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Like the changeover to a new model, the presentation of a new generation of engines by BMW always creates particular expectations. Clearly, newly developed drive units are intended to offer significant improvements in as many areas as possible.

BMW now once again defines this progress in very clear and specific terms, presenting EfficientDynamics as the overriding philosophy behind precisely those qualities which enhance sheer driving pleasure while at the same time reducing fuel consumption and thus also optimising the car's emissions. Hence, every new power unit is lighter, more powerful and at the same time more fuel-efficient than its respective predecessor.

BMW's leadership in technology and engine construction acknowledged the world over is based, not least, on the ability to consistently overcome the conflict of interests between growing dynamics, on the one hand, and optimised economy, on the other, in all vehicle and drive segments. This is clearly proven by the newly developed power units BMW is launching at the 2007 Innovation Day – clear and impressive proof of EfficientDynamics.

Offering precisely these benefits, BMW's new four-cylinder power units ensure a new dimension of all-round economy – and at the same time enable the motorist to enjoy the sheer driving pleasure so typical of a BMW in every respect.

Harmony of sheer driving pleasure and all-round economy.
The No 1 prerequisite for the harmony of driving pleasure and economy offered by BMW's various engine concepts is the unique innovative power of BMW's engine development specialists. And so the wide range of innovations giving the new generation of four-cylinder diesel engines their outstanding efficiency extends from the ultra-light aluminium crankcase through the latest version of common rail fuel injection all the way to Variable Twin Turbo technology featured for the first time in this drive segment.

Despite an increase in output by 15 and, respectively, 10 kW (20 and, respectively, 14 hp), the new BMW 118d and the new BMW 120d offer an improvement in fuel economy over their respective predecessors by up to 16 per cent: In the EU test cycle the BMW 120d consumes just 4.9, the BMW 118d an even more impressive 4.7 litres/100 km, equal to 57.6 and, respectively, 60.1 mpg Imp.

This progress is also of significance in view of the CO_2 agreement made by ACEA, the European Association of Automobile Manufacturers, with the EU Commission, stating that the average CO_2 emissions of passenger cars are to be reduced on a European fleet average to 140 grams/kilometre by the year 2008. Hence, BMW's newly developed four-cylinder diesel engines are a further step taken successfully by BMW in reaching this objective, with CO_2 emissions on the new BMW 120d dropping to 129, on the new BMW 118d to just 123 grams/kilometre.

The first and foremost reason for the exceptional efficiency offered by the new four-cylinder petrol engines is High Precision Injection already introduced by BMW on the Company's straight-six power units. For the first time, this second-generation direct gasoline injection offers significant reduction of fuel consumption also under practical driving conditions. And now, on BMW's four-cylinder power units, High Precision Injection is featured exclusively in the particularly fuel-efficient lean burn mode. At the same time the new four-cylinders offer a significant increase in driving dynamics and motoring pleasure provided by the increase in power over the previous engines.

The 125 kW/170 hp 2.0-litre four-cylinder with High Precision Injection has already made a truly impressive debut in every respect in the new BMW 320i Convertible. And now this outstanding engine with its dynamic power and performance combined with supreme economy is likewise hitting the headlines in the new BMW 120i, offering a reduction in fuel consumption versus the previous model by approximately 14 per cent to 6.4 litres/100 kilometres or 44.1 mpg Imp.

This engine with its cutting-edge technology shares many common features and similarities with the current racing engine developed by the BMW Sauber F1 Team not only in terms of the number of cylinders and the engine's basic technology, but also in terms of production methods and the choice of materials used. The engine block as such comes from BMW's light-alloy foundry in Landshut near Munich, which also builds the engine blocks for BMW's Formula 1 engines. The crankcase is made of a cast aluminium/silicon alloy, and both the pistons and cylinder head are also made of aluminium. The entire crankcase as well as the crankshaft are extremely compact and ultra-strong, with maximum torsional stiffness.

The V8 power unit featured in the new BMW M3 offers the additional advantage of impressive weight benefits, again reflecting BMW's pledge to EfficientDynamics. For despite the larger number of cylinders and the significant increase in power, this new engine is lighter than the straight-six power unit in the former model.

EfficientDynamics: a powerful strategy with a great tradition.
The quest for EfficientDynamics has a long tradition in the development of BMW power units. And this philosophy is combined with numerous innovations giving BMW's engine range truly unique appeal and popularity.

Introducing fully variable VALVETRONIC valve control in 2001, BMW presented an impressive technology offering a significant reduction of fuel consumption under everyday driving conditions even back then. Also referred to as "throttle-free load management", VALVETRONIC is now featured throughout BMW's entire range of engines and has in the meantime proven its benefits in more than a million cars the world over.

BMW then took another significant step in 2004 with the introduction of the composite magnesium/aluminium crankcase on the straight-six power unit. From the start, this new engine combined 12 per cent more power with a reduction in fuel consumption by approximately 10 per cent. And the weight-saving is equally impressive, the composite magnesium/aluminium crankcase weighing only 57 per cent of a conventional grey-cast iron cylinder block and also about 24 per cent lighter than a comparable aluminium crankcase.

Offering their unique combination of economy and powerful muscle from the ground up, BMW's diesel engines have been increasing their share in the market consistently for several years. So progress in this area also follows the EfficientDynamics development strategy in every respect. BMW's range of engines thus comprises the world's most sporting and dynamic six-cylinder diesel using Variable Twin Turbo technology to develop maximum output of 210 kW/286 hp and peak torque of 580 Newton-metres or 427 lb-ft from 3.0 litres engine capacity. Fuel consumption remains very low despite these impressive figures, this sports diesel making do in the new BMW 535d with just 6.8 litres/100 kilometres in the EU test cycle, equal to 41.5 mpg Imp.

Innovations to the last detail for enhanced efficiency all round.
Over and above the ongoing development of BMW power units as such, a number of innovations in the ancillary units surrounding the engines also serve to reduce both fuel consumption and exhaust emissions. As an example, most BMWs already feature a volume-flow controlled oil pump and an on-demand electrical coolant pump serving to reduce the amount of energy consumed by the ancillary units. And now, depending on the model, BMW engines also offer the opportunity to disconnect the air conditioning compressor, to improve fuel economy by the Auto Start Stop function and to tell the driver precisely when to shift gears for superior economy. Other new features with similar benefits are the new electrical power steering, the pressure-controlled electrical fuel pump, as well as aerodynamically optimised cooling and brake air flap systems.

Brake Energy Regeneration is yet another cutting-edge technology now available on all models and in conjunction with all engine variants: Featuring intelligent alternator control, this new technology concentrates the conversion of fuel into electrical energy on engine overrun and application of the brakes, thus masterminding the generation and use of electrical energy with a high standard of efficiency and at the same time enhancing driving dynamics and performance while the car is under power.

Brake Energy Regeneration is indeed an important step towards intelligent energy management in the car, at the same time providing the foundation for further steps in the hybridisation of drive systems.

Hybrid concepts: moving forward to production standard.

The effect of Brake Energy Regeneration is described by engineers as "passive boosting" or, perhaps even more appropriately, "micro-hybridisation". The medium-term objective in developing power units with EfficientDynamics is however to achieve even more effective interaction in the use of primary and electrical energy.

Precisely this kind of hybrid concept is currently being jointly developed by the General Motors Corporation, DaimlerChrysler, and the BMW Group. This is indeed a fully integrated combination of electric motors and a transmission with fixed transmission ratios, this two-mode concept, as it is called, serving to provide the most fuel-efficient driving mode under all kinds of load conditions. Such a hybrid car might therefore run either on its two electric motors alone, on the combustion engine alone, or with all power units for superior performance. And the hybrid transmission being jointly developed by the partners in this project might also be used on existing combustion engines.

A long-term option already available today: hydrogen drive.

Introducing the BMW Hydrogen 7, BMW already provides a clear outlook at the long-term future of individual mobility in 2006: The world's first luxury saloon for everyday use running on hydrogen paves the way into a new dimension of emission-free mobility independent of fossil fuels. The dual-mode combustion engine featured in the BMW Hydrogen 7 therefore runs on both hydrogen and conventional gasoline fuel in the same cylinders, the V12 power unit developing maximum output of 191 kW/260 hp.

Pursuing a consistent CleanEnergy strategy, BMW is focusing clearly on the use of liquid hydrogen as a source of energy. The introduction of BMW Hydrogen 7 therefore also provides the necessary momentum for developing and enlarging the hydrogen supply infrastructure in our modern world.

The long-term objective in this development process is to consistently use hydrogen gained in a regenerating process as the ideal source of energy for the automobile. So with its trendsetting drive concept, BMW Hydrogen 7 will become the pacemaker for sustained mobility fully compatible with the environment.

2. The world's first direct gasoline injection with genuine fuel savings under practical driving conditions continues its story of success: High Precision Injection now also makes BMW's four-cylinder power units the benchmark for EfficientDynamics.

Introducing second-generation direct gasoline injection and a number of new features around the engine, BMW is now also establishing a new dimension of EfficentDynamics with its four-cylinder power units. The new generation of four-cylinder petrol engines features direct fuel injection appropriately defined by BMW as High Precision Injection, allowing lean burn operation of the engine throughout a wide range of engine speed and therefore helping to significantly reduce fuel consumption in everyday traffic despite the further increase in engine power.

As a result of this new technology, the concept of High Precision Injection already introduced successfully on BMW's straight-six power units is now available in an even larger number of models.

Making this move, BMW is consistently continuing the development strategy of EfficientDynamics, again offering modern technical solutions serving to enhance both sheer driving pleasure and motoring economy at an early point in time throughout the entire model range. In practice, BMW is therefore focusing on the growing significance of fuel-efficient power units in a particularly attractive and consistent manner.

Direct gasoline injection operating in the lean burn mode meets the latest demands of the European automobile market in terms of dynamic performance, all-round economy and emission management in an ideal manner. BMW's new four-cylinder power units furthermore combine ultra-precise and therefore uniquely efficient High Precision Injection with numerous other technologies for enhanced fuel efficiency. These include Brake Energy Regeneration, the Auto Start Stop function, a gearshift point indicator, new electrical steering, a pressure-controlled fuel pump, and the option to disconnect the climate compressor from the engine's belt drive.

Again reflecting the concept and philosophy of EfficientDynamics, this means a perfect combination of greater performance and optimum economy. The new four-cylinder petrol engine displacing 2.0 litres thus offers an increase in output in its most powerful version by 15 kW or 20 hp over the previous engine. At the same time the new BMW 120i powered by this engine, to take one example, offers a reduction of fuel consumption versus its

predecessor by approximately 14 per cent to 6.4 litres/100 kilometres in the EU test cycle, equal to 44.1 mpg Imp. The new BMW 118i, in turn, providing an increase in output by 10 kW or almost 14 hp, comes with a reduction of fuel consumption by approximately 19 per cent to 5.9 litres/100 kilometres, equal to 47.9 mpg Imp. And at the same time this model's CO_2 emissions are down to just 140 grams/kilometre.

Fast-revving performance, superior running smoothness, all-round economy – BMW's new four-cylinder power units excel on all of these points, in all criteria crucial to up-to-date driving pleasure. Through their temperamental development of superior engine power, they ensure sporting performance at all times and under all conditions. And apart from dynamic performance, motoring culture is also enhanced to a level of refinement quite outstanding in this segment: In its most powerful version, the 2.0-litre four-cylinder develops maximum output of 125 kW/170 hp and peak torque of 210 Newton-metres/155 lb-ft. The second version of the new drive unit develops maximum power of 105 kW/143 hp, with torque peaking at 190 Nm/140 lb-ft. Yet a further version of the engine following at a later point in time will be a 1.6-litre four-cylinder offering maximum output of 90 kW/122 hp and peak torque of 160 Nm/118 lb-ft.

In both engine classes and in all power stages, High Precision Injection gives the new generation of four-cylinders a standard of all-round efficiency quite unique on a petrol engine.

This progress over the first generation of direct gasoline injection deliberately not used by BMW results from the central position of the piezo-injectors featured for the first time on High Precision Injection between the valves, in the immediate vicinity of the spark plug. This arrangement is indeed the prerequisite for the innovative jet-guided combustion process allowing far more precise dosage of fuel and maintenance of the lean burn mode throughout a wide operating range on the engine control map.

Significant advantages in fuel economy without compromises.
High Precision Injection was presented for the first time in BMW's 225 kW/306 hp straight-six power unit with Twin Turbo technology featured in the BMW 335i Coupé. Initially, this new fuel injection system was focused on the specific requirements of a particularly powerful engine.

Now High Precision Injection offers an even greater potential for enhanced fuel economy on both a six- and four-cylinder in the lean burn direct injection mode. Applying this combustion concept also referred to as stratified charging, the composition of the fuel/air mixture is masterminded with particular accuracy. This means that unlike a conventional gasoline engine,

such an advanced power unit no longer requires a fuel:air ratio of 1 : 14 (lambda = 1). Rather, the share of fuel in the mixture may be reduced significantly throughout a wide operating range (lambda > 1). This is possible because the piezo-injectors positioned directly next to the spark plugs offer controlled combustion in layers (stratified arrangement) over a wide operating range, with the exact composition of the fuel:air mixture varying from one layer to the other.

Significant enhancement of driving dynamics.
Benefiting from this revolutionary injection technology, BMW's new four-cylinders are entering a new dimension of all-round economy: With High Precision Injection, fuel consumption of the already very efficient engines with variable VALVETRONIC valve management is down once again. And this further optimisation of fuel economy does not in any way detract from the engines' dynamic performance. On the contrary – the most powerful version of the new engines outperforms the 2.0-litre four-cylinder with VALVETRONIC by a significant 15 kW/20 hp.

Through their supreme engineering performance, BMW's engine development specialists are able to capitalise more than ever before on the savings potential of a modern petrol engine, BMW's petrol power units thus offering a standard of fuel economy so far provided only by a diesel. Not surprisingly, therefore, the new generation of engines ranks clearly at the top in any comparison with the competition.

High Precision Injection – the solution for maximum efficiency in everyday motoring.
The combination of efficiency and dynamics clearly demonstrates that the second generation of direct gasoline injection is far superior to all systems and concepts in the first generation. So far the hopes invested in this technology for a considerable enhancement of fuel economy did not become reality in practice, despite significant technical efforts and far-reaching developments – which is precisely why the BMW Group decided to forego the first generation of direct gasoline injection. The systemic drawback of the first generation was in particular that the economic advantages of running the engine with a large surplus of air were only provided within a very narrow load range at low engine speeds.

With the BMW Group's engine development specialists recognising this drawback at an early point in time, they started out to develop an alternative solution in order to ensure superior fuel economy also under practical driving conditions, that is an improvement of realistic significance. Precisely this is why BMW introduced throttle-free VALVETRONIC engine load management as early as in 2001, a system now used worldwide throughout BMW's entire model range, having proven its value in the meantime in more than a million cars.

Innovative piezo-injectors in an optimum position.
The only way to really capitalise on the substantial potential of direct gasoline injection was to develop High Precision Injection, the technology now being introduced by BMW: The BMW Group's engineers have succeeded in positioning the piezo-injectors between the valves directly next to the spark plug, despite the confined space in the cylinder head. At the same time the injectors are designed and built to resist the high temperature and pressure loads prevailing at this point.

The high-pressure pump on the cylinder head is supplied with fuel by an electric pump in the fuel tank operating on demand, that is exactly as required under all specific conditions. Within the common rail, the high-pressure pump generates pressure of 200 bar for the four injectors delivering fuel to the combustion chambers, with the injector needles responding extremely quickly and consistently to the injection pulses electronically transmitted by a specially developed engine control unit. A further point is that contrary to conventional solenoid valves, piezo-injectors allow up to six injection processes in each operating stroke.

Fuel/air mixture reaching the cylinders with precise and fine dosage.
Opening to the outside, the piezo-injectors form a stable, conical injection jet within the combustion chamber and, as a result, ensure particularly fine dosage of the fuel/air mixture. A further point is that the total amount of fuel injected in each operating stroke may be split up into several "helpings", thus providing perfect conditions throughout a wide load and speed range for a precise supply of fuel and, accordingly, for a controlled, clean and efficient combustion process.

Contrary to wall-guided fuel injection as the technology applied so far, the jet-guided process ensures a much faster and, in particular, more efficient fuel/air mixing process in the direct vicinity of the spark plug, without any loss otherwise caused by fuel resting on the walls of the cylinder. This provides exactly the right conditions for a stratified cylinder charge characteristic of lean burn operation, various, intersecting zones of differently composed fuel:air mixtures forming within the combustion chamber. In the process the share of fuel in the mixture decreases consistently with an increasing distance from the spark plug, a rich, ignitable fuel/air mixture being maintained only in the direct vicinity of the spark plug, in the interest of maximum efficiency. As soon as this richer mixture is ignited, the leaner layers further away from the spark plug will also start burning in a clean, smooth and consistent process.

This concept serves to maintain fuel-efficient lean burn operation throughout a very wide range of engine speeds and loads. And this again is a significant reason for the enhanced economy provided by High Precision Injection versus first-generation direct gasoline injection.

Additional innovations for optimum economy.
Both within the car as a whole and on the various ancillary units around the engine, a wide range of innovations serve in addition to High Precision Injection to make the new generation of BMW's four-cylinder petrol engines a new benchmark in technology in terms of both dynamic performance and all-round economy. This wide range of technical innovations comprises Brake Energy Regeneration, the Auto Start Stop function, a gearshift point indicator, an electrical, map-controlled coolant pump, a pressure-controlled high-pressure fuel pump, a climate compressor with a magnetic clutch, lightweight structures on the crankcase and crankshaft as well as EPS Electric Power Steering.

Intelligent lightweight technology also within the engine compartment.
Over and above the enhancement of performance and economy, optimisation of the car's weight is another development aim in the overall context of EfficientDynamics. Precisely this is why BMW's engineers pursued a consistent lightweight technology strategy in developing BMW's new four-cylinder petrol engines, neither the additional power nor the enhanced fuel economy coming at the cost of extra weight. So despite the increase in power by 15 kW/20 hp, the new 2.0-litre four-cylinder is approximately 4 kilos lighter than its predecessor with VALVETRONIC – and this ideal weight benefits both the optimisation of fuel economy and the agility of the respective car under practical driving conditions.

This reduction of weight is made possible by a number of lightweight improvements. Two particularly significant components in this process of reducing weight, among others, are the lightweight camshaft made in a hydrofoaming process and the variable intake manifold (DISA) made of a special synthetic material.

The new four-cylinder: proven foundation, detailed innovations.
The all-aluminium power unit with its stable bedplate construction and grey-cast iron cylinder liners cast into the cylinders themselves is based on BMW's proven four-cylinder with fully variable valve drive. The cylinder bore (84 mm/3.31 ˝), piston stroke (90 mm/3.54 ˝) and, accordingly, engine displacement (1,995 cc) are identical, while the compression ratio has been increased from 10.5 : 1 to 12 : 1 in the interest of enhanced performance. Two balance shafts rotating in opposite directions eliminate any rotational vibration on the four-cylinder and ensure a high standard of smoothness and refinement at all times.

One requirement in implementing lean burn operation with a stratified cylinder charge was to redesign the cylinder from the ground up, the piezo-injectors being positioned between the valves at an optimum point relative to the spark plug, despite the confined space available.

A highly efficient charge cycle within the cylinders is ensured by conventional valve drive with two overhead camshafts and roller-type drag arms optimised for minimum friction. Compared with engine variants featuring VALVETRONIC, this type of valve management allows a significant increase in engine speed by 800 rpm to 7,000 rpm. To maintain a "beefy" torque curve throughout the entire engine speed range, both camshafts come with double-VANOS for infinite adjustment of valve opening times. In order to build up high torque as soon as possible at low engine speeds, in turn, the engine also incorporates a special intake system with variable manifold length (DISA technology).

Clean and efficient: NO_X storage catalysts.

The new lean burn engine comes with a main catalyst close to the engine itself and storage catalysts further down the line to avoid NO_X emissions. Introducing this wide range of innovations serving to reduce both fuel consumption and emissions from the engine, BMW is once again proving its outstanding skills and competence in the area of engine design.

The progress achieved on the new four-cylinder petrol engines in terms of both efficiency and emission management are also an important step in the further reduction of fleet consumption and emissions with BMW's new cars. In this way BMW is clearly expressing its commitment to keep the promise made voluntarily by the Association of European Automobile Manufacturers (ACEA) to reduce the average CO_2 emissions of newly registered passenger cars in European car fleets to 140 grams/kilometre by the year 2008.

A wide range of improvements in the area of drive technology, aerodynamics and lightweight construction already introduced by the BMW Group already ensures a significant reduction of fuel consumption and CO_2 emissions by BMW cars. Hence, the BMW Group has already made its contribution to the voluntary commitment assumed by the Association of the German Automobile Industry (VDA) to reduce fuel consumption by 25 per cent in the period between 1990 and 2005, even outperforming the commitment made by achieving a reduction of approximately 29 per cent. The introduction of VALVETRONIC technology alone in all new petrol engines has reduced fuel consumption in the EU test cycle and, accordingly, CO_2 emissions by approximately 10 per cent.

The significant effect of this progress in technology also comes out clearly in a more long-term comparison: Fuel consumption of the entry-level model in the BMW 3 Series with its four-cylinder petrol engine was reduced by 22 per cent from 1983–2003, while at the same time the cars involved gained 32 per cent more weight on account of greater safety and comfort requirements. In the process the emissions relevant to the determination of exhaust standards have been reduced by an even more significant – and quite remarkable – 95 per cent.

The new family of BMW four-cylinder petrol engines is being introduced initially only in the European markets, since a complete supply of sulphur-free fuel over the entire area is guaranteed only here – and this is essential for the NO_X storage catalysts on the engines. European customers will nevertheless be able to use their cars also in other countries where sulphur-free fuel is not yet available everywhere, the only drawback being that there the engines will not be able to fully capitalise on their particular economy benefits and technologies, since the storage catalyst, running under such conditions with sulphur in the fuel used, will require a regeneration cycle more often than is otherwise the case.

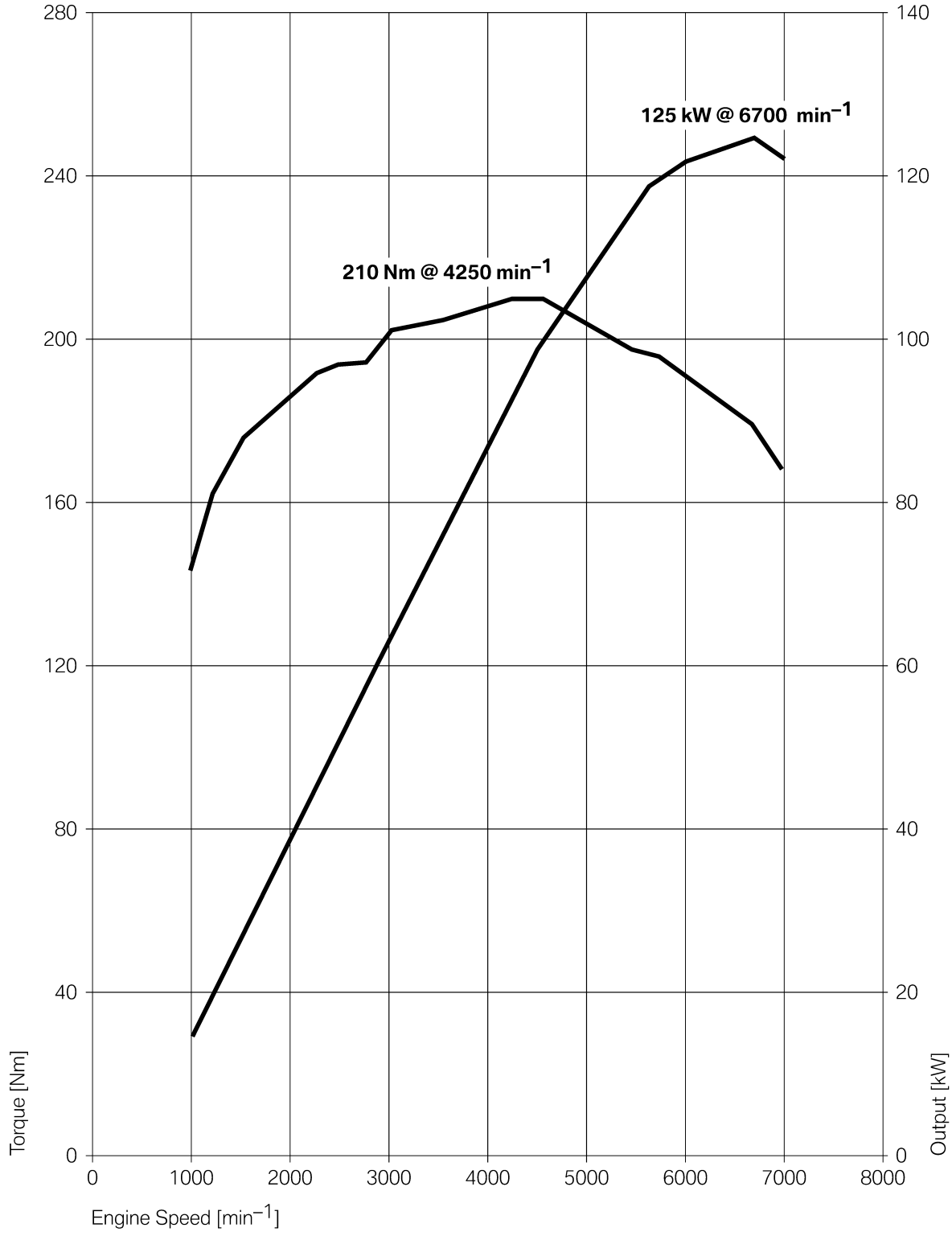
High Precision Injection operating in the lean burn mode can therefore only be introduced step-by-step also in other markets when such environmentally-friendly fuel is also available in those countries. Precisely this is why VALVETRONIC will continue to play an important role in BMW four-cylinder engines also in future, offering excellent conditions for extremely economic operation of the engine in the same way as before.

Indeed, emission management by the latest generation of BMW's four-cylinder power units with VALVETRONIC has now been optimised once again, with modifications, inter alia, of the engine management, the cylinder head cover, exhaust technology, and the injection valves. And last but not least, the optimisation of weight ensured by consistent lightweight engineering also helps to further improve the efficiency of BMW's four-cylinder power units with VALVETRONIC.

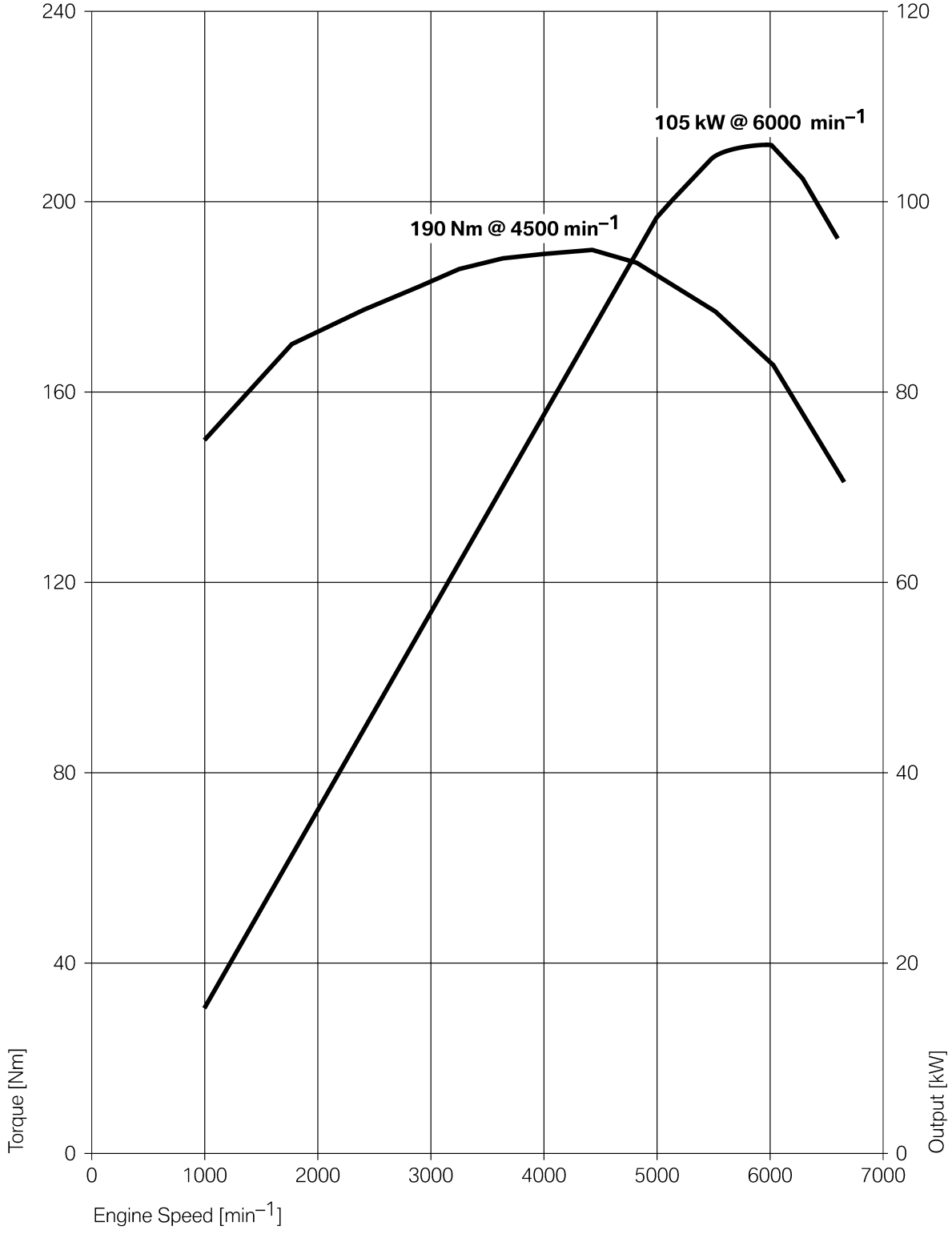
2.1 Specifications of BMW's new four-cylinder gasoline engines with High Precision Injection.

Feature/entity	Unit	Normal aspirated 4 cylinder engine with lean-burn second-generation direct gasoline injection (High Precision Injection)	For comparision: Normal aspirated 6 cylinder engine with lean-burn second-generation direct gasoline injection (High Precision Injection)
Fuel		Gasoline (RON 91–100)	Gasoline (RON 91–100)
Max output	kW/hp	125	200/272
at	rpm	6,700	6,750
Max torque	Nm	210	315
at	rpm	2,250	2,750
Max engine speed	rpm	7,000	7,000
Stroke	mm	90.0	88.0
Bore	Mm	84.0	85.0
Displacement	cc	1,995	2,996
Distance between cyls	mm	91	91
Cylinder arrangement		Four-cylinder inline	Six-cylinder inline
Valve plate diameter, intake	mm/in	31.4	32.4
Valve plate diameter, outlet	mm/in	28.0	29.0
Compression ratio		12.0 : 1	12.0 : 1
Fuel injection		Second-generation direct injection (High Precision Injection); piezo-injectors; λ >>1	Second-generation direct injection (High Precision Injection); piezo-injectors; λ >>1
Fuel injection pressure	bar	200	200
Engine weight to BMW standard	kg	135	168
Output per litre	kW/L	62.7	66.8
Engine power-to-weight ratio	kg/kW	1.08	0.84
Crankcase		Aluminum with cast liners	Composite magnesium/aluminium
Waterpump		electrical	electrical
Camshaft		Composite, hydroformed	Composite, hydroformed
Inlet manifold		2 stage	3 stage
Valvetrain		Infinite camshaft adjustment for intake and outlet (double-VANOS); roller rocker arms	Infinite camshaft adjustment for intake and outlet (double-VANOS); roller rocker arms

2.2 Torque and output diagram of the BMW second-generation 125-kW 2.0-litre four-cylinder gasoline engine with lean-burn direct injection (High Precision Injection).



2.3 Torque and output diagram of the BMW second-generation 105-kW 2.0-litre four-cylinder gasoline engine with lean-burn direct injection (High Precision Injection).



3. Compact performer with exemplary emission standards: EfficientDynamics in a new dimension – Variable Twin Turbo now also in the BMW four-cylinder diesel.

More power, lower weight and a further improvement in emission management – these are the highlights of the new four-cylinder diesel engines with which BMW now sets the standard for EfficientDynamics in this segment of powertrains. Featuring an all-aluminium crankcase, turbocharging technology, third-generation common rail fuel injection, diesel particulate filters placed closed to the engine, and numerous detailed innovations, the new compact power units open up a new dimension of economic and clean motoring.

BMW's new four-cylinder diesels displace 2.0 litres cubic capacity and come in three power and performance stages: Both the "basic" model developing 105 kW/143 hp maximum output and the 130 kW/177 hp version come with a turbocharger featuring variable turbine geometry for superior power and performance. The most powerful version of the new engine also boasts Variable Twin Turbo technology already lauded in BMW's six-cylinder diesel models. This technology also referred to as multistage turbocharging gives the 2.0-litre power unit maximum output of 150 kW/204 hp, making this the first all-aluminium diesel engine in the world to develop output of more than 100 hp per litre.

The new diesel concept is integrated within a network of improved components around the engine serving to minimise fuel consumption and emissions and optimise management of the engine's ancillary units.
On all models driven by a new-generation four-cylinder diesel Brake Energy Regeneration, an Auto Start Stop function and a gearshift point indicator for manual gearbox cars as well as new electrical power steering serve to enhance efficiency to an even higher, unprecedented level.

Development strategy for EfficientDynamics consistently implemented.
Introducing the new four-cylinder diesel engines, BMW is implementing the development strategy for EfficientDynamics consistently also in this drive segment. Compared with the former power units, the new engines are significantly lighter and offer a substantial improvement of both fuel economy and emission management despite their considerable increase in power and performance.

BMW's new four-cylinder diesel engines are featured in a number of model series, ensuring that trendsetting innovations in technology for the enhancement of efficiency are available to the customer in several car segments with a particularly high volume of sales. Customers opting for diesel power thus benefit for the first time in both the four- and six-cylinder segment from supreme engine technology offering the highest standard of power and performance plus equally superior economy. A further advantage particularly of BMW's modern diesel engines is the significant reduction of CO_2 emissions.

As a result of all these strengths, BMW's highly appealing new four-cylinder diesels make an important contribution to the overall reduction of fuel consumption and emissions.

The engines in BMW's new generation of four-cylinder diesels develop their superior power from a capacity of 1,995 cc and come in three power and performance stages. Their distinction lies in the specific modification of the injection components and the turbocharger system. Developing maximum output of 105 kW/143 hp and peak torque of 300 Newton-metres/221 lb-ft, even the "basic" version of the new diesel outperforms its predecessor by 15 kW/20 hp and, respectively, 20 Nm/15 lb-ft.

The most powerful version of the new engine develops maximum output of 150 kW/204 hp, 30 kW/41 hp more than the formerly most powerful four-cylinder diesel from BMW – and at 400 Nm/295 lb-ft, the engine's peak torque is up by 60 Nm or 44 lb-ft. The middle engine in the four-cylinder diesel range is a 130 kW/177 hp power unit developing maximum torque of 350 Nm or 258 lb-ft.

Another important factor clearly confirming the extra temperament of the engines is the engine speed band approximately 10 per cent broader than before. Hence, the superior pulling force from low engine speeds so typical of a BMW diesel is now combined with even faster and more dynamic revving characteristics.

This impressive enhancement of engine dynamics comes hand-in-hand with an equally impressive optimisation of all-round economy. In practice, this means that fuel consumption by the new BMW 118d in the EU test cycle is down by approximately 16 per cent versus the former model to a mere 4.7 litres/100 kilometres or 60.1 mpg Imp – despite an increase in power by 15 kW to 105 kW/143 hp. The new BMW 120d, in turn, comes with an increase in output by 10 to 130 kW (177 hp) and an improvement in fuel economy of the same magnitude, the engine now making do with just 4.9 litres of diesel fuel/100 kilometres (equal to 57.6 mpg Imp).

Impressively reaching even the most ambitious targets.
In developing the new family of diesel engines, BMW's engineers sought from the start to enhance both output and torque while at the same time optimising the weight of the engine and reducing fuel consumption significantly versus the former power units. So it is precisely these features that characterise the BMW Group's development strategy for EfficientDynamics, with the new four-cylinder diesels impressively fulfilling all of these requirements.

For reasons of production technology and efficiency, BMW follows the principle to build four- and six-cylinder diesel engines of the same size (displacement) but in different power configurations. So looking at the new generation of four-cylinders, this means that the 2.0-litre has been developed in no less than three different versions.

All-aluminium crankcase for optimum engine weight.
Both the "basic" and the top engine significantly outperform their predecessors in terms of both output and torque. And at the same time the new engines are 17 kg or more than 37 lb lighter than the former-generation four-cylinder diesel. This optimisation of weight has a positive impact not only on the car's all-round economy, but also on the harmonious distribution of axle loads. And this, in turn, means improved agility in the models driven by BMW's new four-cylinder diesels.

In terms of both economy and emissions, therefore, and in the area of driving dynamics, the new engines stand out clearly as the leaders in their respective segments.

The starting point for developing BMW's new family of engines was the successful four-cylinder diesel with the same size as the new power units, developing 90 and, respectively 120 kW (122 and, respectively, 163 hp) in its former configuration. To take the extra power of the new engines into account, the diameter on the main bearings on the crankshaft has been increased accordingly. A further point is that in parallel to the increase in power, engine weight has been significantly reduced mostly by the new aluminium crankcase with its thermally bonded grey-cast iron bushes taking the place of the grey-cast iron block used so far.

Efficient combustion for optimum fuel economy.
The cylinder head with its intake ducts is a new design. The intake ducts are positioned at the side and designed as a spiral and tangential manifold.
To reduce emissions to an absolute minimum, the spiral duct serving to fill the cylinder is electronically variable in an infinite process. With their larger diameter, the valves facilitate the gas charge cycle and are now positioned

upright, facing vertically into the combustion chambers. This avoids the need for extra cavities on the piston surface, which no longer requires separate valve pockets. The turbulence duct, in turn, gives the fresh air flowing into the engine a swirl motion improving the internal mixture formation process.

While the "basic" engine operates at an injection pressure of 1,600 bar and solenoid valves serve to supply the fuel in appropriate doses, the two more powerful engines inject diesel fuel at a pressure of 1,800 and, respectively, 2,000 bar through four piezo-injectors. The most powerful version of the new diesel is incidentally the first engine ever to use piezo-injectors operating at this high pressure of 2,000 bar.

To make the combustion process even more efficient, both the shape of the combustion chambers and the trough at the bottom of the piston have been modified and the compression ratio reduced to 16 : 1. And since fuel is injected in up to three "doses" for each operating stroke of the engine, the ignition flames spreads in a relatively "gentle" process benefiting in particular the smoothness and refinement of the diesel engine.

Various improvements within the engine itself – reduction of friction, redesigned combustion chambers, optimisation of the mixture formation process, combustion and air guidance – ensure a significant improvement in fuel economy right from the start. This improvement is supplemented by various other technologies and features on the car itself, such as Brake Energy Regeneration, the Auto Start Stop function, the gearshift point indicator, as well as EPS Electrical Power Steering.

Making its debut in the four-cylinder diesel: Variable Twin Turbo technology.

Two-stage turbocharging in the 150 kW/204 hp top version of the new four-cylinder diesel ensures a particularly fast response and even more muscular power. Variable Twin Turbo technology has already been introduced in the world's most sporting and dynamic six-cylinder diesel featured in the BMW 535d. Today this 3.0-litre straight-six developing maximum output of 210 kW/286 hp is available in several model series. The technology providing this unique, dynamic power and performance is referred to as twin-stage turbocharging, a principle now featured for the first time also in a four-cylinder diesel.

The turbocharger unit in the Variable Twin Turbo is made up of one small and one large exhaust gas turbocharger. Benefiting from its lower inertia, the smaller turbocharger becomes active at low engine speeds just above idling. At higher speeds the larger turbocharger then also cuts in, developing extra power in the process.

Thanks to this configuration, the turbocharger effect is built up spontaneously without any time lag, developing noticeable thrust and momentum even when the driver barely presses down the accelerator pedal. A turbine control flap distributes the flow of exhaust gases variably to the two turbochargers.

Specially developed, high-performance engine electronics ensure smooth management in the transition phase between the two turbochargers and optimum interaction of the two units with one another. This sophisticated control concept coordinates the complete system of turbines, the turbine control flap, bypass and wastegate as a function of the engine's operating conditions.

The most powerful of the three new diesel engines develops its maximum torque of 400 Nm or 295 lb-ft at just 2,000 rpm. Maximum charge pressure in the system is limited in this engine to 3.0 bar.

Developing maximum output of 150 kW/204 hp, this power unit enters a new dimension of EfficientDynamics. Through its power and performance, it indeed sets new standards not only in the segment of four-cylinder diesels, since this is the first all-aluminium diesel in the world to offer output per litre of more than 100 hp.

Available in two power stages: BMW diesel with variable turbine geometry.
The drive units developing 105 and, respectively, 130 kW (143 and 177 hp) each feature one exhaust gas turbocharger with variable turbine geometry. This technology allows optimum development of power tailored perfectly to all load conditions. An electric step motor serves to adjust the turbine blades with supreme accuracy and minimum delay to the respective operating conditions and running requirements.

This ensures a spontaneous response at low engine speeds as well as high power and superior performance under full load. Maximum charge pressure in the 105 kW/130 hp power unit is 2.5 bar, as opposed to 2.55 bar in the 130 kW/177 hp version. Maximum torque, in turn, is maintained consistently between 1,750 and 2,500 rpm or, in the latter case, between 1,750 and 3,000 rpm.

Compact power pack with carefully conceived solutions.
For reasons of the car's package and efficiency in production, all ancillaries such as the coolant pump, alternator and climate compressor are on the intake side of the engine. This arrangement serves inter alia to provide adequate space for the two exhaust gas turbochargers featured on the top engine.

And since all ancillary units are driven by one single belt, there is no need for a second belt level, which again helps to enhance the overall standard of efficiency by avoiding frictional losses.

The design and construction concept of BMW's new four-cylinder diesels also has a positive effect on the safety standard of future vehicles. To improve pedestrian safety, for example, the chain drive has been moved to the same side as the flywheel. The high-pressure pump, in turn, is driven by a chain from the crankshaft – and then serves itself to drive the camshaft by way of a second chain.

To make the new engines even more compact, the two balance shafts running in needle bearings in the opposite direction to the engine are integrated in the crankcase at the side. This particular arrangement takes the special configuration and space available in an all-wheel-drive vehicle into account. The balance shafts run for the first time in needle bearings to significantly reduce the frictional forces generated in the process. For thanks to their compact dimensions, the new four-cylinder diesels with balance shafts may also be combined with BMW's intelligent xDrive all-wheel-drive system.

The oil/water heat exchanger is also housed in a very compact arrangement, fully integrated in the oil filter casing assembled directly on the crankcase. The filter casing, in turn, is designed for maximum operating efficiency without requiring any hoses otherwise used to connect the heat exchanger to the water shell around the crankcase.

The overall height of the engine has also been reduced by moving the vacuum pump for boosting brake power from its usual arrangement on the same side as the flywheel to the oil sump for the engine. The compact starter, finally, is fitted on the same level as the seals beneath the engine.

Exemplary emission control thanks to the diesel particulate filter.
To keep the periphery of the engine as clear-cut and uncluttered as possible, the feed pipe for exhaust gas recirculation (EGR) is integrated in the cylinder head. The EGR valve is positioned on the hot side of the engine, the EGR radiator features a bypass serving to limit the emission of harmful substances while the engine is warming up. A further advantage of this concept is that it ensures smooth and cultured engine refinement at all times.

All versions of this new engine generation come as standard with a diesel particulate filter fitted close to the engine. This ensures optimised emission control and management quite unique in this drive segment.

The diesel engine is a core technology used by the BMW Group in its strategy to reduce CO_2 emissions. Accordingly, the BMW Group is acting according to the policy agreed by the European Association of Automobile Manufacturers with the EU Commission to reduce CO_2 emissions to 140 grams per kilometre in the European car fleet average by the year 2008 – which equals a reduction by 25 per cent versus the level in 1995.

BMW's newly developed four-cylinder diesel engines are a further step through which the BMW Group is making a clear-cut and decisive contribution in reaching these targets. Indeed, the new BMW 120d already reduces CO_2 emissions to 129, the new BMW 118d to an even more impressive 123 grams per kilometre.

A further point is that BMW already fulfils the commitment made by the German automotive industry to fit all new diesel passenger cars with a particulate filter ex works by the year 2008. The diesel particulate filters used by BMW achieve a separation rate already confirmed by the German Federal Office of the Environment of more than 99 per cent, the concentration of particulates in the exhaust emission of a BMW diesel thus reaching a level similar to the concentration in the ambient air – that is in the environment as a whole.

BMW diesel engines: striking out to success with strong muscle and superior efficiency.
Introducing the new four-cylinder diesels, BMW is continuing the successful development of this drive concept. The combination of dynamics and economy which has already given the diesel engine its growing significance, is now being raised to a new level also with the four-cylinder.

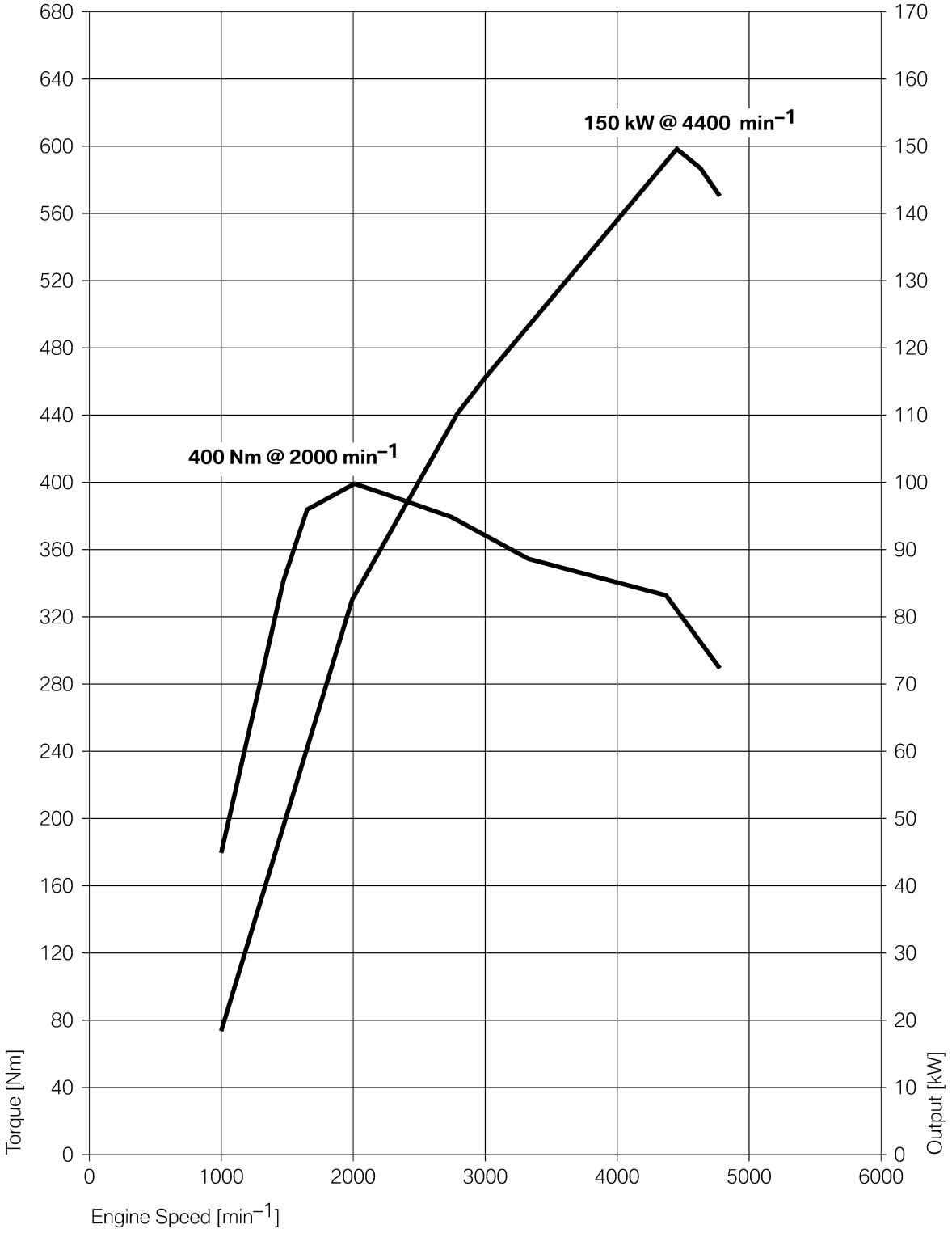
Diesel engines have been a firm highlight within the BMW engine range for more than two decades, the production figures of BMW diesel engines increasing more than tenfold since 1983.

The engines featured in BMW cars offer a particularly attractive and, indeed, convincing combination of dynamics, efficiency and motoring culture. Inter alia, these qualities were also the reason why in the year 2005 no less than 39 per cent of all new BMW cars registered worldwide featured a diesel engine. Depending on the model series and sales market, the share of diesel engines is indeed significantly higher in some cases. As just one example, no less than 88 per cent of all BMW X3s sold in Europe in 2005 were driven by a diesel power unit.

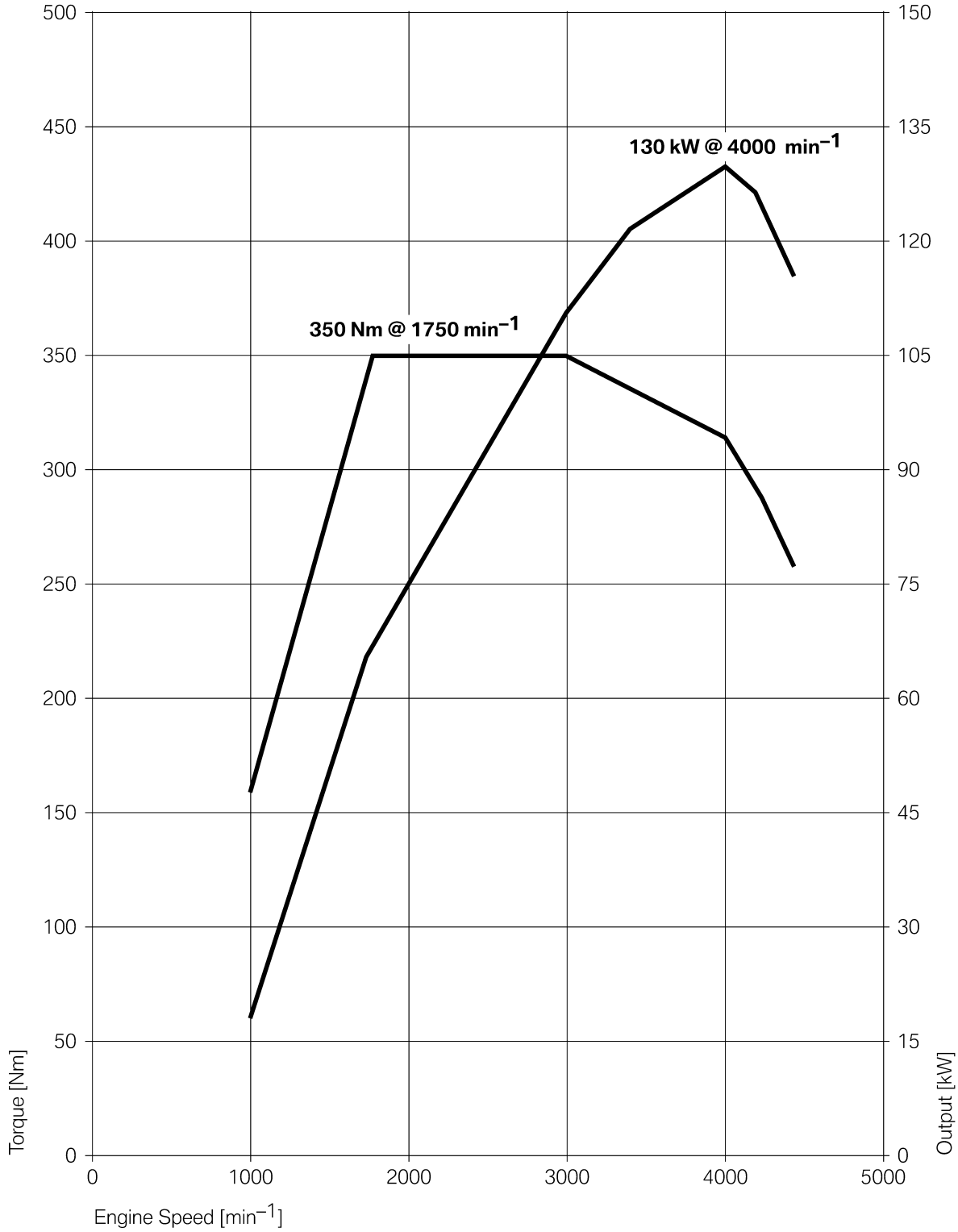
3.1 Specifications of BMW's new four-cylinder diesel engines.

Feature/entity	**Unit**	**4 cylinder diesel engine with aluminum crankcase**			**For comparison: 6 cylinder diesel engine with aluminum crankcase and Variable Twin Turbo technology**
Fuel	[ ]	Diesel	Diesel	Diesel	Diesel
Max output	kW	105	130	150	210
at	rpm	4,000	4,000	4,400	4,400
Max torque	Nm	300	350	400	580
at	rpm	1,750–3,000	1,750–3,000	2,000	1,750
Max engine speed	rpm	5,000	5,000	5,200	5,000
Stroke	mm	90	90	90	90
Bore	mm	84	84	84	84
Displacement	cc	1,995	1,995	1,995	2,993
Distance between cylinders	mm	91	91	91	91
Valve plate diameter, intake	mm	27.2	27.2	27.2	27.4
Valve plate diameter, outlet	mm	24.8	24.8	24.8	25.9
Compression ratio	[ ]	16 : 1	16 : 1	16 : 1	16.5 : 1
Fuel injection	[ ]	Common Rail 2nd generation; electro-magnetic injectors; up to 5 separate injections	Common Rail 3rd generation; piezo-injectors; injectors; up to 5 separate injections	Common Rail 3rd generation; piezo-injectors; injectors; up to 5 separate injections	Common Rail 3rd generation; piezo-injectors; injectors; up to 5 separate injections
Fuel injection pressure	bar	1,600	1,800	2,000	1,600
Maximum charging pressure above atmosphere	bar	1,500	1,500	2,000	1,950
sort of turbo charging	[ ]	Turbo charger with variable turbine geometry	Turbo charger with variable turbine geometry	2 stage charging with 2 turbo chargers in line (Variable Twin Turbo technology)	2 stage charging with 2 turbo chargers in line (Variable Twin Turbo technology)
Average maximum combustion chamber pressure	bar	19	22	25.3	24.5
Maximum combustion chamber pressure	bar	170	180	180	180
Engine weight to BMW standard	Kg	152	152	161	196
Minimum specific fuel consumption	g/kWh	198	198	204	205
Output per litre	kW / L	52.6	65.2	75.2	70.2
Power-to-weight ratio	kg/kW	1.44	1.17	1.07	0.93
Crankcase	[ ]	Aluminium	Aluminium	Aluminium	Aluminium
Camshaft	[ ]	Assembled instead of cast	Assembled instead of cast	Assembled instead of cast	Assembled instead of cast
Valves per cylinder	[ ]	4	4	4	4

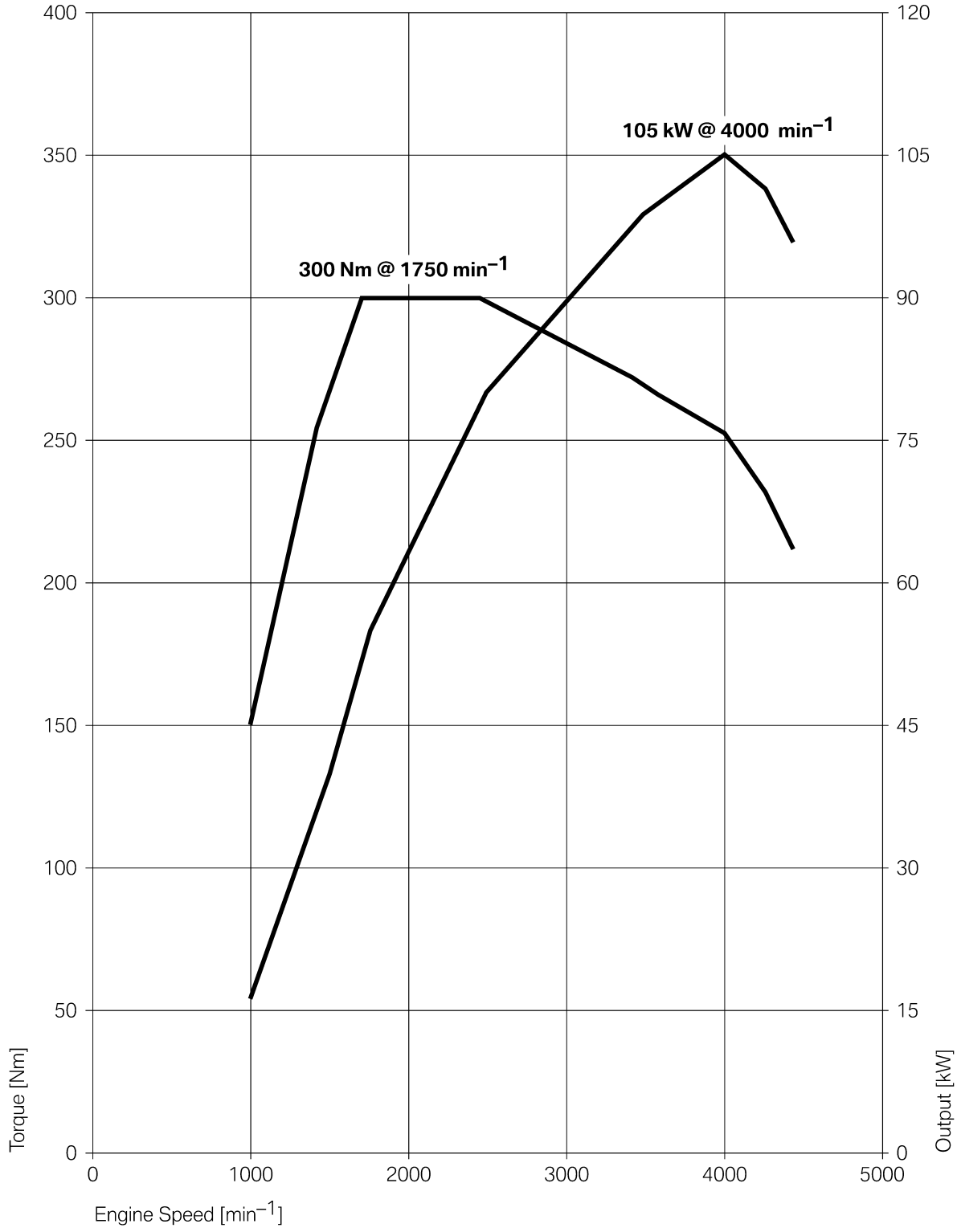
3.2 Torque and output diagram of the BMW 150-kW Variable Twin Turbo 2.0-litre four-cylinder diesel.



3.3 Torque and output diagram of the BMW 130-kW Variable Twin Turbo 2.0-litre four-cylinder diesel.



3.4 Torque and output diagram of the BMW 105-kW Variable Twin Turbo 2.0-litre four-cylinder diesel.



4. Innovation in detail for EfficientDynamics of the highest standard: Reduction of fuel consumption and emissions in BMW's new four-cylinder models.

The new four-cylinder power units now being introduced by BMW offer a supreme standard of EfficientDynamics in particularly compact dimensions. This applies both to the latest generation of diesel engines and to the new petrol engines, each with four cylinders. In both categories BMW's latest power units set the standard in terms of power and performance combined with superior economy.

Regardless of whether petrol or diesel as well as the category of power and performance chosen, all drivers of a four-cylinder BMW thus benefit from BMW's significant progress in engine development defining the strategy of EfficientDynamics. In comparison with their respective predecessors, all new-generation four-cylinders offer lower weight, more power, greater fuel economy, and optimised emissions.

In addition to the various improvements and modifications within the engine – ranging from the reduction of internal friction and the redesigned combustion chambers through the optimisation of the combustion process, air flow and turbocharging all the way to High Precision Injection as a lean burn direct injection concept with the petrol engines and, respectively, the latest-generation common rail fuel injection on the diesel engines – innovations specific to the vehicle ensure further enhancement of all-round economy in every respect.

These innovations thus help in various ways to convert the power developed by the engines even more efficiently into genuine driving dynamics. The engines develop their superior qualities under all kinds of loads and operating conditions, ensuring that the higher standard of efficiency offered in all BMW cars powered by these new four-cylinders is reflected in everyday motoring by a measurable reduction of fuel consumption.

Auto Start Stop function: zero fuel consumption while idling.
To avoid the consumption of fuel during long idling periods at road junctions or in traffic jams, BMW's new four-cylinder petrol and diesel engines with a manual gearbox feature an Auto Start Stop function. This function is activated as soon as the car comes to a standstill, the driver shifts to neutral and takes his foot off the clutch pedal. Then, to go on driving, all the driver has to do is press down the clutch to start the engine without delay. Both the electric starter and the starter battery are specifically laid out for the extra burden of such additional starting processes.

The Auto Start Stop function is activated automatically every time the driver starts the engine and is switched off automatically once the engine oil has reached the operating temperature required. For reasons of safety and motoring comfort, there is no automatic deactivation under certain conditions, for example when the battery is almost flat or at very high (more than 30° Celsius) or very low (less than 3° Celsius) outside temperatures. When coming to a brief halt, the engine will also go on running as long as the temperature inside the car has not yet reached the level preselected on the air conditioning or if heater power is required to remove ice or surface mist from the windscreen. And last but not least, the driver has the option to de-activate the Auto Start Stop function at any time simply by pressing a button.

With this function being very comfortable and convenient, the driver will get used to such automatic engine control very quickly indeed. The engine restarts very smoothly and spontaneously as soon as required, since the control unit "remembers" the position of the crankshaft at precisely the point when the engine was switched off, activating the ignition and fuel injection without the slightest delay. Building up pressure in the fuel injection system does not take any extra time, either, since the pressure already generated in the fuel pipe is kept unchanged while the vehicle is at a halt.

To optimise the efficiency of the system also while driving, the Auto Start Stop function is combined with a gearshift point indicator, the engine's electronic "brain" calculating the optimum point for shifting up gears in the interest of maximum fuel economy, as a function of driving conditions. So the gearshift indicator – an arrow symbol lighting up and specifying the optimum gear – in the instrument cluster "tells" the driver to shift gears at exactly the right time.

Brake Energy Regeneration for efficient electric power supply.
Intelligent management of the flow of energy in generating, storing and using electric power on board the car makes a further contribution to the reduction of fuel consumption and CO_2 emissions. Brake Energy Regeneration moves the process of converting primary energy to electric power to the overrun and brake application phases. This reduces the load acting on the alternator while the car is accelerating and driving under power, with the on-board electric network being supplied with electricity exclusively by the battery under such conditions. Clearly, this means more engine power for accelerating and driving dynamically. The alternator will only be reactivated when the engine enters the overrun mode.

Electric power is therefore generated primarily when the driver applies the brakes, intelligent alternator control also considering the current charge level of the battery. So once battery capacity drops below a defined minimum level, the alternator will generate and supply electric current regardless of driving conditions.

With such intelligent control also increasing the number of charge cycles, the alternator control system is combined with modern AGM (absorbent glass mat) batteries able to withstand far higher loads than conventional lead acid batteries. In an AGM battery, acid is kept in micro-glass-fibre mats between the layers of lead, maintaining its energy storage capacity for a long time even when recharged and discharged frequently.

Saving energy: steering assistance only when really required.
BMW models driven by the new four-cylinder power units also come with BMW's new EPS Electrical Power Steering. EPS provides electrohydraulic steering assistance, with the hydraulic steering assistance pump being driven by a small electric motor.

While on hydraulic power steering the pump driven by the combustion engine generates pressure permanently and therefore consumes energy all the time even when no power assistance is required, EPS operates independently of the engine and is therefore very efficient, the pump building up pressure only when steering assistance is actually needed. Compared with a conventional steering system, this means a significant reduction of fuel consumption.

Operation of the air conditioning in BMW's new four-cylinder models is also tailored more precisely to the actual needs and requirements of the occupants, serving again to reduce the consumption of energy. For as long as there is no need to cool the interior, the system is able to save energy in the interest of enhanced economy. A conventional climate compressor, through its operating principle alone, is subject to a permanent loss of power even when the air conditioning is not in use. The compressor on BMW's new four-cylinder power unit, in turn, may be separated completely from the belt drive by a magnetic clutch, thus continuing to minimise the loss of power as soon as the air conditioning has been deactivated.

Ancillary units controlled and operated on demand.
BMW's engineers save additional energy on the new four-cylinder petrol engines by activating ancillary units such as the coolant, fuel and oil pumps only when really required. Controlled as a function of temperature, the electric coolant pump operates only when really needed, thus helping the engine achieve a higher level of all-round efficiency. The electric water pump, in turn, adjusts the amount and flow of water to the engine's actual cooling requirements, regardless of engine speed, reducing the drive power required for the pump by up to 90 per cent or approximately 200 Watt.

A further point is that there is no flow of coolant when starting the engine cold, enabling the engine to reach its operating temperature more quickly. And last but not least, this technology offers additional customer benefits through the option to use the residual heat in the coolant even when the engine is at a standstill in order to warm up the interior.