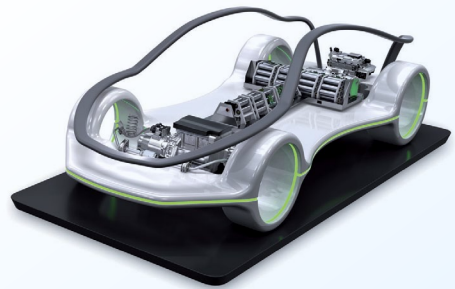
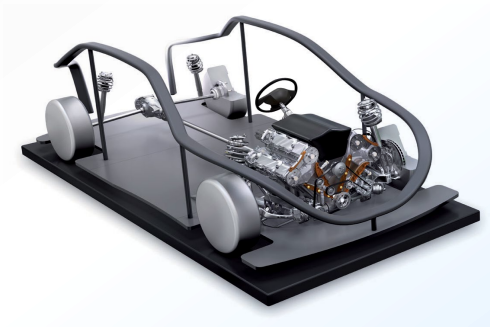


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The Future Powertrain – Challenge between Internal Combustion Engine and Electric Mobility

Der Antriebsstrang im Spannungsfeld von Verbrennungsmotor und Elektromobilität



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Abstract

Public discussions may have put an end to the joy felt by those who expected electric mobility to be implemented quickly and comprehensively, but the automotive industry has not slowed down in the least. On the contrary, the focus is now on pushing forward development programs geared towards improving conventional drives and, at the same time, on promoting the introduction of electrified and electric drives.

Schaeffler is consistently working at the component, module, and system level to further optimize drive trains with internal combustion engines. Today, the reduction of friction and weight, and above all variable valve trains – continuous and non-continuous systems – all have significant potential with regard to the task at hand.

Transmissions and wheel-related components are also areas in which action can be taken to further the development of drives based on internal combustion engines.

However, internal combustion engines and electric mobility are not complete opposites. Downsizing and downspeeding concepts are complemented by electrified systems, and the resulting combination ensures a driving experience that lives up to the demand for further improvements in both driving dynamics and fuel economy.

The area in which all-electric driving displays the most potential is in the world's booming „Megacities“, where it can help ensure emission-free local mobility. New vehicle concepts that are designed to cope with the tense traffic situation are now being created. Schaeffler is already making an important contribution by developing wheel hub motors that significantly improve vehicle maneuverability and make it possible to create automobiles with new spatial concepts.

Solutions for Efficient Future Mobility

Ladies and Gentlemen,
Schaeffler stands for “Efficient Future Mobility”.

This principle represents our commitment to providing innovative products and solutions to meet the challenges posed by mobility and energy efficiency today, tomorrow, and in the future.

As a leading automotive and industrial supplier, we are involved in numerous areas related to mobility, from automobiles to commercial vehicles and from construction machinery to rail traffic – but also from resource procurement to power generation.



We believe that energy efficiency is an issue that is relevant not only to the automobile industry, but rather that we must meet the challenge of harnessing all potential along the energy chain, regardless of its specific application.

As an innovative development partner with in-depth systems expertise, we are constantly working to improve the units, machines, and equipment into which we integrate our products, and we therefore have a global production, research, and development network at our disposal. After all, the goal of reducing friction and thus ultimately using energy in an efficient manner is deeply embedded in Schaeffler's genes.

Global Megatrends

Shorter innovation cycles, new technologies, and rapidly changing markets mean that companies must examine long-term developments and trends and look beyond immediate tasks now more than ever.

Knowledge of future requirements and opportunities is necessary for retaining the capacity to generate innovations in the future and therefore to secure the company's success in the long term.

When it comes to today's key future developments – of which we are systematically keeping track – we can all agree on one thing: World-wide population growth (9 billion people will inhabit the Earth by the year 2050) and increasing urbanization (7 billion of those people will be living in cities) mean that our future mobility faces major challenges, especially when it comes to ensuring individual mobility.

We are seeing shifts and new market participants in the value added chain as a result of technological changes, especially in the fields of power generation and energy use.

The regional changes that are taking place, especially the increasing significance of China/Asia and the other BRIC countries, do not need to be explained in detail here as they already play a very significant part in the decisions we make.



This brings with it further challenges in that increased requirements are placed on employees and their qualifications. Last but not least, it is necessary to mention the rising demand for new raw materials and the importance of securing supplies of these.

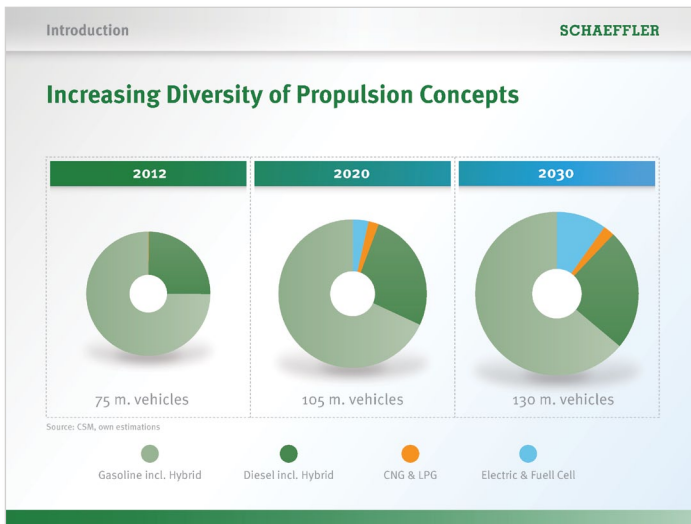
Increasing Diversity of Drive Concepts

The diversity of drive concepts will increase in the future as a result of increasingly stringent environmental legislation and concerns about limited supplies of fossil fuels – and we see this first and foremost as an opportunity for our industry.

If we look forward to the year 2030, a mere 20 years from now, we will see the internal combustion engine still playing a major role on the market while electric vehicles will also enjoy rapid growth rates. Viewed

as an absolute, the number of internal combustion engines will in fact be higher than it is today. It must be taken into account, however, that hybrid drives also incorporate an appropriately designed internal combustion engine.

A direct consequence is that harnessing the potential of the internal combustion engine puts us in an excellent position to reduce CO₂ emissions. The same naturally applies to electrified drive trains as well – from start-stop systems to plug-in-hybrids – which are becoming increasingly important, and also to drive train concepts that incorporate

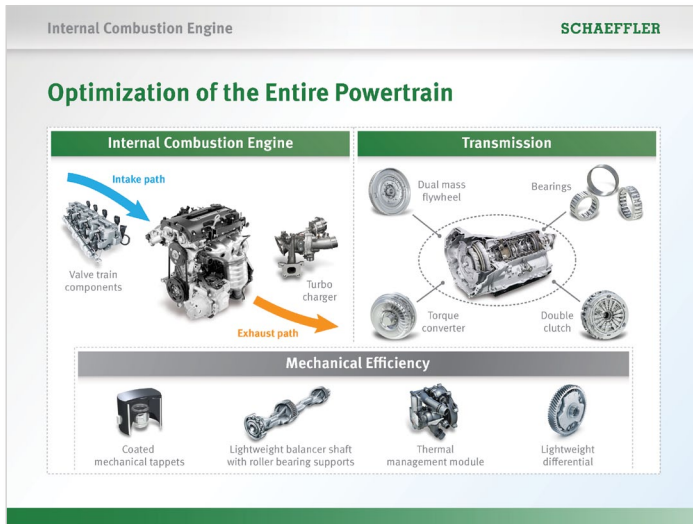


the internal combustion engine as a range extender alongside a primarily electric drive. Megacities in particular will require emission-free local mobility and thereby accelerate the development of purely electric vehicle drive systems.

The automobile industry has to face these challenges and combine the different technologies together in an economically optimized way.

Optimization of the Entire Powertrain

Vehicle drive systems are thus caught between the conflicting priorities of increasingly stringent legislation on emissions, increasing customer requirements, and the search for the “right” drive concept.



At Schaeffler, we believe that the internal combustion engine still has significant potential – potential that can be increased by first and foremost taking a holistic approach to optimizing the entire drive train in a targeted manner.

The most significant technological trends in this context are downsizing, which goes hand in hand with forced induction in diesel and especially gasoline engines, speed reduction, load point shifting, start-stop systems, and the reduction/prevention of friction.

The specific contribution made by Schaeffler is based on components designed to improve mechanical efficiency, and includes systems that optimize the combustion process, such as the fully-variable MultiAir

valve train system, and systems that allow a more efficient transmission of force, such as mechatronic modules for double clutch transmissions.

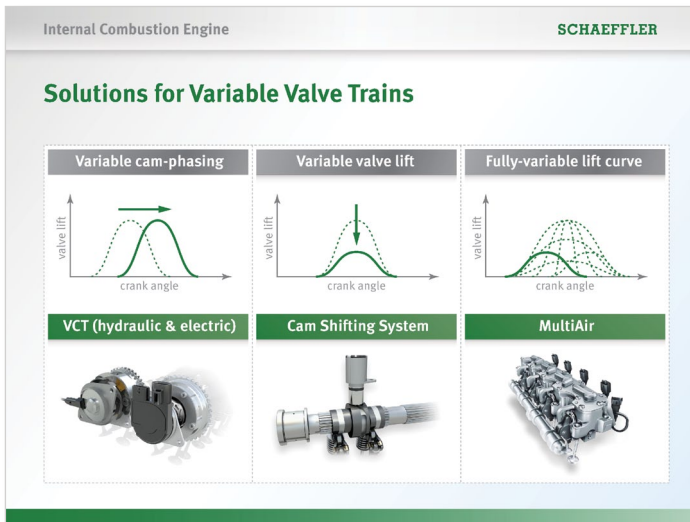
We are thus already supplying key technologies that allow the potential for improvement offered by drive trains based on internal combustion engines to be utilized.

Numerous individual measures must be taken that span the entire drive train – from the internal combustion engine and transmission to the axle drive and wheels – and only by implementing all of these together can we achieve lasting improvements in fuel economy.

I would like to take a more detailed look at some of these technologies.

Solutions for Variable Valve Trains

The variable valve control system is one of our core areas of expertise, and we see our technology as an „enabler“ that allows the combustion process to be optimized and thus fuel consumption and emissions to be reduced.



Our portfolio includes solutions that make phase shifting, two-stage, three-stage, and continuous valve lift adjustment, and combined variability possible. Camshaft timing systems are now indispensable to modern engines.

In addition to hydraulic systems that function on the inlet and exhaust side, electromechanical camshaft timing systems are also becoming increasingly interesting, as they better fulfill the requirements that will be placed on phase adjustment systems in the future.

Valve lift curves can be influenced continuously and non-continuously, though both variants are always combined with phase adjustment systems.

Non-continuous solutions include both switchable tappets and pivot elements and also two and three-stage cam shifting systems that are already on the market or are currently being developed.

And finally, Schaeffler's fully-variable MultiAir valve control system delivers a solution that, thanks to a wide range of functions that includes influencing the valve lift, the opening period, and (when the full functional scope is achieved) cylinder deactivation, contributes significantly to improving fuel economy and exhaust gas quality while simultaneously increasing performance and torque.

Electric Variable Camshaft Timing

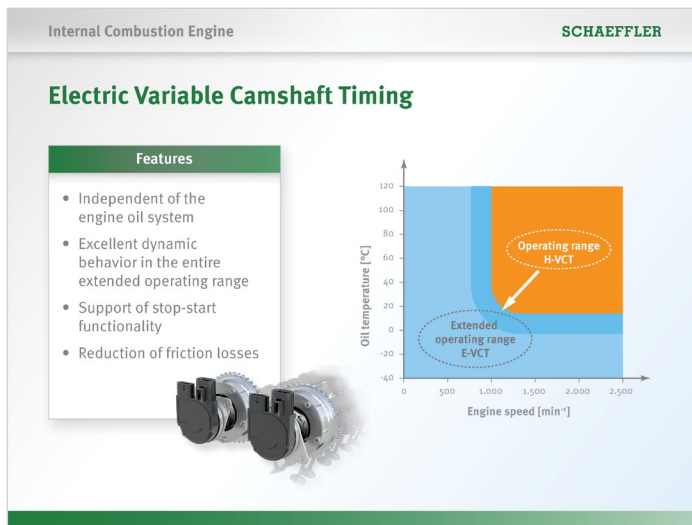
Conceptual changes in the drive train necessitate significantly faster camshaft timing systems that are independent of the engine oil system in order to fully exploit the potential for improving fuel consumption.

While hydraulic phase adjustment units are not effective until there has been a build up of hydraulic pressure after starting the engine, electric cam phasing units allow adjustment of the camshaft timing before starting.

This has the major advantage that phase adjustment can be matched to the environmental conditions, thereby making a significant contribution to reducing emissions, particularly when the engine is cold.

The capability of making phase adjustments when the engine is switched off is particularly interesting for hybrid drives, which are characterized by frequent start-stop operations. This applies for simple start-stop systems and complex hybrid modules.

In addition, electromechanical phase adjustment offers significantly higher phasing dynamics combined with considerably improved accuracy in the entire operating range, which ultimately enables more dynamic calibration.

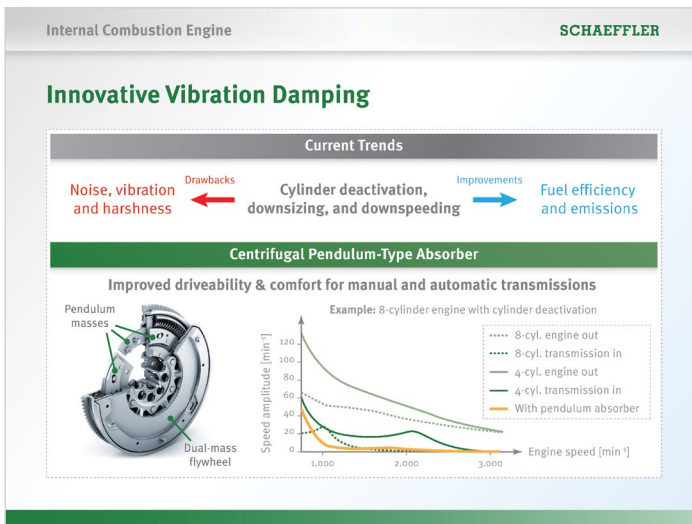


A minor advantage of electromechanical systems worth mentioning is that they prevent friction because, in contrast to hydraulic systems, they operate according to the power-on-demand principle and therefore make a comprehensive contribution to reducing CO₂ emissions.

Innovative Vibration Damping

As already mentioned, downsizing and downspeeding are innovative trends in the entire drive train. While cylinder deactivation was mainly used to increase the efficiency of V8 engines until several years ago, this technology is now also used in downsized engines and rounds off our modular system of variable valve trains.

Both downsizing and cylinder deactivation initially have an adverse effect on the NVH behavior of engines or drives. Vibrations that reduce driving comfort can be reduced by engine balancer shafts, which can be made more efficient if they are designed with rolling bearing supports.



Schaeffler also offers suitable damping elements “between” the engine and transmission for every application.

The invention of the dual mass flywheel 25 years ago laid the foundation for these damping elements and has committed us to continuously develop this product line. On the basis of our experience and customer requirements, we have developed this solution by adding an innovative centrifugal pendulum-type absorber. This ensures the usual level

of comfort “despite” downsizing, downspeeding and cylinder deactivation, both with manual transmissions and automatic transmissions with torque converters.

Trends in Transmissions





Modern transmissions play a significant role in enabling engines to be operated at their optimal operating point, which ultimately results in a further reduction in CO₂ emissions.

The trend towards more gears and a wider spread of transmission ratios starts with manual transmissions and extends to double clutch transmissions and is particularly apparent in automatic transmissions with torque converters – CVT transmissions also gain from a wider spread of transmission ratios.

We have a broad portfolio of start-stop and hybrid solutions, which start in the transmission environment and make a significant contribution to improving system efficiency. In addition to the measures that have already been mentioned, the focus of further development must also be placed on the internal efficiency of transmissions.

Internal Combustion Engine SCHAEFFLER

Trends in Transmission Technologies

Manual Transmission <ul style="list-style-type: none">1. Automation for emerging markets2. Stop-start capability  <p>Clutch position sensor</p>	Double Clutch Transmission <ul style="list-style-type: none">1. High growth rates2. Electromechanical actuation  <p>Double clutch lever actuator</p>
Automatic Transmission <ul style="list-style-type: none">1. Transmission ratio spread and number of gears2. Hybridization  <p>Torque converter with hybrid module</p>	Continuously Variable Transmission <ul style="list-style-type: none">1. Key market Japan2. Hybridization  <p>CVT pulley set</p>

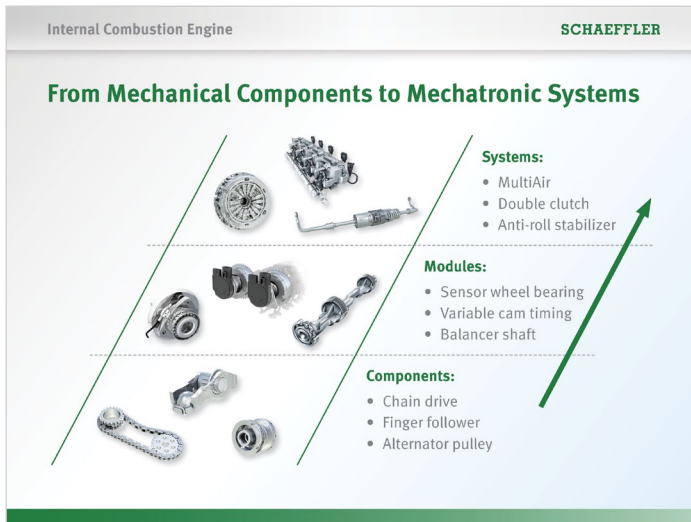
This includes lightweight design concepts, reducing friction and electromechanical actuator systems. The trend towards automation will continue in the foreseeable future, whereby the regional focus will be on different concepts. While double clutch transmissions are enjoying a boom in Europe and China, we are seeing significantly improved automatic transmissions with torque converters in the premium segment and in North America and, for example, CVT transmissions in Japan.

Even automated manual transmissions should not be written off because they are the basic automatic transmission in emerging markets.

From Mechanical Components to Mechatronic Systems

Schaeffler's origins as an automotive supplier lie in the development and manufacture of rolling bearings, which formed the basis for further high-precision mechanical parts.

We have systematically expanded our product range to include modules and systems by building on this solid basis of engineering ideas and production expertise.



The focus was always on the best possible understanding of the relevant higher-level system, in which we “developed” components or modules, so as to offer the customer optimal solutions.

The current range extends from components, which comprise only a small number of individual parts, right up to mechatronic systems, which combine different disciplines.

Schaeffler’s MultiAir, double clutches and electric roll stabilization systems emphasize that we are also an expert partner for the automotive industry in this field.

Extending the System Approach to Electric Mobility

We have consistently transferred this idea – from the component and module to the system – to the electrification of the drive train.

Here too, we have also started with mechanical components, which, for example, are fitted as high-speed bearings in electric drives.



In addition, we are electrifying familiar Schaeffler products thereby developing hybrid modules, which simply comprise a clutch and an electric motor. We are currently testing these systems.

We have therefore created solutions, which will help to change the mobility of tomorrow: Regardless of whether this is by increasing efficiency and agility or driving safety in new vehicle concepts – the keywords here are electric axle drives and highly-integrated wheel hub drives. The prerequisites are always an understanding of systems, interdisciplinary thinking and a holistic approach to solving problems.

A Holistic View on Electric Mobility

Electric mobility must begin with renewable energies in order to take a decisive step towards reducing CO₂ emissions.

We have therefore decided to serve the “electric mobility ecosystem” via the “eMobility Systems Division”, which bundles expertise from our industrial and automotive business.



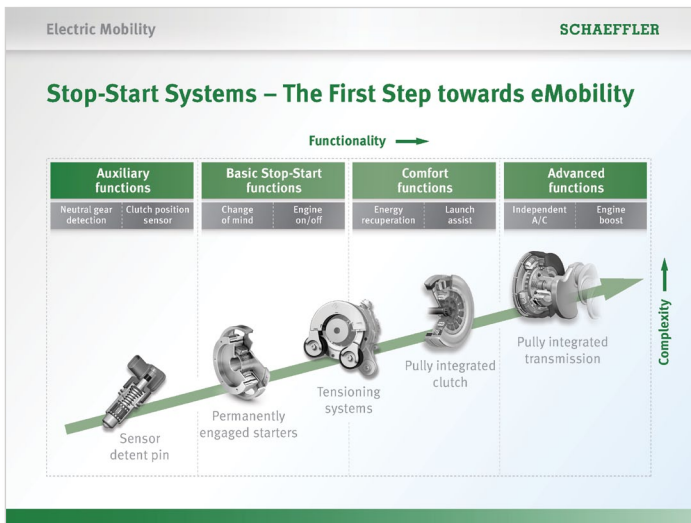
In addition to four-wheel electric mobility, we are also expecting that electrified two-wheel vehicles will continue to gain in importance and electric mobility will pave the way, particularly in urban centers. We are placing our focus on efficient solutions for electric vehicles, but we are also convinced that the areas of renewable energy generation, electrified two-wheel vehicles and complex electric vehicle drive systems must also supplement each other.

Schaeffler is thereby pursuing a holistic approach that integrates both its Automotive and Industrial divisions and thus combines the numerous individual competencies in order to serve the market on a system level.

These issues have additionally been addressed and discussed by the automobile industry with government, universities and research bodies – and we are also actively participating in this process.

Start-Stop Systems – The First Step towards Electric Mobility

Start-stop systems are the first step to electrification and they are already capable of doing much more than just starting the engine.



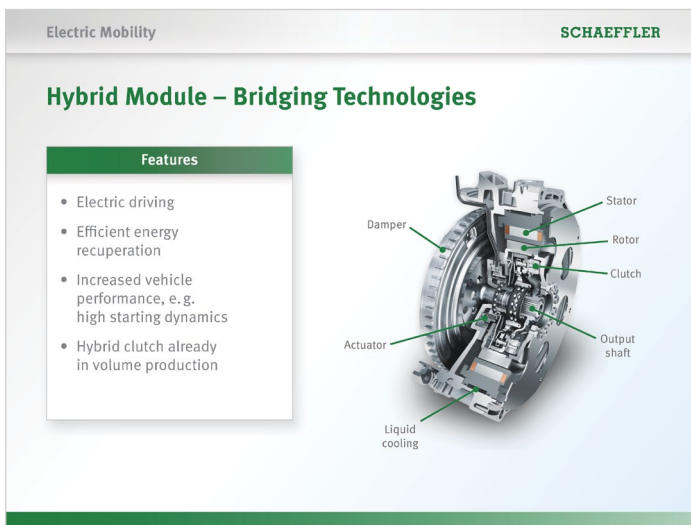
Schaeffler considers itself as a pioneer for different concepts with its broad technology portfolio: While sensors for gear and neutral position detection lay the foundation for start-stop systems, decoupling elements in the belt drive form the basis for extended functionalities and also maintain the efficiency of the auxiliary drive system.

Particularly in developed markets, the readiness of customers to accept start-stop systems will depend on whether basic comfort functions are provided such as change-of-mind and air conditioning while the engine is switched off.

More extensive systems will also enable boosting, i.e. assisted acceleration, and at the same time ensure that the required energy is available by means of high-speed charging.

The Hybrid Module – Bridging Technologies

The first step towards all-electric driving is the full hybrid configuration. This configuration enables all-electric propulsion for short periods or assists the internal combustion engine with a boost function.

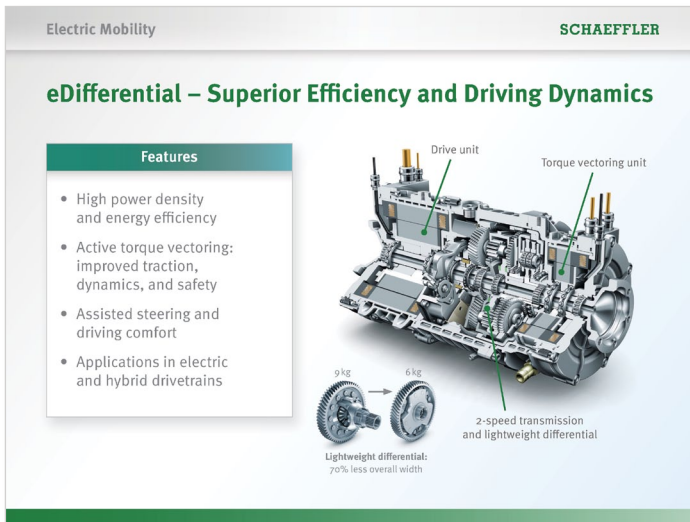


In addition, the hybrid clutch enables efficient energy recuperation. Schaeffler already produces the hybrid clutch in volume and complete hybrid modules are under development.

These modules offer a compact solution, particularly in an axial direction, for dual mass flywheel arrangements and a clutch that is radially integrated in the electric motor.

eDifferential – Superior Efficiency and Driving Dynamics

Plug-in hybrids will become more important in the medium term. An electric axle concept is highly suited to this type of vehicle, which Schaeffler is offering as an innovative solution called the eDifferential. The technical basis for this solution is our extremely compact lightweight differential with 70% lower overall width and 30% less mass compared with conventional designs.



In combination with an electric motor, this results in a drive arrangement on one axle. The eDifferential is produced by adding a superimposed transmission stage. In addition to the pure drive function,

the eDifferential also enables electric torque vectoring, i.e. a transverse distribution of torque, and creates an ideal platform for innovative driving dynamics control. The range of applications spans from applications in conventional vehicle categories right up to extremely-dynamic sports cars.

eWheel Drive – Enabling All-new Vehicle Concepts

With the wheel hub drive eWheel Drive, we are focusing on future, fundamentally new vehicle concepts and presenting the most consistent technology for realizing urban mobility.



The eWheel Drive is a mechatronic module, which combines drive, deceleration, energy recovery, driving dynamics and driving safety functions.

It comprises the highly-integrated components of electric motor, power electronics, friction brake including an adaptive controller and a powerful cooling system.

The driving dynamics can be directly influenced due to the short gear-less transmission path between the agile and precisely controlled drive motors and the road. This not only improves driving behavior, but also allows driving dynamics control in a quality not previously available.

The performance of current brake and stability systems will be exceeded by cooperative wheel slip control of conventional friction brakes and electromotive braking. The issue of unsprung or wheel-sprung mass is in our view uncritical with compact city vehicles and comparatively low speeds.

Some basic research must still be conducted on this technology, although large quantities of similar solutions for electric scooters are now being produced.

Efficient Future Mobility

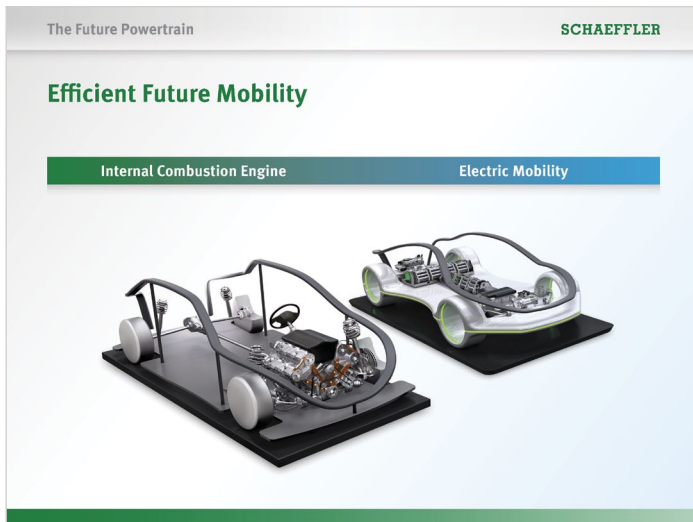
How do we solve the challenge between the internal combustion engine and electric mobility?

Our mechatronic systems expertise is the driving force behind our innovations, whereby we rely on interdisciplinary thinking, an understanding of systems and a holistic approach to solving problems.

We are working on the assumption that:

1. The internal combustion engine will continue to influence the automobile for many years and offers significant potential for optimization.
2. We will comprehensively serve the “electric mobility ecosystem” from the eMobility Systems Division: From renewable energy generation and the pedelec right up to the passenger car.
3. This will enable us to offer solutions for the drive train of today, tomorrow and in the future, irrespective of whether this is with an internal combustion engine or electric drive train.

We consider it essential to use our development resources in both fields and above all to find solutions for the interaction of technologies in order to achieve the long-term goal of sustainable reductions in fuel consumption and emissions.



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