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Challenges and solutions for the future powertrain

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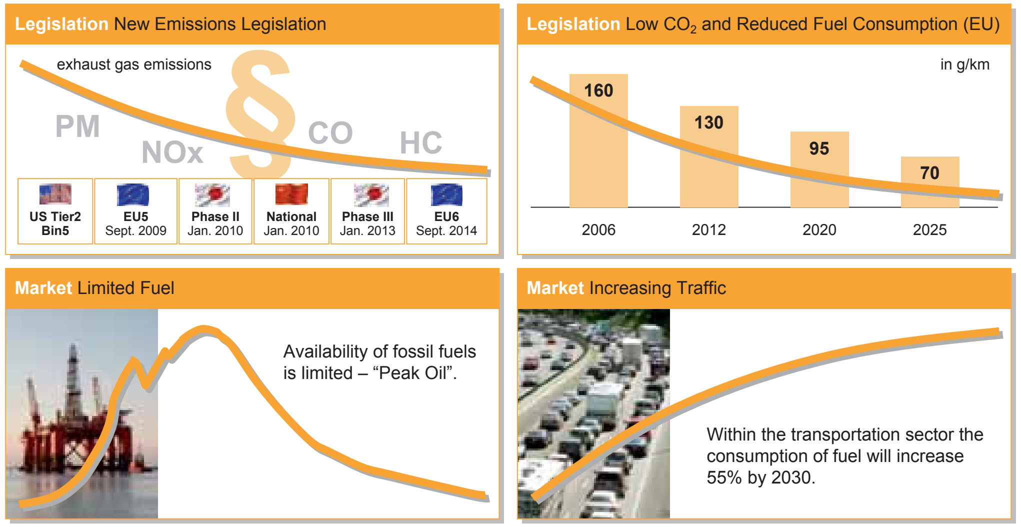

Figure 1 Drivers for the development of emissions-free mobility

Framework conditions

Thermodynamics, mechanics and the electronic control level of the powertrain can continue to make a major contribution to make vehicles more economical and environmentally friendly. The efficiency of an engine, for example, can be significantly increased through a combination of suitable technologies, while at the same time the energy requirement of engine accessories can be reduced with electrification. New types of components and sensors also enable ever more accurate control and regulation strategies to be established in control units (ECU) – including transmission control as a key function. The engine and transmission control software required is optimized for the present technological challenges. Since the combustion engine will remain the dominant drive system for motorized vehicles for many years to come, it is imperative that it is further optimized. With the technology already available, double-figure improvements in consumption will be possible in the short term, which will be a significant environmental factor in view of the large numbers of vehicles involved.

At the same time, significant progress is being made in the form of a combustion engine supported by an electric motor (hybridization) because the increase in efficiency that can be achieved is even higher than through optimization of the combustion engine alone. In the longer term, the ideal of an emission-free vehicle will be achievable in the form of electric vehicles which draw their electric current from renewable sources.

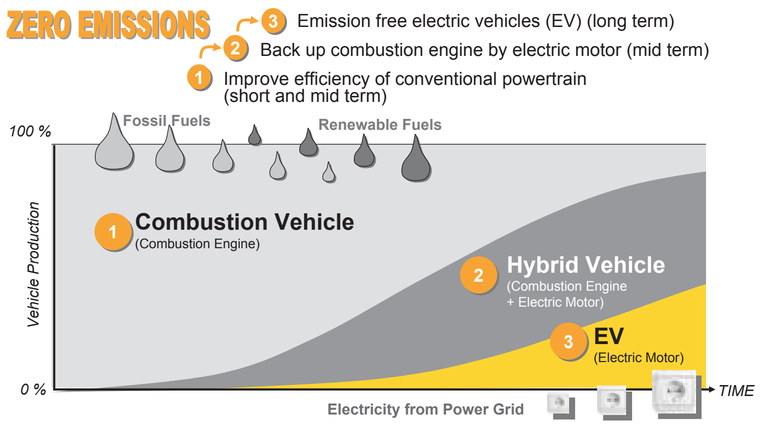

Figure 2 Steps on the road to freedom from emissions

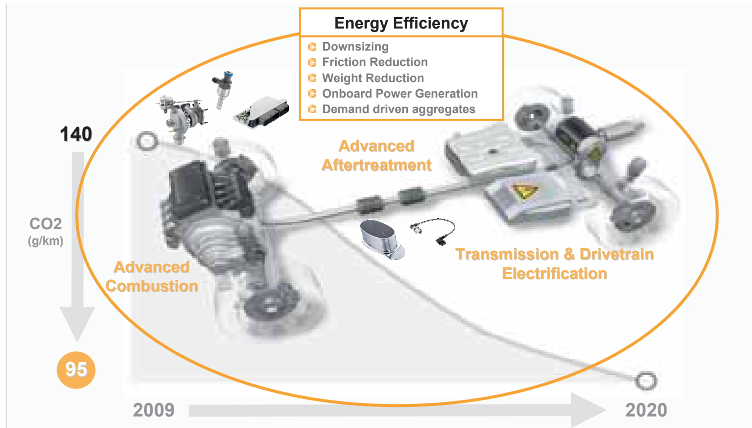

Figure 3 Challenges ahead (Euro 7)

Because of the demand for quick action in regard of increasingly strict emissions legislation and finite supplies of crude oil (Figure 1), the powertrain division of the Continental Automotive Group is pursuing a systematic approach which comprises modular solution elements for all current and future powertrain configurations. These solutions can be selected and combined according to the vehicle category and requirements profile: from direct petrol injection in combination with exhaust-gas turbocharging for highly efficient petrol engines or diesel engine technology for further optimized firing processes and hybrid vehicles of all types to a pure electric vehicle (Figure 2).

With this portfolio of solutions Continental has created a future-oriented base from which it can meet exhaust emission standards such as Euro 6 (September 2014) and Tier2Bin5. The vehicles of tomorrow will therefore be more economical and cleaner than ever (Figure 3). The amount of CO_2 that they emit will continue to fall, enabling them to meet the most stringent requirements of vehicle buyers, vehicle manufacturers and legislation. Selected examples below show the efficiency technologies employed by Continental to support this future of individual mobility.

Figure 4 Newly developed exhaust-gas turbocharger

Engine

Turbocharging

Smaller engines but higher specific performance – this apparent contradiction describes the prominent trend in engine development. Specifically in the case of the petrol engine, turbocharging in combination with direct injection and optimized valve timing are rapidly gaining importance. This has long been the standard with the diesel engine. This combination of technologies enables an increase in performance in smaller-capacity engines (downsizing) and lower speeds (downspeeding). Due to turbocharging the engine is operated more frequently in areas with high degrees of thermodynamic efficiency. The result is a drop in consumption but at the same time a more powerful engine.

Continental has already developed its first generation of exhaust-gas turbochargers (ATLs) to market maturity (Figure 4). The new charger will be used from 2011 in petrol engines on a European vehicle platform. Although turbochargers have been seen largely as a mature standard technology, the design features of the Continental ATL illustrate the advantages of rigorous new development. One example of innovation is the design of the ATL which can be assembled completely from one direction – and therefore automatically. At the same time, the charger is of a modular construction and can be particularly well adapted to various engine sizes. The largest advantage of the new turbochargers, however, lies in their potential for more accurate regulation of the boost pressure.

Electrically operated waste gate

A further feature of the modular ATL concept is the facility to use an electrically adjustable actuator for the waste gate. This valve is opened as soon as the exhaust gas volumetric flow becomes too great for optimal turbine functioning. At low engine speeds and a small exhaust gas volumetric flow, on the other hand, the waste gate remains closed. The function of this valve has a large influence on the initial response and sensitivity of the charger in the lower speed range, and therefore on the performance of the engine (so-called turbo lag) Continental has patented a ball valve design for its ATS generation which has two key advantages:

- Firstly, little power is required to lock the valve tight. This means that a compact electric motor is sufficient to close the waste gate even at a high ambient temperature, even though the coils of an electric motor permit a lesser performance at high temperatures. Moreover, the valve leakage is dramatically less than with conventional valve designs (Figure 5).

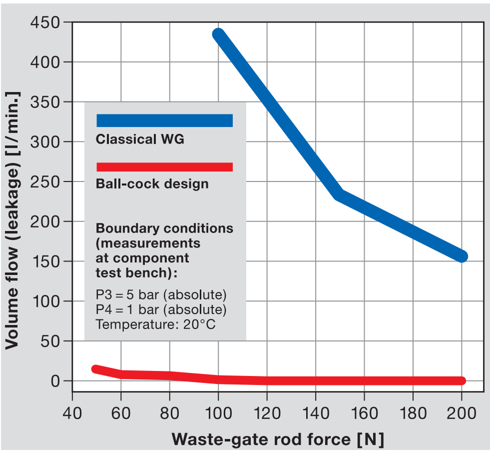

Figure 5 Continental turbocharger (red line) with minimal leakage for better initial response and sensitivity

- Secondly, the flow curve of the electrically operated waste gate is far more linear than with valves in common use today. The new ATL therefore enables the boost pressure control in the engine control unit to be optimized even further. That, in turn, means clean, defined combustion.

Efficient combustion through precise fuel injection

The basis for good thermodynamic engine efficiency is a fuel-delivery control phase which can be adapted as accurately as possible to the current operating situation. Direct injection (DI) into the combustion chamber is the technology of choice in this respect. This has long been the case with diesel engines. But DI also makes petrol engines more economical. First and foremost, however, DI is the ideal solution when used in combination with a turbocharger. The directly injected fuel has an evaporative cooling effect which enables higher compression ratios without a knocking tendency on petrol engines fitted with ATL. This also makes DI a key technology in petrol engines. To that extent, diesel and petrol engines are becoming more similar.

Today, there are two basic injector design (injection valve) in use for the different classes of vehicle and engine requirements: For petrol engines with direct injection, Continental has developed a new XL3 generation of injectors with solenoid actuation (solenoid injector). The component enables improved minimum-quantity injection and the ability for multiple injection which can create a so-called charging layered arrangement in the part-load range. An ignitable mixture is only generated near the spark plug. The rest of the combustion chamber is filled with an extremely lean mixture, i.e. with a lot of excess air and a very small quantity of fuel.

In diesel engines, the piezo technology introduced by Continental has now proven its worth millions of times over. In this type of injector, the

Figure 6 The latest generation of piezo injector

inverse piezo effect lifts the nozzle needle. The term “piezo effect” is used to refer to the property of certain ceramics which enables them to create an electric voltage under pressure or through an impact effect (for example piezo ignition in a lighter). The effect also works in reverse, however (hence the term inverse): as soon as a voltage is created at the ceramic piezo stack in the injector, the molecular structure of the ceramic moves. This effect occurs extremely quickly and, in combination with powerful engine management, enables highly accurate injection with a very high spread between minimum and maximum injection volumes.

Continental has confirmed its position as the leader in this technology with the latest generation of piezo injectors for diesel engines (Figure 6). Whilst earlier versions of the piezo injector required a hydraulic boost to the needle lift, the piezo element of the new generation of injectors activates the nozzle needle directly. The opening times and the degree of opening can be controlled precisely so that the adjusting characteristics of the injection rate can be formed flexibly; this represents an alternative to the current norm of multiple injection.

On top of this, the piezo effect also makes the injector a sensor at the same time: Because the voltage created and the expansion of the ceramic are proportional, the piezo actuator can report the position of the nozzle needle to the control unit. This means that, for the first time, a closed loop control is created in which the control unit can correct individual volume deviations for each cylinder while the vehicle is being driven. This enables optimum values in terms of not only the emission of nitrogen oxides (NO_x), but also consumption.

Engine management: Greater integration and an open software architecture

In addition to the mechanics and electrical/electronic hardware, a powertrain system also includes primarily the software with the logic of the actual control functions. Continental operates successfully in the market with its modular design ECU platform Engine Management Sys-

Figure 7 Engine Management System 3 – EMS3 platform

tem 2 (EMS2) for all types of petrol and diesel engines, but also for power units for natural gas (CNG) and liquefied petroleum gas (LPG) materials and for bio fuel materials and for hybrid systems. EMS2 was trendsetting because it enabled the efficient reuse of tried and tested function modules in flexibly extensive solutions with specially optimized hardware. Over the coming years, EMS2 will be replaced by the completely revised EMS3 platform (Figure 7). This will offer hardware and software functionality which, from 2012, will provide the necessary efficiency for Euro 6 applications and a further reduction of CO_2 emissions.

Outstanding innovations include higher function integration in the chipset, improved scalability and the associated reduction in terms of size and weight. With five newly defined microcontroller performance classes, markets will be served in future by simpler engine management with intake-manifold fuel injection to complex truck engine management systems. Other innovations will appear in the form of smaller and lighter housings. At the same time, EMS3 represents the rigorous use of the potential of application-specific integrated circuits (ASICs) and microcontrollers with the associated software drivers and hardware-related software layers.

The open software architecture employed by EMS3 brings together the functional basis of petrol and diesel systems. It is based on the AUTOSAR standard (AUTomotive Open System ARchitecture). A major gain in terms of the platform's functionality is a lambda oxygen sensor interface which, through the software configuration of the interface ASIC, enables the probes to be exchanged without changing the hardware. Moreover, further probe manufacturers will be supported with this interface.

Sensors: Innovative solutions for reducing CO_2 and exhaust gas emissions

As seen from today's perspective, it is likely that exhaust gas treatment to reduce the emission of nitrogen oxides (NO_x) will be necessary mainly on larger diesel vehicles. Systems for selective catalytic reduction (SCR) of NO_x also require, like the support for regeneration of soot particle filters, injectors in the exhaust system. In SCR systems,

Figure 8 HC sensor

they atomize an aqueous solution in the exhaust gas which contains urea. In order to regenerate the particle filter, fuel has to be injected into the exhaust gas under certain circumstances. NO_x sensors from Continental are used to determine engine, catalytic converter and environmental data and evaluate it in the engine management electronics which, based on these figures, control the SCR system to optimal effect. Continental is also developing a soot particle sensor to meet future OBD (on-board diagnostics) requirements in NAFTA and Europe.

It is not only a combustion engine that emits unburned fuel: Processing the vapors laden with fuel in the tank system also helps to reduce hydrocarbon (HC) emissions. These vapors are collected in an activated charcoal filter. When this filter is fully laden it must be purged. The fuel vapor thus retained is fed into the intake pipe, and from here to the engine. The new Continental HC sensor (Figure 8) enables accurate measurement of hydrocarbon proportions in the purge air line. The purging process of the activated charcoal filter can thus be optimized. On hybrid vehicles, in particular, there is too little low pressure available for purging in certain operating situations (when the engine is idle). If the information base of the most accurate HC measurement possible is used and the filter purged with the help of an active pump, then purging is possible with optimized emission on demand.

Demand-regulated fuel supply

While a fuel pump in the tank normally operates at a fixed speed, the new type of space-like fuel conveyor unit from Continental communicates with

Figure 9 Electronics in the flange of the fuel conveyer unit

the engine management system and regulates the speed of the pump according to the current demands of the engine. In addition, control electronics are integrated into the flange (secured and locked in the tank bubble) of the conveyer unit (Figure 9) which can activate both DC and electronically activated (EC) pumps. The requirements regulation of the pump saves on electrical energy, which in turn reduces fuel consumption and therefore CO_2 emissions. Depending on the manner in which the vehicle is driven and its engineering, this measure can bring savings of between 1 and 2 g CO_2/km.

Electrically driven auxiliaries

Another crucial factor in determining the efficiency of a powertrain is how much of the engine's energy has to be diverted for the purpose

Figure 10 Variably controllable coolant pump

of driving accessories. With the conversion of mechanical systems to electrically driven units, there is a possibility to supply accessories with energy only as required. The electric water pump is one such example (Figure 10). It regulates the flow of coolant dynamically according to how much is required, so that the optimum engine temperature can be achieved in all operating conditions. The pump can be installed in any position. This allows automotive manufacturers greater freedom in terms of engine heat management. As the pump is operated independently of the engine, it can supply the cooling power actually required at any time. Moreover, the pump no longer requires a drive belt, which means that the engine belt can be driven more easily. This brings the belt-less engine within grasp – which will significantly reduce maintenance effort in future.

With the first fully integrated electric transmission oil pump, Continental, in collaboration with a partner, has developed a pump which, regardless of the driving situation, supplies hydraulic pressure in the transmission and therefore enables specific fuel-saving operating points. This unit, which consists of a vane pump, brushless motor and actuating electronics, also makes a substantial contribution to the reduction of CO_2 emissions.

Transmission

Control of a highly efficient dual clutch gearbox

Primarily in Europe, but also in China, dual clutch gearboxes are enjoying high growth rates. As the world market leader for transmission control technology, Continental offers control systems for the entire range of automatic gearboxes, and in 2009 brought an electromechanical transmission control system for dry dual clutch gearboxes onto the market – a global innovation (Figure 11).

Dual clutch gearboxes combine the convenience of an automatic gearbox with the efficiency and sporting character of their manual counterpart. In combination with electromechanical operation of the clutches and control rods, even the

Figure 11 Electromechanical transmission control system

consumption figures in the driving cycle compare more than favorably with those of a manual gearbox. With the introduction of an electromechanical control unit for dual clutch gearboxes, Continental is covering the complete range of current technologies. Both dry and wet dual clutch gearboxes (in which the two multi-plate clutches run in an oil bath), can optionally be activated electromechanically or electro-hydraulically.

Electrification of the drivetrain

The combustion engine of today will develop step by step into the zero-emission electric car of tomorrow. Continental expects around 2 million hybrid and electric vehicles to be on the roads worldwide by 2012. The transition will be fluent and characterized by a wide range of powertrain concepts. It is therefore crucial that systems be made both scalable and flexible by virtue of their modular design. In terms of the Continental module for power electronics and lithium ion batteries, as well as the activities in the area of electric motors, this has been done for all of the major components for hybrid and electric vehicles – right up to complete system solutions with integrated powertrain management.

In a first step, conventionally driven vehicles will become increasingly equipped with stop-start systems, which will make fuel savings of up to 10 % possible depending on the road profile. Continental is also creating the fundamental principles in this respect, as the on-board network voltage must not be interrupted during automatic starting of the engine. Otherwise consumers such as a radio, ventilation and others would be interrupted during each starting procedure. This is precisely what has been prevented by a compact DC boost converter developed by Continental which tunes a stable 12 V in the on-board power supply when the engine is started.

Electric pump for stop-start applications

Continental has developed a compression-proof single-piston high-pressure pump with media separation for the fuel supply in vehicles fitted with a stop-start system. This pump maintains petrol pressure of 50 bar while the engine is idle. During an automatic start, the fuel can be injected immediately at high pressure, which results in a more spontaneous response and improved exhaust gas figures.

Adapted drive concepts for different areas of use

The future diversity of powertrain concepts can be illustrated by three user profiles:

- The driving of electric vehicles will become increasingly important mainly in urban and their surrounding areas.
- Hybrid vehicles will assert themselves on medium-length routes. Here developments will range from a vehicle with a combustion engine that is supported by an electric drive through to electric vehicles featuring a range extender (Figure 12). The small combustion engine in this powertrain only generates electric current when there is insufficient battery charge for a longer route.
- For long-distance vehicles, drives with optimized combustion procedures and small, power-optimized engines will play a central role. The keywords in this respect will be downsizing, turbocharging and second-generation synthetic fuels.

Hybrid technology will also be used in the short term in commercial vehicles. Light trucks for goods traffic and buses in built-up areas can save around 30 % or more on fuel because they mostly operate over short distances in stop-and-go traffic in which the hybrid drive is able to utilize its advantages to the full. In the commercial vehicles sector, Continental is making its contribution to the latest generation of lithium ion batteries as part of a co-operation.

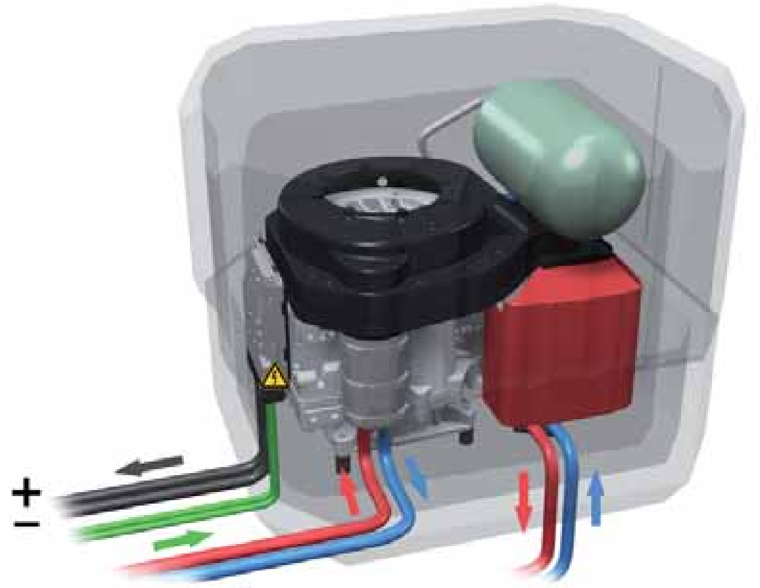

Figure 12 Range extender driving concept, e.g. in the form of a natural gas engine (CNG)

Scalable module for electrification of the powertrain

Continental powertrain has developed cost-effective drive components and complete systems for electrification of the powertrain to a production standard. This will enable the fastest possible penetration of the market for environmentally friendly technology. One of the tasks of power electronics includes converting a direct current from a battery to AC current for the electric motor. During the recuperation stage (recovery of brake energy), this procedure functions in the opposite direction – the electric motor is driven as a generator and supplies current which is stored in the battery. A DC/DC converter integrated into the housing of the power electronics converts the voltage of the hybrid battery appropriately for the standard on-board electrical system, and vice versa. In the next generation, Continental will reduce the overall installed size of these complete power electronics by a further 30 % compared with the first generation to around five liters, that is to say the space requirement will continue to fall. The components will then be integrated into a housing which corresponds to the space of the starter/generator, which becomes superfluous in this system (Figure 13). This considerably reduces the effort required for integration into the vehicles.

A further development topic is the electric axle drive. The compact design makes integration of the electric drive into different vehicle platforms easier and more flexible, which in turn provides alternative opportunities for use in existing vehicle concepts.

Continental is currently able to supply lithium ion energy storage for applications in hybrid and electric vehicles. Continental is the world's first manufacturer to produce lithium ion batteries for use in

Figure 13 Compact power electronics

Figure 14 Modular-design lithium ion battery

hybrid vehicles. It has done so since the end of 2008 (Figure 14). The latest generation of lithium ion energy storage devices provide far greater storage density than the nickel metal hybrid batteries still in use today.

Both the power electronics and the lithium ion battery are of a modular design. They can therefore be adapted to different installation spaces and performance classes at comparatively little expense. Individual assemblies are standard. Their number is only multiplied – or the various elements combined – according to the system application. This allows a broad field of application – from the stop-start system and the mild and full hybrid across to plug-in hybrids – to be implemented at high quality and optimized cost, along with electric and fuel cell vehicles.

Outlook

The potential for cooperation between the Schaeffler and Continental companies gives rise to a competence which is far greater than the sum of their individual parts. Both companies will grow courtesy of their specific know-how in the common topics fuel, air and exhaust gas, as well as engine management, transmission and mechanics (Figure 15).

There is great potential for the vehicle manufacturers particularly in the synchronization of research and development. What were formerly separate specialist areas of knowledge can together contribute to a better understanding of the entire combustion process. This is how system know-how will be broadened in the powertrain. Increased networking of the powertrain advanced development of both companies has already begun. This will enable mastering the decisive future task in the field of the powertrain, namely to optimize the complete powertrain system from an overall perspective.

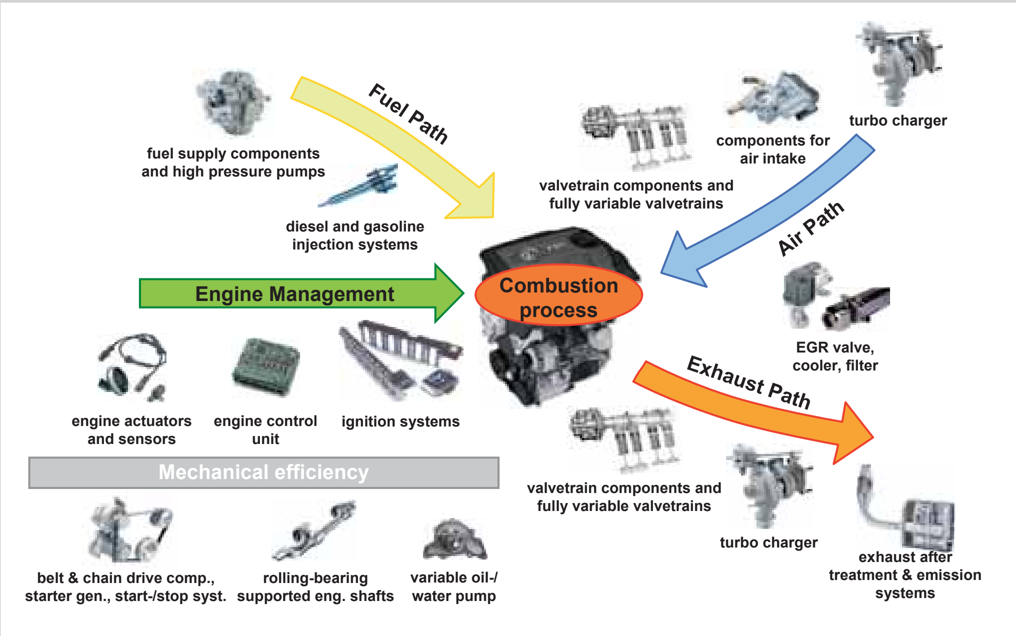

Figure 15 Joint approach by Schaeffler and Continental