Power for the future: Engines in mobile machinery – driving the economy
Foreword

You think an adequate diet is a necessity? You wish to go to work on asphalted roads? You do not want to live in a tent? Then you are dependent on mobile machines. For there is scarcely a single area of our lives that would function without mobile machines. Agricultural machines provide our food, construction machines build our houses and roads. Without forestry machines, paper would be a rare luxury and our furniture probably barely affordable. But even our electrical devices and energy production require raw materials and, without the use of enormous excavators and dumpers in copper and coal mines, these would be difficult to obtain.

This brochure gives you an insight into the core of these machines: efficient, economical and environmentally friendly engines. They reliably ensure that mobile machinery does its job problem-free day after day and even under extreme conditions. The drives are becoming increasingly low in emissions and resource consumption — and by 2014 at the latest their emissions will have been reduced to just four percent of the first limit values from the late 1990s.

What many people do not know is that behind these drives lies a significant industry, in which members of the VDMA Engines and Systems Association employ approximately 125,000 highly motivated staff worldwide. These employees have been instrumental in defining progress in this branch of industry since the invention of the diesel engine over 100 years ago. They are working on new technologies, solutions perfectly tailored to customer needs — and comprehensive measures for the protection of our environment. Because saving resources and protecting the climate is also an opportunity: an opportunity for high-quality engines and a successful collective future.

Thorsten Herdan
Managing Director
VDMA Engines and Systems
Combine harvesters make their way across the fields. During harvest time, their beams of light can be seen deep into the night. Their task is to bring in the entire harvest in a short space of time. A little further away, in the vineyard, the soil is loosened with the help of a small tractor. The tractor must be narrow and maneuverable so that it can work between the vines.

All these vehicles have engines which meet extreme demands. Dust, heat and operational days of 18 hours or more cannot harm them. But these engines are not only robust and powerful, but also economical, green and low-maintenance. Their engine power ranges from lower than 20 kW for compact tractors up to engine outputs of 750 kW for forage harvesters – and all that with a compact design and the lowest possible operational noise and exhaust emissions. These goals require the highest level of engineering skills – and for decades the engine industry has met these challenges with great success.
Excavators work themselves ever deeper into the ground on the construction site. Alongside them, work has already progressed further. Seven-axle mobile cranes hoist girders weighing several tons from heavy-duty transporters so that they can later be put in place a hundred meters up.

Construction machinery, which around the world is erecting ever taller buildings in ever shorter timeframes, requires powerful engines with high torque over a broad range of engine speeds. Only then are these ponderous leviathans agile enough to work quickly and efficiently on the construction site and yet still able to move rapidly from one site to another. It almost goes without saying that the engines must also endure years exposed to the harsh conditions of deserts or high mountains. Yet high demands are also placed on the economy and environmental compatibility. As a result, minimal maintenance expenses, low consumption and negligible emission values are increasingly becoming the focus of users. Even in areas such as this, VDMA members have an impressive and extensive range of ultra-modern and perfectly adapted assemblies, for applications ranging from the hand-operated vibrator plate to enormous bulldozers.

Those who dig deep and set their sights high need power at all engine speeds.
An Airbus A380 takes off. It has around 500 passengers on board and a journey of over 9,000 km ahead of it. To enable it to get under way in the first place, a lot of preparation is first necessary at the airport. Aircraft must be towed from their parking positions by heavy and powerful towing tractors. Fork-lift trucks and conveyor belt vehicles help to handle luggage and cargo in the shortest possible time. Not only that, but a fire engine prepared for all eventualities must be at the scene of an emergency within minutes.

Such different special machinery also requires very different drives. Fork-lift trucks with gas or diesel engines must make their rounds in the warehouses of logistics companies quietly and with low emissions. Towing tractors must be maneuverable and extremely powerful. The tractor itself for the A380 weighs 70 tonnes and with an engine power of 1,000 kW can move eight times its own weight. Airport fire engines need engines which are exceptionally reliable and can accelerate the 52-tonne hulks to 80 kph in under 25 seconds. When it comes to satisfying such demands, the German engine manufacturers are among the leaders. This is particularly due to the ability of their engineers always to provide the drive solutions that fit exactly even for these highly specific cases.

Even high-flying innovations need high-performance ground personnel.
With a loud roar, the stones crash onto the loading platform. It has a capacity of over 350 tonnes and belongs to an eight-meter-tall dumper. This is loaded by a gigantic mining excavator, which weighs over 800 tonnes and can move up to 75 tonnes of material with one scoop of its bucket.

Giants such as these need not only engines with exceptionally high power, but also drive concepts which can make reliable and efficient use of the enormous forces involved. The engines used for this generate up to 3,000 kW and resist not only constantly whirling dust and extremely wet conditions, but also withstand long-lasting continuous operation at altitudes of over 4,000 m. The particular climatic conditions in narrow tunnels underground also represent highly specific challenges for the drives employed there – challenges which must be surmounted just the same as extremely compact installation dimensions. The engine manufacturers represented in the VDMA also offer solutions for these purposes which are appreciated in Chilean copper mines every bit as much as they are in mines in Europe.

Those who want to move great boulders effortlessly demand reliable power.
The internal combustion engine as a basis for customer-orientated drive solutions.

Entirely different mobile machinery requires differing drive concepts. Depending on the application and site of operation, different technological approaches can prove particularly advantageous — and still more concepts will come along in the future. For every system, the aim is to find a perfect balance between the individual characteristics of the machine, the customer’s needs for economy and availability and the increasing requirements for environmental protection. That the internal combustion engine always forms the basis of the drive is no accident. These engines are robust, durable and highly efficient at the same time. They have been proving their worth for over a hundred years, are today used in millions of applications and will continue to be the definitive drive machines thanks to their well-developed technology. Driven by diesel, gas, biofuels or synthetic fuels, they reliably deliver the power required to fulfill their different functions. There are various drive concepts for transferring the energy delivered by the internal combustion engine.

A mechanical drive transfers the engine power mechanically via couplings, gears, shafts and axles to, for example, the wheels or with belts or power take-off shafts to add-on units such as rotary mowers. It can always be used when the necessary transmission ratio is not too great and a robust and reliable technology is needed.

With a diesel-electric drive, the energy from the diesel engine drives a generator which converts the mechanical energy into electrical energy, thereby powering electric motors. Here, the mobile machine has what could be called its own power station directly on board in the form of the internal combustion engine. What at first sounds cumbersome is in fact thoroughly sensible in the case of large and powerful vehicles such as locomotives or the giant dumpers for mines. For a start, couplings and gears are at the limits of their loading capacities with powerful machines. Not only that, but power supply cables are easier to lay than mechanical drive elements, which increases flexibility in the construction of the machines.

Diesel-hydraulic drive concepts use fluids to transfer energy. The internal combustion engine is used to build up pressure in a pipe system via a pump. This pressure is then converted back into movement by hydraulic motors or pistons. Hydraulic drives have the advantage that they can be positioned directly in the places in the machine — such as an excavator — where they are required. This is because each drive engine can be connected flexibly with the pump via hose lines or pipes. Diesel-hydraulic drives are robust, wear-free and very precise.
To reduce fuel consumption, drive concepts in which an electric motor complements the internal combustion engine have recently come into use. With mobile machines, this is generally a mild hybrid. In this case, the internal combustion engine continues to form the basis of the drive train. It is networked with a secondary electric motor, a battery and a controller. If large amounts of power are needed, the electric motor then assists the internal combustion engine. The prerequisites for a hybrid drive are favorable in the case of certain mobile machines, such as excavators or industrial trucks. This is because the high power for the initial acceleration or to lift the load is only briefly necessary. Here, it makes sense for the electric motor to complement the internal combustion engine as a “booster”. The regular application of the brakes is also beneficial for energy recuperation. In this situation, braking energy is converted into electrical energy, stored in the battery and then placed at the disposal of the electric motor for use in the event of power peaks. Further savings potential can be achieved by means of an automatic start/stop system, which switches off the internal combustion engine when it is idle. The advantage of this hybrid system is that the combustion engine can be made smaller and thus consume fewer resources as a result of the supporting function of the electric motor.

Hybrid concepts, which make the best use of the strengths of internal combustion engines and electric motors, create a synergy between benefits to the customer and the environment. Concepts which rely on a completely electric drive under the catchword “e-mobility” currently face a whole host of challenges. The battery life is rarely sufficient for industrial applications, the CO₂ balance from electricity production must still be improved considerably against the backdrop of ambitious emissions targets, and locations where mobile machinery is used very often lack the necessary infrastructure for supplying electricity. Nevertheless, this technology certainly has potential for selected applications and will expand its area of use in future.
Enormous efforts for next to no emissions.

Reducing fuel consumption and CO₂ emissions has always been a primary goal when it comes to developing engines, not least because fuel consumption has a direct effect on the income of users and customers.

With the introduction of limits on nitrogen oxide (NOₓ), the main focus of engine development shifted and a classic conflict of goals ensued. With a given engine concept, the optimization of the engine in terms of lower NOₓ emissions physically leads to increased consumption. Technological advances like the introduction of the common rail injection system and increasing boost pressure do indeed enable a reduction in consumption and emissions in comparison with older engines, but again: NOₓ levels can only be reduced if increased consumption is accepted.

Whereas the emissions levels applicable thus far have been attainable by means of engine internal measures, the limits which will come into force in the future in Europe and the USA will barely be achievable without additional treatment of the exhaust gases. The development of effective, low-maintenance and enduringly powerful exhaust gas after-treatment systems is therefore a particular challenge.

**Diesel particle filter**

The diesel particle filter screens the sooty particles out of the exhaust gases. The closed version (wall-flow filter) consists of porous material through which the exhaust gas passes completely. The particles collect on the surface and form a filter cake. Concerning the separation rate closed filters are very effective.

With partial-flow filters, the exhaust gas is passed through the metallic filter material, with one part flowing through a bypass and then being screened in the next stage. The separation rate of partial-flow filters depends on their dimensioning.

Both systems are available for retrofitting.

The collected sooty particles must be removed for the regeneration of the diesel particle filter. In the passive process, the soot is permanently chemically oxidized via the integration of nitrogen oxide also present in the exhaust flow. For active regeneration, the temperature in the filter is temporarily increased and the particles burnt at defined intervals.

**SCR technology**

SCR technology (selective catalytic reduction) is a technology for significantly reducing nitrogen oxide emissions. In this process, a urea solution is injected into the exhaust flow upstream of a special catalyst. This catalyst then ensures that the harmful NOₓ is converted into harmless nitrogen and water. With the help of the urea solution, which is commercially available under the name AdBlue®, more than 80% of the nitrogen oxide can be removed from the exhaust gas in a dynamic operation.

The complexity increases when exhaust gas after-treatment systems are used. Optimally configuring the individual components to each other is a challenge for the industry. One that is worthwhile, as with these measures, the particle and nitrogen oxide emissions of mobile machinery will sink to a level of around four percent of the first emission limits from the late 1990s.
The use of SCR exhaust gas after-treatment systems has another positive effect besides NOx reduction: engine developers now once again have more freedom to optimize the efficiency of their engines. The specific fuel consumptions will also drop further in the future and the diesel engine will continue to maintain its position as the most efficient drive machine. Hence, the industry will also make an important contribution to the protection of the environment and the climate.

CO2 balance

Besides the engine, there are many other influencing variables for the CO2 balance of mobile machinery. For example, it is vital to optimize the whole drive power and deploy the energy efficiently across the entire work process. With combine harvesters, for example, the drive serves not only for movement but also for mowing, threshing, chopping, separating residual corn and producing compressed air for cleaning and for ejecting chaff. The tires have just as well influence on consumption as the behavior of the driver.

The choice of fuel also has an effect on CO2 emissions. Diesel fuel is to be evaluated differently from gas, while biofuels are in turn different from synthetic or vegetable and animal fats. The conceivable drive with hydrogen internal combustion engines is pollutant-free in operation, but the energy necessary for producing the hydrogen must be incorporated into the evaluation of the environmental balance.
What already counts for us today and what you can count on tomorrow.

The internal combustion engine will continue to play a key role in future as the engine that keeps the economy going. The innovative power of the industry will ensure that continuing development will soon lead to practically emission-free drive concepts for mobile machinery.

Engine manufacturers are rolling out ever more powerful and yet more economical engines. That enables downsizing – the use of smaller, less resource-hungry engines. Gas engines, with their particularly low-emission combustion, can make an additional contribution to climate protection. Harmful nitrogen oxide and sooty particles are filtered out of the exhaust gases. Finally, hybrid drives connect the internal combustion engine to the electric motor to form a highly efficient and energy-saving drive system.

The engine and supplier industry organized in the VDMA is today playing a leading role worldwide in the research, development and testing of drive concepts suitable for the future. It views the emissions laws as appropriate and necessary measures for climate, environment and health protection and therefore supports them actively. The associated innovations not only serve to protect the environment, but open up new market opportunities for the engine industry, strengthen its competitive position and safeguard countless jobs at home and abroad.
"Since it was patented, the diesel engine has maintained its position of being the most efficient drive machine through consistent development. The continuous improvements in increasing efficiency and reducing harmful substances and greenhouse gases distinguish German engine technology for the good of the environment."

Peter Schippers, Director Sales Engines & Components, MAN Nutzfahrzeuge AG

"The international competitiveness of modern diesel engines will be ensured for the future, particularly as a result of fulfilling the emission requirements with an increasing level of efficiency. The optimal coordination between exhaust gas aftertreatment and engine technology has a key role to play in achieving this."

Stefan Fuss, Vice President Sales & Marketing Air Purification, Süd-Chemie AG

"Every new or progressive development of an engine is defined by the specifications of emission legislation. Integrated system solutions from engine and exhaust gas technology are today's answers to tomorrow's questions."

Dr.-Ing. Helmut Leube, Chairman of the Management Board, DEUTZ AG

"In times of increasingly stringent emission requirements being placed on industrial engines, clean drive concepts take on increased significance. Modern gas engines from the automotive industry are environmentally friendly and efficient, and prove their suitability for everyday use as power sources in diverse mobile machines."

Dr. Rudolf Krebs, General Manager Engine Manufacturing Division, Volkswagen AG

"In the world industrial engine market, common rail injection systems with scalable pressure and customer-specific applications contribute to lowering pollutant emissions, reducing fuel consumption, improving economic efficiency and, last but not least, the competitiveness of engine manufacturers."

Helmut Weißbeck, Senior Vice President Sales Diesel Systems, Business Unit Commercial Vehicles, Robert Bosch GmbH
Who is behind these services?

The engine manufacturers and suppliers

The member companies of the VDMA Engines and Systems Association are manufacturers of industrial engines with a performance range from a few kilowatts up to 90,000 kW, plus their suppliers from the areas of fuel supply, turbocharging, engine components, exhaust gas after-treatment and drive elements.

They have customers in the areas of

- mobile machinery
- ships and inland waterway vessels
- rail traffic
- stationary engines for energy conversion.

The companies are established internationally, and include group companies and medium-sized, family-run companies alike. The spectrum encompasses well-known “global players” as well as “hidden champions” with sizeable market shares in their sector. The engine industry has been affected by the current economic fluctuations. However, the long-term prospects for the industry look good, irrespective of short-term effects.

The increasing global trade flow of commodities and raw materials can only be conveyed on sea routes. The internal combustion engines on ships are therefore every bit as essential as the engines in mobile machines for the movement of goods and for the construction of transport infrastructure on land. The growing world population has increasing needs for living space and food. Needs which are met with the help of machines in agriculture, construction and forestry. The demand for biofuels will stimulate also agricultural production, and modern energy concepts rely on decentralized generation of power and heat in engine-driven power stations. With their expertise, the engine manufacturers and their suppliers will successfully master the challenges of a globalized economy, strict emission regulations and ambitious climate targets.

VDMA Engines and Systems – service provider and trade association

The VDMA is the largest investment goods association in Europe. It is a key lobby group, service provider and contact partner for around 3,000 German and European companies in the mechanical and plant engineering sector. In Germany, 900,000 people are employed in the sector, with sales of €200 billion. The VDMA Engines and Systems Association is the information and communication platform for manufacturers of engines for industrial applications, as well as their supplier companies. We bundle topics relevant to the sector in the interest of the industry and represent them in discussions with politicians and lawmakers on a national and international level.

Our main focuses are

- emission legislation
- classification requirements
- combating product piracy
- standardization
- market analysis
- public relations work
Manufacturers of engines and components for mobile machinery

- ABB Automation GmbH
- ABB Turbo Systems AG
- Behr Industry GmbH & Co. KG
- Robert Bosch GmbH
- Bosch Rexroth AG
- Demag Cranes AG
- DEUTZ AG
- Emitec Gesellschaft für Emissionstechnologie mbH
- Federal-Mogul Friedberg GmbH
- Geislinger GmbH
- GPM GmbH
- Greaves Farymann Diesel GmbH
- GREENTOP
  Aircondition and Filtersystems GmbH
- MOTORENFABRIK HATZ GmbH & Co. KG
- Heinzmann GmbH & Co. KG
- HJS Fahrzeugtechnik GmbH & Co KG
- HUG Engineering GmbH
- HUSU Umwelttechnik GmbH
- INTERKAT Katalysatoren GmbH
- KS Kolbenschmidt GmbH
- L’Orange GmbH
- MAHLE GmbH
- MAN SE
- MAN Diesel SE
- MAN Nutzfahrzeuge AG
- MANN+HUMMEL GMBH
- MTU Friedrichshafen GmbH
- RENK Aktiengesellschaft
- RICKMEIER GmbH
- Steinbach AG
- Süd-Chemie AG
- Thermamax
  Hochtemperaturdämmungen GmbH
- Tognum AG
- TWINTEC Technologie GmbH
- Umicore AG & Co. KG
- VOLKSWAGEN AG
- VULKAN Kupplungs- und Getriebebau B. Hackforth GmbH & Co. KG
- Woodward Governor Germany GmbH

The complete and constantly updated directory of manufacturers “Engines and Systems” can be found online at www.vdma.org/engines.