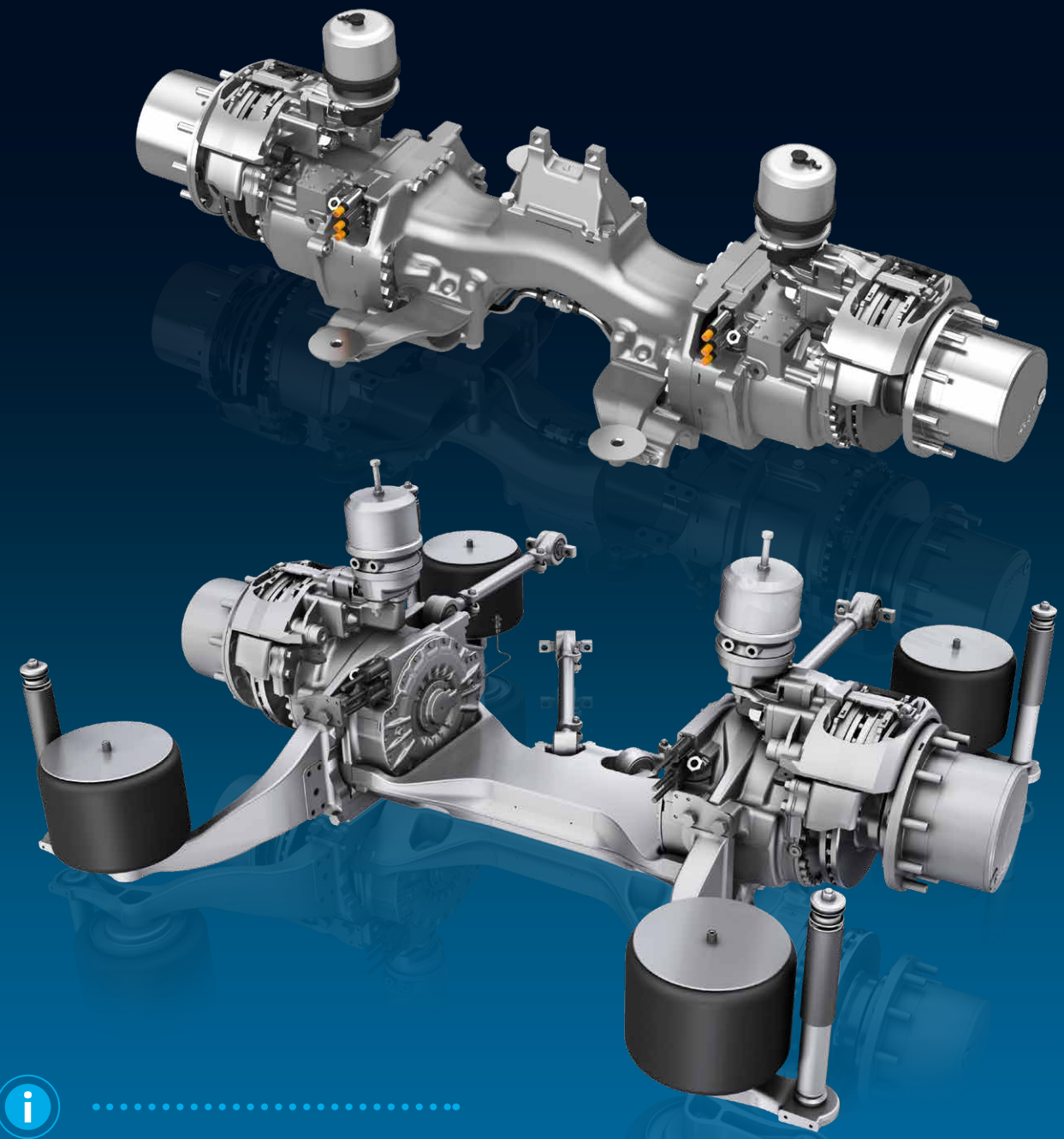
Flexibility is a central requirement for drive technology for electric city buses. The AxTrax AVE can be used with all electric drive concepts. Furthermore, AxTrax also enables trucks to drive in urban emission-free zones. Apart from zero-emissions driving, AxTrax offers further advantages in urban stop-and-go traffic, because high-torque electric motors provide fast thrust. During braking, they switch to generator mode and recover valuable braking energy.

In the bus version installed as an electric portal axle, dispensing with the conventional drive and the rear propshaft creates room for more seats and standing places. That means the passenger compartment can be designed with a step-free entry and exit area and on one level all the way through.

The truck design allows for installation in a standard body-on-frame. It can easily be adapted to different vehicle concepts. Dispensing with the cardan shaft means the battery packs can be accommodated in the body-on-frame. No load space is lost.

AxTrax / Axtrax AVE weighs up to 500 kg less than solutions with electric central motors from other manufacturers.

The ZF system: AxTrax / AxTrax AVE plus inverter and the ZF EST 54 control unit form the basis for the systematic interplay of power request, recuperation and energy storage. This gives vehicle manufacturers an optimally coordinated complete package.



Advantages at a glance

- Advanced zero-emission drive
- Flexible application: liquid-cooled electric motors in combination with all alternative energy concepts
- Passenger and fleet-friendly: significant comfort and installation space advantages
- Low noise due to helical gearing in both transmission steps
- Same installation space and connecting dimensions as conventional ZF portal axles.

Climbing ability

28-ton articulated bus with only one electric portal axle

15 %

CeTrax

For Conventional Driveline Concepts

Buses and trucks should be fast and effective as well as – today more than ever – clean and quiet! Logistics companies and transport operators demand low-cost, low-emission vehicles. Especially for conventional driveline arrangements, ZF offers its CeTrax electric central drive.

Torque density (system)
Nm/kg

15.8

The new CeTrax system is an all-electric central drive that can be used in different bus applications as well as in delivery trucks. CeTrax was specially developed for demanding inner-city applications. Installed in battery-driven vehicles, the system operates with zero local emissions!

The focus is on manufacturers that want to integrate an electric drive into their existing conventional vehicles. Bus manufacturers benefit from the option of using the system both for low-entry and high-floor applications as well as for low-floor buses in combination with the AV 133 portal axle. It is also suitable for replacing internal combustion engines in truck chassis in conventional arrangements. CeTrax saves on costs and reduces the workload involved in technical integration as well as in service.



With a maximum power output of up to 300 kilowatts and a maximum torque of 4,500 newton meters, CeTrax is second to none in terms of performance when compared with a classic drive.

Just like all commercial vehicle electric drive systems from ZF, the CeTrax system is supplied complete with inverter and electronic control unit.



Advantages at a glance

- Can be combined with common drive axles and ratios
- Application of proven components from ZF-EcoLife city bus transmission
- Use of standard axles with common ratios possible
- ZF system including inverter and electronics

TraXon Hybrid

Clean. Quiet. Efficient.

Reducing CO₂ emissions is the order of the day. Low-cost goods transport, plus delivery in city centers that have diesel vehicle bans. Coach operators who want to reach tourist attractions or city-center hotels face similar challenges.

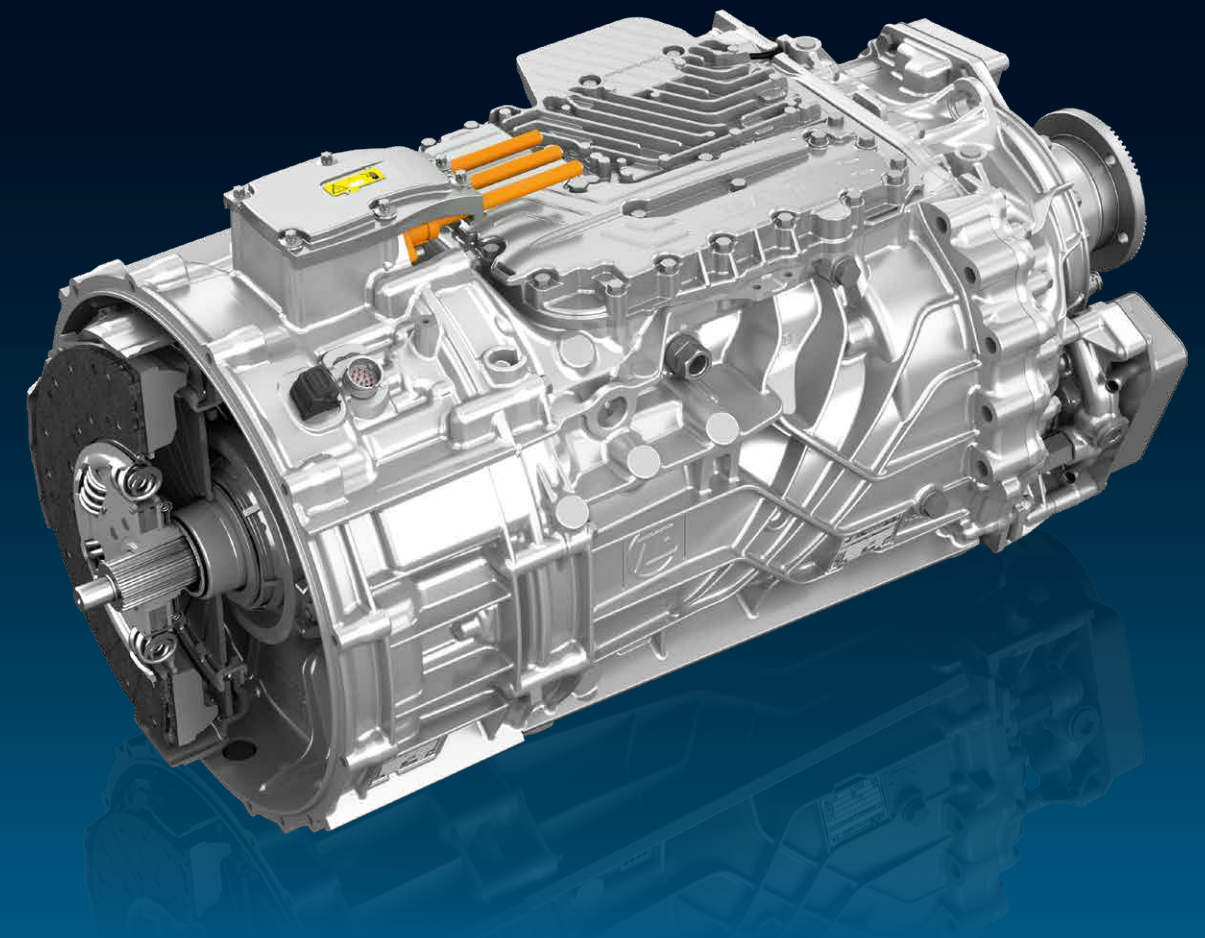
Reduction in fuel consumption
by up to

7 %

The solution is vehicles that are both economical in long-distance travel and also permitted in zero-emission zones. Specially for this purpose, ZF offers its TraXon transmission system in combination with a powerful hybrid module that enables electric driving. The basis for this is the state-of-the-art TraXon transmission system, which comes with outstanding characteristics.

The TraXon hybrid concept supports the vehicle drive while saving fuel, and its boost function simultaneously improves vehicle dynamics in long-distance travel. In inner-city operation, the hybrid drive can be uncoupled from the internal combustion engine for locally emission-free driving.

While a fuel saving of up to 7% is realistic on long-haul routes, trucks in all-electric operation drive emission-free and almost noise-free.



During braking, electric energy can be recuperated at all times.

The electric motor with innovative cooling concept develops a peak performance of up to 130 kilowatts, which is enough for even heavy vehicles. The highly integrated hybrid module requires a transmission system installation space that is barely longer – approx. 210 millimeters.

The hybrid system comes complete with inverter and electronic control unit, traction control system, fault memory, driving functions and more. It features interfaces to the energy management system as well as to the Openmatics telematics platform.

Right from the start, when designing the clutch, ZF took into account the special requirements that result from the additional mass of the electric motor and the hybrid functions.



Advantages at a glance

- Complete hybrid system with inverter and EST 54 electric control unit
- Suitable for buses and trucks with a total weight of 26 or 40 tons
- Electric motor with integrated ratio stage
- 130 kW peak performance / 75 kW continuous performance
- Hybrid functions such as all-electric driving, boost mode, regenerative braking and stop/start
- Clutch specially designed for the hybrid system

Bus Products

When it comes to power sources for electric buses, ZF offers a broad range, from central drives to drives close to the wheel, to hybrid drives. Matching inverters and control units complete the drive systems. All-electric power steering makes the perfect addition.

The compact, lightweight **CeTrax lite** drive system for minibuses features fully integrated electronic control unit and inverter. When it comes to the electrical components, ZF relies on scalable solutions from the passenger car sector and validates them for commercial vehicles. CeTrax lite can be combined with standard axles and common ratios.

Another fully integrated system with electric components from passenger car production is the **CeTrax mid** for midibuses. It distributes the load over two idler shafts in a single housing. That enables highly efficient power shifts.

An electric axle drive is currently in the advanced concept phase. The motor and shift technology are based on the CeTrax lite/mid. Depending on the bus size and operating range, single or multiple-gear solutions with outputs of 150 to 300 kilowatts are possible. That means the axle drive, combined with market-specific brakes and wheel rim sizes, can be used in all markets worldwide.

The **CeTrax electric central drive** can be integrated simply into vehicle designs with a conventional driveline layout. It can also be combined with standard axles and common transmission ratios. With a top performance of 300 kilowatts and high system efficiency at low weight, it is suitable for all bus types up to a vehicle weight of 29 tons. A multispeed version is under development.

The **AxTrax AVE electric portal axle** is suitable for all electric energy sources. High-torque electric motors installed directly in the axle hub units deliver top

performance of 250 kilowatts to get fully loaded buses in motion quickly. During braking, they recuperate energy. The lack of a conventional driveline leaves space that allows for new vehicle designs. Using standard components saves warehousing and service costs compared to other near-wheel drives.

In the **TraXon Hybrid** modular hybrid system, the electric motor is fully integrated in the TraXon automated manual transmission. Combustion boosting and braking energy recuperation save up to seven percent fuel in long-distance travel. Depending on the system design, purely electric driving is also possible.

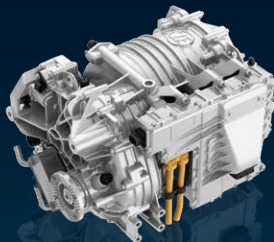
ZF **high-voltage inverters** with nominal voltages of 350 to 650 volts control the asynchronous motors of ZF electric drives.

The electronic **EST 54 control unit**, which has already proven its value in EcoLife transmissions, uses the SAE-J-1939 standard to communicate with drive and vehicle components. It features a diagnostic interface. The software can be adapted to the specific vehicle. The Openmatics telematics platform offers a variety of additional features.

The **fully electric ReAX EPS electric power steering** is compact, lightweight and economical. Thanks to its powerful electric motor, it needs no support from hydraulics or a combustion engine. That makes it predestined for especially eco-friendly, all-electric or hybrid commercial vehicles.

Electromobility Products for Buses

Electric Central Drives



CeTrax lite

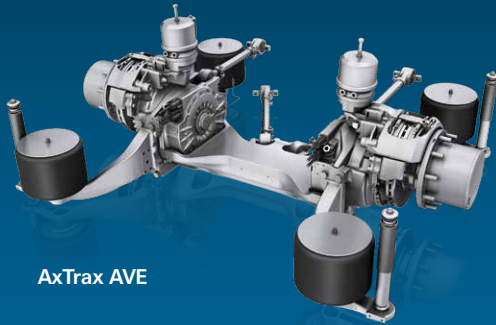


CeTrax mid



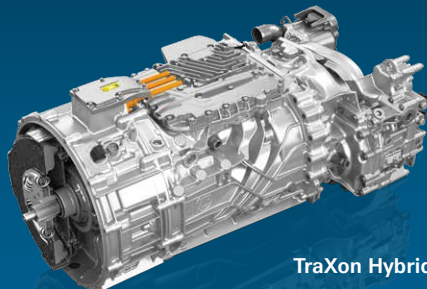
CeTrax

Electric Drive Axle



AxTrax AVE

Hybrid Drive



TraXon Hybrid

Electronic Components



Inverter



EST 54

Electric Steering



ReAX EPS

Truck Products

ZF electric drive systems provide all-electric or semi-electric solutions for light commercial vehicles and trucks. They range from central drives to axle and wheel drives or hybrid drives, complete with suitable inverters and control units. Also available is all-electric power steering.

Fully integrated here are electronic control unit and inverter for the compact, lightweight **CeTrax lite** drive system for vans and light trucks. For the electrical components, ZF relies on scalable solutions from passenger cars and validates them for commercial vehicles. CeTrax lite can be combined with standard axles and common ratios.

Another fully integrated system with electric components from passenger car production is the **CeTrax mid**. It distributes the load over two idler shafts in a single housing. That enables highly efficient power shifts.

The **CeTrax electric central drive** can be integrated simply into vehicle designs with a conventional drive layout and combined with standard axles and common ratios. With its high system efficiency, it is suitable for light and medium-duty commercial vehicles, for example waste collection vehicles. A multispeed version is under development.

The compact **eVD2 electric drive unit**, which is already proven in passenger cars, also makes vans and light commercial vehicles eco-friendly and emission free. The electric motor and transmission are located in a single housing together with the inverter and the control unit. The driven axles can be connected directly to this.

Furthermore, ZF is planning an electric axle drive for light and medium-duty trucks. Its motor and shift technology will be based on the CeTrax lite/mid. With outputs of 150-300 kW combined with a single or multi-speed transmission, this solution is designed for trucks in municipal and delivery transport worldwide. Market-specific brakes and wheel rim sizes ensure maximum flexibility.

The **AxTrax electric driven axle** for purely electric trucks is based on the proven electric portal axle for city buses. The electric motors integrated in the wheel heads are capable of full recuperation in coast mode. No cardan shaft is needed, which leaves space for battery packs along the body-on-frame. The result is highest-possible safety in case of collisions.

In the **TraXon Hybrid** modular hybrid system, the electric motor is fully integrated in the TraXon automated manual transmission. Combustion boosting and braking energy recuperation save up to seven percent fuel in long-distance travel. Depending on the system design, purely electric driving is also possible.

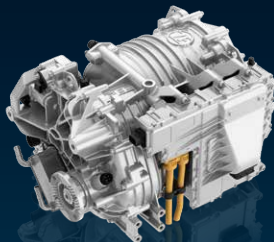
The **high-voltage inverters** used by ZF have a nominal voltage of 350 to 650 volts. They control the asynchronous motors of the electric ZF drives.

Already tried and tested in the EcoLife transmission, the **EST 54 control unit** communicates via the SAE-J-1939 standard with drive and vehicle components and also features a diagnostic interface. The software can be adapted to the specific vehicle. The Openmatics telematics platform offers a variety of additional features.

The **fully electric steering system ReAX EPS** is compact, lightweight and economical. Thanks to its powerful electric motor, it needs no support from hydraulics or a combustion engine. That makes it predestined for especially eco-friendly, all-electric or hybrid commercial vehicles.

Electromobility Products for Trucks

Electric Central Drives



CeTrax lite



CeTrax mid



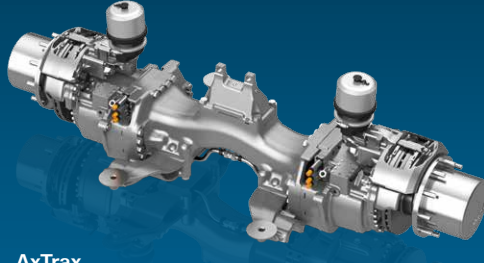
CeTrax

Electric Axle Drive



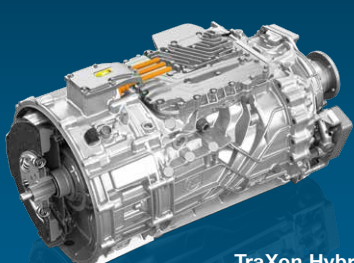
eVD2

Electric Drive Axle



AxTrax

Hybrid Drive



TraXon Hybrid

Electronic Components



Inverter



EST 54

Electric Steering



ReAX EPS

Innovative Chassis Concepts

Electric vehicles present many new challenges for chassis technology; however, they also open up new chassis layout options.

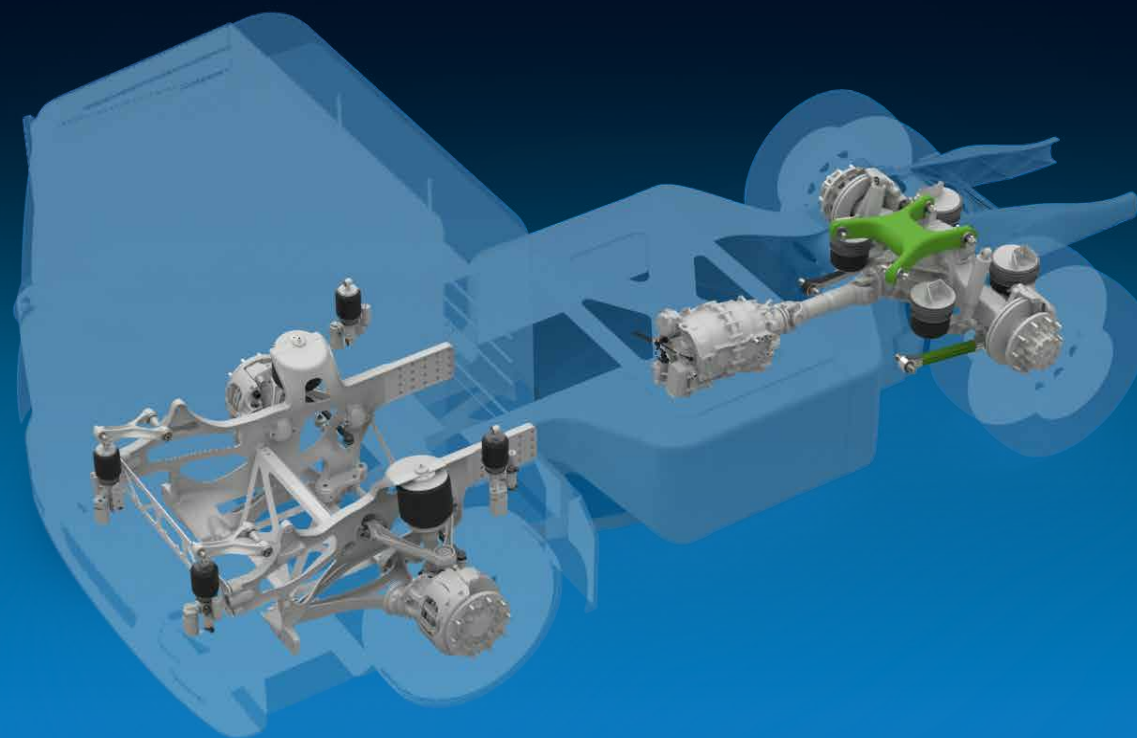
The permitted payload is the decisive factor for the cost-effectiveness of a commercial vehicle. Components required for electric drives, especially batteries, increase the empty weight. The challenge here is to offset this with systematic lightweight design. At the component level, the answer is using lightweight materials. Intelligent chassis solutions are required for developing new space and weight-saving vehicle architectures.

Depending on the electric vehicle concept, the relevant factors for dynamics, stability and comfort vary. New suspension and damping systems help offset unfavorable center-of-gravity positions or higher unsprung masses.

ZF is the right partner for innovative vehicle concepts. We ideally offer driveline and chassis technology from a single source, both on the system level and the component level.

Example of a weight-optimized chassis:

- Lightweight-design rear axle suspension with 4-point link and GRP torque rod
- ITS independent suspension on the front axle



Worldwide On-site Service – for Conventional and Electric Products

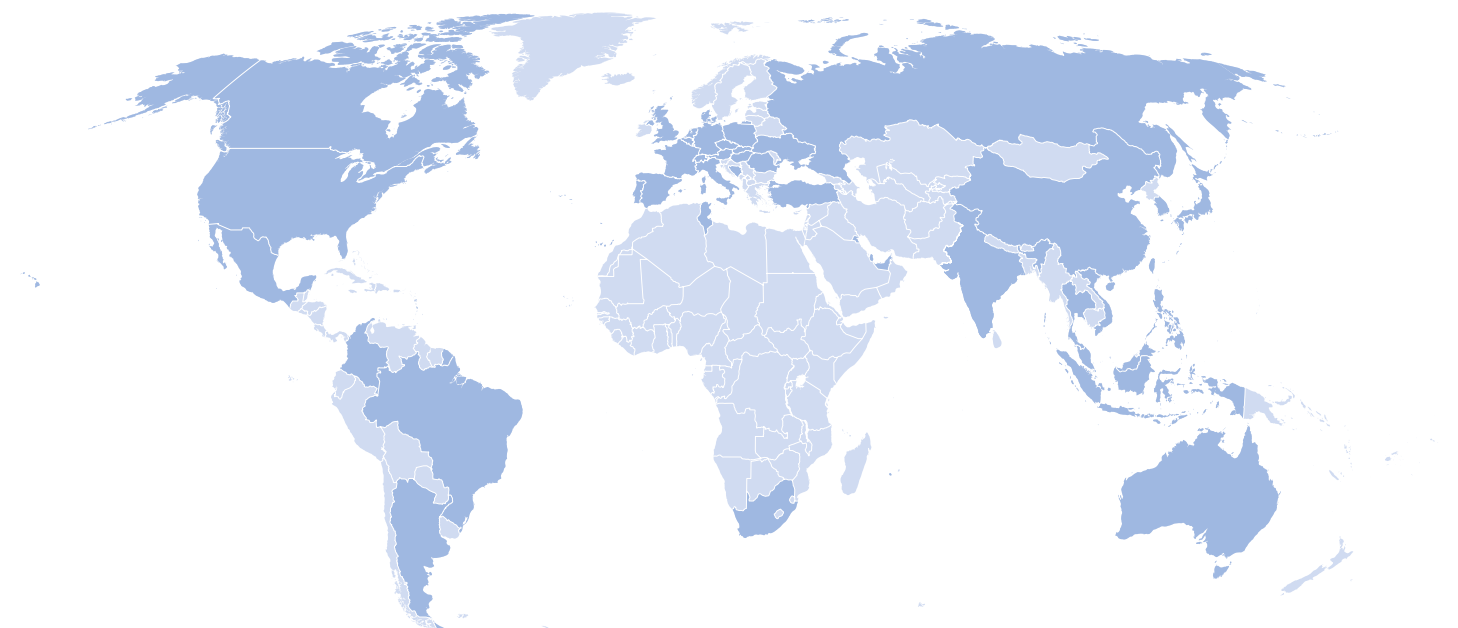
ZF is there to serve its customers, always nearby with more than 700 service centers and production locations around the globe ready to help drivers, owners or fleet operators whenever they need professional support.

Customers around the globe trust in ZF products, which is why ZF provides corresponding services on the ground in every market. Added to decades of experience with conventional drives is the know-how in electric drives our specialists have gained in cooperation with our customers.

Here's how you benefit: **ZF offers service for both conventional and electromobility products from one source** and supports you as you move into electromobility. For all your service questions, you can rely on the same contacts who support you with your conventional

ZF products. Similarly, in preventive maintenance and warehousing, you benefit from our comprehensive expertise. For example, our AxTrax AVE electric portal axle features many of the same parts as our conventional ZF rear axles, which have been proven hundreds of thousands of times in the field. It is also just as easily accessible. That means maintenance is quick and there is no need for large inventories.

Also available from ZF are additional services such as warranty extension contracts (LCC) or repair risk insurance contracts (ECP), preventive maintenance or fleet management.



ZF Friedrichshafen AG
Commercial Vehicle Technology Division
88038 Friedrichshafen
Germany

Phone +49 7541 77-0
zf.com