BMW Technology Day 2009. EfficientDynamics. Contents.

1. BMW Technology Day 2009. EfficientDynamics. (Introduction)

Lower emissions, more driving pleasure: No other car maker besides the BMW Group applies this principle so convincingly and successfully in practice. Both today and in a long-term comparison, BMW and MINI are far ahead of all competitors in the premium segment in reducing both fuel consumption and CO_2 emissions.

This unique position held by the BMW Group is the result of the EfficientDynamics development strategy comprising all innovations serving to reduce fuel consumption and emissions versus the former model and, at the same time, enhance road performance to an even higher standard.

This is made possible by the fundamental, all-round philosophy of BMW EfficientDynamics. Optimisation of vehicle efficiency is indeed the guideline applied by the BMW Group in all areas of vehicle development, bearing testimony to the unique competence of the BMW Group in terms of powertrain, transmission and suspension technology, promoting the intelligent flow of energy within the vehicle as well as the intelligent choice of materials for superior lightweight construction, and ensuring the permanent optimisation of aerodynamics.

Like the latest results in the area of engine and transmission development, the new Aerodynamic Test Centre (ATC) now completed by the BMW Group clearly confirms the Company's consistent quest for further progress in the context of EfficientDynamics. Ongoing reduction of fuel consumption and emissions calls time and again for new, massive investments in the Company's research and development facilities, since only highly qualified specialists using the most advanced technology are able to create trendsetting, future-oriented concepts for individual mobility.

As the world's most successful manufacturer of premium cars, the BMW Group readily faces this responsibility and develops an above-average commitment in offering Sheer Driving Pleasure on even less fuel and with even lower emissions.

The most efficient premium cars come from BMW and MINI.
Innovations serving to reduce fuel consumption and emissions are an elementary part of the product substance in each and every BMW and MINI. So it is fair to say that every new BMW and MINI comes with the latest features in EfficientDynamics combined individually in each case in accordance with the character and nature of the respective model.

No other car maker currently offers such a huge range of efficiency-promoting technologies throughout all vehicle segments, without even charging an extra price for these breakthroughs in technology. So again, this approach to the requirements of today and tomorrow confirms the unique character and philosophy of BMW EfficientDynamics in the world of motoring.

Through the consistent use of appropriate technologies with their high impact throughout the entire model range, BMW is able to offer a full-scale, all-inclusive improvement significantly reducing CO_2 emissions in road traffic.

The unique BMW EfficientDynamics strategy comes out clearly in an objective comparison of average fuel consumption and emission figures. According to statistics compiled by the German Motor Vehicle Registration Authority, the average fuel consumption of all BMW and MINI vehicles registered in Germany in 2008 is just 5.9 litres/100 kilometres, equal to 47.9 mpg imp, the average CO_2 rating is 158 grams per kilometre. Both figures are significantly lower than the average of all vehicles registered in Germany in 2008.

Making further progress in the improvement of efficiency in recent times, the BMW Group stands out clearly also from other manufacturers in the premium segment. From 2006 to 2008 alone, BMW's average fuel consumption and CO_2 ratings were down by 16, the average MINI ratings by 20 per cent. These improvements are more than twice as good as the next-best level of improvement achieved by a competitor in the premium segment.

In all, the reduction in average CO_2 emissions achieved by the BMW Group, as calculated by the German Motor Vehicle Registration Authority as a non-partisan observer, is four times greater than the average figure for all car makers operating in the German market.

EfficientDynamics: a firm part of the BMW Group's product substance and corporate philosophy.

The leadership held by the BMW Group over the competition results not just from short-term action or new priorities, but is rather the result of a consistent, ongoing strategy. On a European level this is borne out, among other things, by a reduction of fleet consumption between 1995 and 2008 of far more than 25 per cent, meaning that the BMW Group with the BMW and MINI brands has already over-fulfilled the commitment made by the Association of European Automobile Manufacturers (ACEA).

The EfficientDynamics development strategy, production processes able to save resources, and high social standards for employees at all company locations are fundamental highlights of the BMW Group's corporate philosophy. These factors help not only the products made by the BMW Group, but also the Company itself, to take on and maintain an outstanding position within the car industry – a position reflected, among other things, by the latest Dow Jones Index. This ranking compiled jointly by the Dow Jones Indices, Stoxx Limited, and the Zurich-based Assets Management Company SAM, is acknowledged as the world's most important benchmark for entrepreneurial responsibility. And precisely here the BMW Group is ranked for the fourth time in a row as the "World's Most Sustainable Car Maker".

Through its clear focus on innovation and sustainability, the BMW Group is particularly well prepared for the challenges of the future. The BMW Group uses its competence in technology and financial resources specifically to offer vehicles combining supreme efficiency and fascinating performance both today and in the future.

An investment in the future: the Aerodynamic Test Centre.

No other car maker is as committed as the BMW Group to making lasting and substantial investments in the enhanced efficiency of new models. Building the new Aerodynamic Test Centre, the BMW Group now has even greater competence and qualifications than before in the area of innovative technologies contributing in the medium and long term to the further improvement of all BMW and MINI models in their fundamental strengths and benefits. For optimisation of the car's aerodynamic qualities improves both its performance and efficiency, as well as the driving stability offered by the car on the road. Precisely this is why optimum aerodynamics is already a fundamental factor today in the development of new models.

Building the ATC, the BMW Group is giving even greater emphasis to the ongoing enhancement of aerodynamics as an essential cornerstone of the EfficientDynamics philosophy. Optimised aerodynamics have a direct impact on the car's fuel economy and emission management, a reduction of air drag by 10 per cent offering the customer a reduction in fuel consumption on the road by more than 2.5 per cent – and even such an at first sight "insignificant" improvement is of great importance to the BMW Group as part of an overall package for the enhancement of efficiency.

With BMW Group cars already offering excellent aerodynamic qualities today, further improvement and, indeed, optimisation, calls for a substantial investment. So making such an investment in the ATC, the BMW Group clearly expresses its intention to use all facilities also in future in order to improve both fuel economy and emission management to an even higher standard.

The ATC offers new options and potentials in analysing the aerodynamic qualities of a car – and at the same time flexible processes applied at the ATC as well as its location in the immediate vicinity of the BMW Group's Research and Innovation Centre (FIZ) optimises the integration of all activities in the overall process of vehicle development. In future, therefore, the BMW Group's aerodynamic specialists will be working next door and hand-in-hand with BMW's designers, constructors, engine specialists and other experts.

Over and above such enhanced integration into the development process, the ATC has facilities and capabilities unique the world over in determining aerodynamic features and qualities in a truly realistic process. One option, for example, is to analyse new models at a very early stage of development in a wide range of different situations with all test scenarios following real-life driving conditions. This means not only the consideration of all kinds of speed ranges, but also different driving situations such as driving in a bend, taking the actual movement of the body into account.

A further point is that the ATC is now able for the first time to render and analyse the interaction of a car with other vehicles, for example when overtaking, thus offering yet another new benefit in the development of production cars.

So far such tests could only be conducted on the test track, with cars almost completely developed in every respect. Now the knowledge gained in this process can be fed back into the development process much earlier, serving to effectively optimise a new model right from the start.

Most advanced wind tunnel technology for realistic measurements.
The BMW Group's new Aerodynamic Test Centre is the world's most modern facility of its kind throughout the entire automotive industry. The ATC comprises a wind tunnel serving to analyse vehicles in their original size. To reproduce the most important effects and phenomena when driving on the road, the road surface is modelled through a simulation process using no less than five rolling tracks.

A second wind tunnel allows the engineer to move the models tested from one position to the other by means of a control system operating in all directions above the world's largest rolling road in a wind tunnel. This serves to analyse vehicle flow conditions under all kinds of circumstances, applying a concept already used for a number of years in motorsport. Now, therefore, aerodynamics and driving dynamics may interact and be combined with one another also in the development of production cars.

The number of scenarios available as well as the precision of the test processes applied at the ATC offer a standard quite unique for a facility of this kind. Both wind tunnels, to mention just one example, are able to generate an air flow velocity of up to 300 km/h or 186 mph, for the first time providing exactly the right, correct physical conditions for the measurement of true-to-scale models.

In all, the BMW Group has invested some Euro 170 million in the construction of the Aerodynamic Test Centre and the facilities/equipment used. Within about three years, the five-floor building constructed on a piece of land measuring approximately 25,000 square metres or 6.2 acres has been completed in the immediate vicinity of the Munich FIZ Research and Innovation Centre and boasts architecture quite unique at very first sight, providing a clear hint from the beginning that the technology used inside is very special indeed.

One example of this distinctive look and architecture is the round contour of the fan for the horizontally arranged air flow ring in the main wind tunnel clearly recognisable on the southern side of the building. The vertical air flow ring for the model wind tunnel, in turn, likewise stands out clearly in the centre of the ATC.

BMW's EfficientDynamics specialists focusing in the ATC specifically on aerodynamics used to work at no less than five different locations before moving into the new Test Centre, travelling up to 20 kilometres in order to work together in the wind tunnel. Now, by putting all these specialists together in one building, the BMW Group ensures direct contact with extremely small distances between the various specialists and has established new processes for highly efficient interaction and cooperation. In all, some 500 specialists in BMW EfficientDynamics will be working together in the new building.

Even more efficient: new generation of straight-six power units with turbocharger technology.

Together with the new ATC, BMW is proudly presenting the latest results in the development of particularly powerful and, at the same time, impressively economical straight-six power units. Indeed, these new engines, whether running on gasoline or diesel fuel, offer a significantly better balance of fuel economy and superior performance than ever before – quite simply, because both engines use special technologies developed by BMW to enhance both efficiency and dynamic performance. Both power units therefore offer the same kind of momentum and superiority in the development of power otherwise provided only by a much larger eight-cylinder, while at the same time they are naturally much lighter and offer substantially better fuel economy and emission management.

BMW's new TwinPower Turbo gasoline engine developing 225 kW/306 hp for the first time combines turbocharging, direct fuel injection and fully variable valve management in one drive unit. This combination of a twin-scroll turbocharger with High Precision Injection and VALVETRONIC exclusive to BMW gives the new engine fully suited for the world market not only unusually spontaneous and direct behaviour, but also exceptionally low fuel consumption and emission ratings.

This 3.0-litre six-cylinder develops its maximum torque of 400 Newton-metres or 295 lb-ft at an engine speed of just 1,200 rpm and then maintains this superior torque level all the way to 5,000 rpm. In comparison with the straight-six featuring Twin Turbo technology and High Precision Injection already featured in several model series, the engine at the same time offers a further reduction of fuel consumption by up to 9 per cent.

Introducing an additional top version of the six-cylinder diesel already featured in the BMW 730d and the BMW 330d, BMW once again proves the outstanding potential this engine technology has to offer. Again, the new generation of BMW's straight-six diesel, combining multi-stage turbocharging with common-rail direct fuel injection, offers fascinatingly dynamic power and performance with maximum efficiency. And again in the spirit of BMW EfficientDynamics, numerous innovations on the all-aluminium engine as such, the two turbochargers and the injection system ensure a significant increase in power as well as a further reduction of fuel consumption and emissions. Not only the turbocharger system is even more efficient than before, but also the supply of fuel through piezo-injectors operating at an injection pressure of up to 2,000 bar.

The new 3.0-litre BMW TwinPower Turbo diesel delivers maximum output of 225 kW/306 hp at an engine speed of 4,400 rpm, with peak torque of 600 Newton-metres/442 lb-ft at just 1,500 rpm. These figures alone allow the new engine to take over the leading position from its own predecessor as the most sporting and dynamic six-cylinder diesel in the world, at the same time offering some 4 per cent lower fuel consumption and CO_2 emissions.

BMW's new eight-speed automatic transmission: the intelligent way to more gears, greater efficiency and enhanced driving dynamics.
BMW's new eight-speed automatic transmission is yet another example of how outstanding engineering qualities are able to offer a significant improvement in driving pleasure and, at the same time, far greater efficiency than ever before.

This innovative power transmission first introduced in the twelve-cylinder BMW 760i and BMW 760Li excels in particular through its exceptional efficiency and wide range of qualities. At the same time, through its special characteristics, the new eight-speed transmission raises both the motoring comfort and the dynamic performance of the respective model to an even higher standard.

Yet a further important point is that this significant progress over BMW's six-speed automatic transmissions already lauded the world over for their superior gearshift dynamics and efficiency has been achieved in a particularly intelligent manner. The two additional gears give the entire transmission an even broader range of increments and, at the same time, keep the change in engine speed when shifting from one gear to the other even smaller than before. Thanks to the innovative configuration of the gearsets, the number of additional components required and, accordingly, the weight of the new eight-speed automatic transmisson, has been reduced to a minimum.

Converter slip limited to the lowest range of engine speeds, a high degree of inner efficiency, low frictional losses with only two clutches open at a time, the longer transmission ratio of the higher gears, and the improved suppression of vibrations enabling the driver to use the car much more at low speeds, help to reduce fuel consumption versus the former six-speed automatic transmission by approximately 6 per cent.

A further important point is that the eight-speed automatic transmission enhances the dynamic qualities of the engine by opening and closing only one clutch at a time in nearly all gearshifts, even when shifting down by more than one gear. This offers an important benefit so far provided only by the double-clutch gearbox and combined in this case with all the benefits of an automatic transmission relevant to the customer, such as dynamic acceleration from low engine speeds.

The new eight-speed automatic transmission is also a particularly future-oriented solution for the transmission of power in a premium car. It may be combined with all kinds of engines varying in their design and performance, being used not only in cars with rear-wheel drive, but also in all-wheel-drive models. And at the same time the eight-speed automatic transmission also has all the qualities to form a perfect combination with hybrid drive. This alone ensures a unique blend of efficiency and dynamism on a brand-new level, proving that this concept perfectly suited for the future will be heading for success after reaching production level in the course of 2009.

The new options offered by BMW's Aerodynamic Test Centre, together with current and future innovations in drivetrain technology, will serve on many occasions to solve the conflict of interests between growing dynamics and optimised economy in all segments of the market. As a result, therefore, the BMW Group has an even better position than ever before in developing cars for the future which, through their design and driving qualities, will offer a fascinating driving experience combined with equally supreme fuel economy and emission management.

2. Less Air Resistance, Lower Fuel Consumption and Emissions, More Sheer Driving Pleasure: Innovative Aerodynamics Contributing to BMW EfficientDynamics.

The drag coefficient of the current BMW 320i Convertible with its roof closed is just 0.27. This benchmark, usually expressed as the C_d or C_x factor, is the decisive criterion for the aerodynamic qualities of a car – and indeed, a low drag coefficient sets the foundation for dynamic and efficient motoring.

Air resistance as a whole is a result of the drag coefficient and the cross-sectional area of the car, with most of the drive power being used to overcome air resistance even at low speeds in town. A good drag coefficient and good aerodynamics in general therefore have a positive effect also on the car's fuel consumption, a reduction of air resistance by one-tenth generally leading, under practical driving conditions, to an average reduction in fuel consumption by more than 2.5 per cent.

This alone obviously makes the development of superior aerodynamics an important factor in the BMW EfficientDynamics development strategy. Progress in this area has already been significant in the past with every new generation of models introduced into the market. Back in 1987, for example, the BMW 320i Convertible still had a drag coefficient of 0.39.

The options and benefits provided by the BMW Group's new Aerodynamic Test Centre now serve to consistently enhance the process of improving the car's streamlining.

Apart from air resistance, modern developments in aerodynamics have to consider a wide range of other criteria. Optimisation of lift forces in the interest of maximum driving stability, a precise supply of cooling air to the engine, the transmission and the brakes, the reduction of wind noise and the minimisation of dirt on the car caused by air turbulence, are among the objectives pursued by the engineer these days, using the most advanced technical equipment and detailed analysis.

A further factor in developing Convertibles and roadsters is the need to minimise air draught within the interior when driving with the roof down.

The demands made of a modern car in the premium segment in terms of aerodynamics have become greater and more diverse over the years. Given this challenge, the BMW Group now benefits from ideal conditions at the new Aerodynamic Test Centre (ATC) to meet the highest standard on new models also in terms of their aerodynamic qualities.

In the wind tunnel and on the computer: precise analysis of air flow.
Precisely calculating the flow of air and conducting realistic tests in the wind tunnel, the development engineer is able to analyse the interaction of the car itself and the flow of air under the most varied conditions. To obtain a good knowledge of the aerodynamic qualities of a new car right from the start, three-dimensional true-to-scale models of the designs proposed are examined and compared with one another in the model wind tunnel or Aerolab, as it is called. Then, in the ongoing development process, clay models in full size are tested in order to obtain even more detailed information. The big advantage in this case is that the models may easily be optimised in their various features and details, designers and aerodynamicists working together to reach their various objectives as a closely knit team.

Only when all this has been completed are full-sized models built for further testing in the large wind tunnel at the ATC.

Computerised methods are also used for various analytical purposes, parallel to the work done in the wind tunnel itself. To determine the aerodynamic qualities of a virtual 3D model, the BMW Group's development specialists apply so-called CFD (computational fluid dynamics) calculations, highly complex programs allowing them to recognise those parts of the vehicle involving unwanted turbulence, interruptions of air flow or pressure losses, with a corresponding increase in air resistance. They then apply this knowledge right from the start, again to achieve the best aerodynamic results in an early phase of the development process.

CFD calculations and wind tunnel tests are precisely coordinated with one another to obtain an optimum balance of results. The biggest advantage, however, is that this saves time, with the responsible engineers and other specialists always setting the pace of development.

Although the BMW Group's development specialists are able to use extremely powerful and fast computers, the enormous volume of data inevitably means that each calculation process takes up to three working days. Now almost 100 measurements may be conducted within the same period in the wind tunnel.

The BMW Group Aerolab: bringing the road into the testing laboratory.
The BMW Group's new Aerolab also sets the foundation for superior aerodynamic qualities in an efficient and consistent process, allowing the engineer to analyse the three-dimensional models of future production cars right from the start at an early point in the development process.

Apart from air resistance, the Aerolab is also able to measure the influence of aerodynamic forces on the driving stability of a car, realistically simulating all kinds of conditions on the road. And thanks to precise measuring technology and the generation of high wind velocities, the information obtained through the models alone is very realistic and reliable right from the start.

The Aerolab is the world's only facility of its kind able to analyse two models under typical flow conditions at the same time. Such tests show, for example, how the flow of air changes while overtaking and how two vehicles influence one another. So far only road-going prototypes tested on a track were able to provide such a scenario and allow appropriate measurements. But now, for the first time, the Aerolab gives development engineers the option to bring such a road scenario into the test area in order to optimise driving comfort and stability under all conditions.

Optimisation of details in the new wind tunnel: getting closer to reality.
The large wind tunnel in the new Aerodynamic Test Centre where car models are tested in their original size together with prototypes and production models, allows the most precise and realistic rendition of actual air flow conditions on the road. Here the flow of air generated by a fan measuring no less than 8 metres or 26.2 feet in diameter, after being diverted twice, acts directly on the vehicle held down in its measuring position. Thanks to the size of the measurement facility, the precise direction of air flow downstream of the fan and the nozzle opening of up to 25 square metres or 269 sq ft, flow conditions are absolutely realistic and are not distorted in any way.

The wind tunnel comes with a special configuration of rolling tracks incorporating five different track sections. The wheels of the vehicle on the measuring track run on small rolling sections serving to simulate the actual rotation of the car's wheels. These rolling tracks may be varied in width and length, and therefore adjusted to vehicles of various sizes. A wider track between the turning wheels serves additionally to render the flow of air beneath the car.

Using these five rolling tracks, the test engineer is able to determine the so-called flow-split, that is the share of air flow above and beneath as well as at the side of the vehicle, far more precisely than in a conventional wind tunnel.

The central rolling track may be varied in width, in accordance with the wheel track of the vehicle being examined. And measuring 10 metres or almost 33 feet in length, the central track also offers ideal conditions for simulating the changes in air flow typically encountered on the road. Ultimately, therefore, the development engineer can see exactly how the optimisation of specific details affects air resistance, the aerodynamic balance of the vehicle, as well as the supply and extraction of cooling air.

Maximum flow velocity in the new wind tunnel is 300 km/h or 186 mph. Clearly, this allows realistic measurements also of racing cars travelling at high speeds.

ATC provides new momentum in the development of superior aerodynamics.

Using the most advanced measuring technology and innovative test procedures, the BMW Group has made consistent progress in recent decades also in the area of aerodynamics. This is borne out clearly by a comparison of the current BMW 3 Series Convertible and its predecessor from the 1987 model year.

The new Aerodynamic Test Centre now sets the foundation for further momentum in the development process, ensuring specific improvements in many areas primarily benefiting the car's efficiency as well as the driving experience and motoring comfort through enhanced aerodynamic qualities. Optimising air resistance, the development engineers focus in particular on the underfloor of the car as well as the wheels and wheel arches responsible for approximately 50 per cent of overall air resistance also on a modern car. Precisely this is why the true-to-life rendition of realistic driving conditions is of great significance in the large wind tunnel at the Aerodynamic Test Centre, which also allows unprecedented precision in determining the lift forces so crucial to the driving stability of a car.

The wind deflectors used in a Convertible are also carefully analysed in terms of flow conditions and their individual qualities, ensuring that they effectively prevent air swirl within the passenger area. Again, therefore, tests conducted in the wind tunnel help to define exactly the right position and size of the wind deflector. The wind deflector in the new BMW 3 Series Convertible, for example, guarantees greater open-air driving pleasure than ever before, absolutely free of draughts and turbulence.

2.1 Comparison of Specifications.

		BMW 320i Convertible (1987)	BMW 320i Convertible (2009)
Body			
No of doors/seats		2/4	2/4
Length/width/height (unladen)	mm	4, 325/1, 645/1, 370	4, 580/1, 782/1, 384
Wheelbase	mm	2, 570	2, 760
Track, front/rear	mm	1,407/1,415	1,500/1,513
Weight, unladen, to DIN	kg	1,280	1,595
Max load to DIN	kg	400	430
Max permissible	kg	1,680	2, 025
Luggage capacity with roof open/closed	ltr	312/312	210/350
Aerodynamics			
Drag coefficient C_d	Roof closed	0.39	0.27
Cross-section A	sqm	1.86	2.08
Power Unit			
Configuration/cylinders		Straight-six	Straight-four
Capacity	cc	1,990	1,995
Max output (at engine speed)	kW/hp (rpm)	95/125 (6,000)	125/170 (6,700)
Max torque (at engine speed)	Nm/lb-ft (rpm)	164/121 (4,300)	210/155 (4,250)
Compression ratio		8.8 : 1	12 : 1
Chassis and Suspension			
Suspension, front		Single-joint spring strut axle with displaced castor, small positive steering roll radios, compensation of lateral forces, anti-dive	Aluminium double-joint tiebar axle with spring struts, compensation of lateral forces, anti-dive
Suspension, rear		Independent on semi-trailing arms, separate springs and dampers, anti-squat	Lightweight steel five-arm axle with two single arms top and bottom, connected to body by thrust rods, anti-squat and anti-dive
Brakes, front		Single-piston swing-calliper disc brakes	Single-piston swing-calliper disc brakes
Diameter	mm		312 x 24
Brakes, rear		Drum brakes	Single-piston swing-calliper disc brakes
Diameter	mm	–	300 x 20
Driving stability systems		ABS (optional)	Dynamic Stability Control (DSC) including traction mode (DTC), ABS and Dynamic Brake Control (DBC)
Steering		Rack-and-pinion power steering	Electromechanical power steering (EPS)
Transmission		Five-speed manual	Six-speed manual
Tyres		195/65 R14 H	225/45 R17 91W RSC
Rims		5 ½ J x 14/steel	8J x 17/light alloy
Performance, Fuel Consumption			
Acceleration 0–100 km/h	sec	11.5	9.1
Top speed	km/h	195	228
Fuel consumption, combined, to EU	ltr/100 km	Approx 11.2	6.9

3. Testing the Road In-House: The New BMW Aerolab and Development of the EfficientDynamics Air Curtain.

The development of every new vehicle is always a vision pointing into the future. But the primary question to be asked each time is always the same: what impression will the new model have on the customer? Design and comfort, driving dynamics and efficiency – it is only on the road that the quality of the work done by the development engineers over months and years will really become evident once and for all.

As the world's most successful manufacturer of premium cars, the BMW Group uses all kinds of methods to focus the development of new models precisely on the wishes and demands of the most discerning customer. Optimisation of aerodynamics, therefore, also follows the requirements made by the customer in many different areas.

Forming part of BMW's EfficientDynamics development strategy, optimum aerodynamic qualities serve to further enhance Sheer Driving Pleasure BMW-style while keeping fuel consumption and emissions to a minimum. And at the same time such aerodynamic qualities also serve to improve driving stability and motoring comfort.

The outstanding competence of the BMW Group in the area of aerodynamics gained over years and even decades serves to optimise not only the development of new models, but also the creation of new, trendsetting testing and analysis methods. Indeed, this is where practical development interacts hand-in-hand with scientific expertise.

The thorough know-how of BMW's engineers and many other specialists has naturally also gone into the development and completion of the new Aerodynamic Test Centre (ATC). The ATC therefore gives the BMW Group the most modern technical facilities to achieve further progress in optimising the aerodynamic qualities of future models, allowing appropriate tests under very realistic conditions both in the large wind tunnel and in the Aerolab. Both facilities therefore bring the development specialist a lot closer to his objective of bringing the road into the actual test area for convenient testing at all times and under all conditions.

The new Aerolab: perfect conditions for all kinds of tests.
Both in its dimensions and through the measuring equipment available, the Aerolab offers ideal conditions quite unique in the automotive industry for conducting the most detailed, in-depth research and development processes. The measuring area alone referred as the Plenary is 20 metres or 65.6 feet in length, 14 metres or 45.9 feet in width and 11 metres or 36.1 feet high and therefore large enough to easily accommodate not just small-scale test models, but also fully-sized prototypes.

With the air nozzle in the wind tunnel covering an area of 14 square metres or 150 sq ft, any adverse factors generated by the nozzle itself, the wind tunnel collector and the outer walls are limited to an absolute minimum. The unusually consistent pressure curve within the measuring area also helps to ensure particularly meaningful and reliable results.

The facility is even large enough to examine two vehicles at the same time, allowing tests and analyses quite new but highly relevant to everyday traffic. Indeed, the BMW Group's Aerolab is the only facility of its kind in the automotive industry able to simulate a typical overtaking manoeuvre, measuring various air flow phenomena influencing each other in the process.

Getting things right from the start for absolutely efficient development.
Three-dimensional models of the future production vehicle in a scale of, say, 1 : 2 are tested in the Aerolab right from the start in an early phase of the development process. Clearly, this allows the engineers and aerodynamicists to get everything right from the start in optimising the car's aerodynamic qualities. And it makes a significant contribution to the overall efficiency of the development process.

With wind velocities of up to 300 km/h or 186 mph, the results obtained in measuring models may be reliably carried over to the full-sized vehicle. The calculation formula applied for this purpose is based on an aerophysical principle referred to as the Reynolds Similarity specifying that the product of vehicle length and wind velocity must correspond appropriately in order to draw conclusions from a small model to a large, full-sized vehicle. This means that a 1 : 2 model requires twice the wind velocity of the original, full-scale vehicle in order to provide the same results. Using a 50 per cent model at a wind velocity of 280 km/h in the BMW Group's Aerolab, therefore, the aerodynamicist working in the Aerolab receives precise information on the aerodynamic behaviour of a future production model travelling at a speed of 140 km/h – the speed at which the drag coefficient of a vehicle is determined according to the uniform standard applicable to all car makers.

Looking for perfect aerodynamics.
In the Aerolab car models are guided through the flow of air while hovering freely on a suspension unit referred to as the “sword”. At the connection point to the model being tested a precision scale measures even the slightest movements in every direction, enabling the test engineers in the Aerolab control room to read this data simultaneously and record it for subsequent analysis.

During the measurement process the vehicle is kept in the immediate vicinity of the floor where a rolling track 9 metres or 29.5 feet long and 3.2 metres or 10.5 feet wide simulates the movements of the car in accordance with the wind velocity chosen. This distributes the flow of air to the side and beneath the vehicle in the wind tunnel, following the same pattern as on the road.

The direction of rotation of the wheels also has a significant influence on the wind profile in this area and is therefore an important criterion for obtaining realistic measurements.

This test configuration again quite unique allows realistic test scenarios of many kinds by rendering virtually all driving conditions relevant in everyday traffic. Apart from air resistance when driving straight ahead and in bends, the measuring process also serves to determine the susceptibility of the vehicle to cross-wind as well as lift forces/downforces at various angles of the vehicle. Offering a level of precision never seen before, this enables the test engineer to examine in particular the influence of air flow on the driving stability of the vehicle.

To reduce fuel consumption and CO_2 emissions, the objective in the aerodynamic development process is to keep air resistance to an absolute minimum. The overall air resistance factor is made up of the vehicle’s cross-sectional area and the drag coefficient. While the former is determined by the type and size of the respective vehicle, the drag coefficient may be optimised by the general design of the vehicle and many individual features.

In practice about 40 per cent of the overall air resistance results from the proportions and shape of the vehicle, a quarter of this factor coming, respectively, from the surface structure of the vehicle and from other features such as the mirrors, the lights, the numberplate and the aerials fitted. Another 10 per cent of the overall resistance results from function openings guiding air appropriately to the brakes, the engine or the transmisson. Yet a further 20 per cent of the overall air resistance comes from the underfloor, while 30 per cent is attributable to the wheels and wheel arches.

Optimised air guidance around the wheel arches: the Air Curtain.
Realistic, true-to-life rendition of the vehicle moving on the road made possible by the moving floor and the wheels turning under physically correct conditions also on a model, enables the BMW Group's aerodynamicists for the first time to clearly determine and consistently use the great potential for optimising flow conditions around the wheel arches. Precisely this is why specialists in the BMW Group Aerolab are currently working on a new EfficientDynamics concept for appropriate guidance of the air flow around the front end further reducing the level of air resistance.

This innovation comprises openings at the outer end of the front air dam guiding the incoming air into two shafts. These openings are approximately 10 centimetres or 4" high and 3 cm/1.2" wide and are designed to guide the flow of air along the inside of the front air dam in a closed duct leading to the wheel arches and from there, when leaving the vehicle at high speed through a very small opening, continuing on just outside the outer wheel flanks. The jetstream leaving the vehicle in this way rests on the front wheels like a curtain and is therefore referred to appropriately as the Air Curtain. This effect reduces air resistance by improving the coverage of the front wheels and can be measured in the Aerolab as a significant factor.

This aerodynamic curtain around the front wheels is formed without using any additional components on the wheel arches. All the observer will see from outside is the additional openings on the front air dam.

The Air Curtain is therefore an inconspicuous but highly effective improvement in terms of EfficientDynamics, its ongoing development to production standard being made possible only by the new technical facilities offered by the BMW Group Aerolab.

3.1 Facts and Figures: The BMW Group's New Aerodynamic Test Centre.

Construction Data	
Start of construction	December 2005
Completion of the building structure	February 2007
Wind on in the Aerolab	October 2007
Wind on in the main wind tunnel	December 2007
Overall amount of concrete	36,000 m^3
Overall amount of steel	6,200 tonnes
Overall facade area	18,000 sqm/193,700 sq ft
Total investment Building, technical equipment and facilities	Euro 170 million

Building Data	
Ground area	25,000 sqm/269,000 sq ft
Length of building	120 m/394 ft
Width of building	90 m/295 ft
Height of building	22 m/72 ft
No of floors	5
Gross area	32,500 sqm/349,700 sq ft
Gross built-up volume	20,000 m^3
No of workplaces	500

Main Wind Tunnel	
Ground area (length/width)	84 x 40 m/276 x 131 ft
Direction of flow	Horizontal
Fan diameter	8 m/26.2 ft
Fan speed	300 rpm
Fan output	4.4 MW
Max wind velocity	300 km/h (186 mph)
Overall airstream volume	18,000 m^3
Size of nozzle	18 - 25 sqm /194–269 sq ft, electrically adjustable
Size of measuring area (length/width/height)	22 x 16 x 13 m/72 x 52 x 43 ft
No of tracks	5
Size of underfloor track (length/width)	10 m x 1- 1.10 m (32.8 ft x 3.3 ft–3.6 ft) (variable)

Aerolab	
Ground area (length/width)	74 x 16 m/243 x 52 ft
Direction of flow	Vertical
Fan diameter	6.30 m/20.7 ft
Fan speed	400 rpm
Fan output	3.8 MW
Max wind velocity	300 km/h (186 mph)
Overall airstream volume	6,000 m^3
Size of nozzle	14 sq m/151 sq ft
Size of measuring area (length/width/height)	20 x 14 x 11 m/66 x 46 x 36 ft
No of tracks	1
Size of underfloor track (length/width)	9 m/3.20 m (29.5 ft/10.5 ft)

4. Aerodynamics and Design in the Context of BMW's EfficientDynamics Development Strategy.

The sporting history of the BMW brand shows from the start that the optimisation of air flow has a long tradition at BMW in providing greater efficiency and driving dynamics. As an example, the aerodynamic qualities of the BMW 328 Mille Miglia Touring Coupé were one of the factors ultimately leading to BMW's overall win in this legendary race in 1940. Ever since a lot of the know-how acquired by BMW's engineers on aerodynamic efficiency has come from experience gained in motorsport.

The development of regular production vehicles also benefits from this know-how, designers and aerodynamicists working together closely to incorporate their knowledge and skills in the design of new models. And indeed, the progress made in this way comes out clearly in each new model generation and is clearly felt on the road.

These improvements are even more obvious and significant in an open car. By tradition, BMW Convertibles and Roadsters have always had a horizontally aligned, low-slung waistline. Another characteristic feature is the significant space between the frame around the windscreen and the heads of the driver and front passenger resulting in particular from their seating position moved far to the back.

The unique experience of driving an open-air BMW therefore also means an intense experience of the wind flowing by. This makes it all the more challenging to distinguish between the pleasure of driving in the open air, on the one hand, and the avoidance of unpleasant air draughts within the interior, on the other. The wind rushing by is guided specifically in the right direction to enhance Sheer Driving Pleasure, and not to impair the driver's and passengers' enjoyment.

Aerodynamics setting the foundation for success in motorsport.
To this day, the BMW 328 stands out through the consistent implementation of principles still significant in BMW's modern EfficientDynamics development strategy. Even back then it was clear that optimised efficiency has a positive effect on the dynamic performance of the car. As a result, BMW has always been able to achieve a supreme standard of driving dynamics and a strong competitive edge on the race track despite a relatively low level of engine power.

The production version of the BMW 328 is also an outstanding example of constructive lightweight production and aerodynamics. Over and above the almost completely smooth underfloor, this revolutionary car featured special covers on the rear wheels. And to add the final touch, the winning car in the Mille Miglia came with an aluminium body consistently designed for supreme aerodynamics.

Back in the 1930s BMW did not yet have any aerodynamic test facilities. But even so the development engineers used the most modern methods and the latest scientific know-how in aerodynamics research, cooperation between BMW and the German Research Institute for Motor Vehicles and Power Units helping to promote both the level of science and the development of racing cars. As an innovation unheard of at the time, the wind tunnel run by the Research Institute already had a rolling track serving to simulate flow conditions on the road. And applying appropriate methods in their work, BMW engineers also set important foundations for their successors and generations of development engineers to come.

A good example of the productive cooperation of scientists and car developers is the comparison conducted at the time at the Research Institute of the BMW 328 Mille Miglia Touring Coupé and a racing saloon developed on the same basis by Wunibald Kamm, the famous pioneer in aerodynamics. Both cars featured a basic design following the principle of a wing profile. While the Touring Coupé shows the lines and the long, stretched-out tail named after aerodynamics researcher and airship constructor Paul Jaray, the Kamm version features a shorter wing profile.

The comparative tests and optimisation processes conducted on these two vehicles provided important information for ongoing research as well as data carried over directly into motorsport.

The BMW Roadster: classic proportions, design typical of the brand.
The long and successful tradition of BMW Roadsters comes out clearly also in the brand's current models. The design of the new BMW Z4, for example, is characterised both by the classic proportions of an open two-seater and the design language so typical of the BMW brand as such. The sophisticated finish of the car's surfaces gives this latest BMW Roadster a wonderful look of exciting elegance to be admired from every angle, the new BMW Z4 boasting the appearance of a genuine sculpture moulded from one single piece of material.

As a modern interpretation of the classic roadster, the new BMW Z4 offers the typical combination of a long and sleek engine lid with a long wheelbase, large wheels, short overhangs and a low-slung driver position near the rear axle. The driving experience created offered in this way is visualised authentically by the design of BMW's new two-seater.

The new BMW Z4 comes with the classic proportions of a genuine roadster BMW has upheld for decades – and at the same time it boasts features and details likewise typical of the brand. Similar to the BMW 328 in days gone by, the new BMW Z4 features an extra-smooth underfloor reducing air swirl with its negative effect in terms of air resistance to an absolute minimum. At the same time the flow of air required to cool drivetrain and suspension components such as the brakes, the exhaust system or the final drive, is guided even more appropriately in exactly the right direction.

The new BMW Z4: perfect roadster lines, optimised aerodynamics.
The new BMW Z4 excels through its thrilling driving dynamics and excellent motoring comfort. It is the first BMW Roadster to feature a fully retractable hardtop combining the comfort of a fixed roof coupé with the harmonious and sporting design of an extra-low roadster.

When closed, the hardtop creates a coupé-like flowing roofline underlining the elegant appearance of the BMW Z4. The large window areas give the driver and passenger a generous feeling of space and good all-round visibility at all times. Then, once opened, the two-piece roof construction is discreetly and harmoniously integrated into the low rear end of the car.

Deciding in favour of a retractable hardtop, BMW's engineers have also created brand-new parameters in terms of aerodynamics on a roadster. The rear design of the new BMW Z4 is indeed the result of close cooperation between the Company's designers and aerodynamicists, contributing to the low-slung roadster proportions of the BMW Z4 and at the same time promoting the car's aerodynamic qualities.

Compared with its predecessor, the new BMW Z4 offers aerodynamic features improved on several counts. Apart from air resistance, the aerodynamic balance has also been optimised, particularly through the reduction of lift forces at the rear by approximately 25 per cent.

The flow of air with the roof open has also been given full attention in order to minimise any draught or air swirl possibly impairing the driver's and passenger's driving pleasure. So here again, the new BMW Z4 sets the standard in its segment.

In its overall aerodynamic concept, the new BMW Z4 considers both the need for efficiency as well as driving stability and motoring comfort. It is the result of close cooperation between highly specialised aerodynamicists and developers in many other areas. Particularly the cooperation of designers and aerodynamicists served to create the right concept at an early point in time – a factor key to an efficient process of vehicle development. And now with the new Aerodynamic Test Centre being close to the BMW Group's Research and Innovation Centre, this potential may be put to even greater use in the interest of the customer.

4.1 Specifications.

		BMW Z4 sDrive23i	BMW Z4 sDrive30i	BMW Z4 sDrive35i
Body				
No of doors/seats		2/2	2/2	2/2
Length/width/height (unladen)	mm	4,239/1,790/1,291	4,239/1,790/1,291	4,239/1,790/1,291
Wheelbase	mm	2,496	2,496	2,496
Track, front/rear	mm	1,511/1,559	1,511/1,559	1,511/1,537
Weight, unladen, to DIN	kg	1,405	1,415	1,505
Max load to DIN	kg	330	330	330
Max permissible	kg	1,735	1,745	1,835
Luggage capacity with roof open/closed	ltr	180/310	180/310	180/310
Aerodynamics				
Drag coefficent C_d	Roof closed	0.34	0.34	0.35
Cross section A	sq m	1.96	1.96	1.96
Power Unit				
Configuration/cylinders		Straight-six	Straight-six	Straight-six
Capacity	cc	2,497	2,996	2,979
Output (at engine speed)	kW/hp (rpm)	150/204 (6,400)	190/258 (6,600)	225/306 (5,800)
Max torque (at engine speed)	Nm/lb-ft (rpm)	250/184 (2,750)	310/228 (2,600)	400/295 (1,300–4,250)
Compression ratio		11 : 1	10.7 : 1	10.2 : 1
Chassis and Suspension				
Suspension, front		Aluminium double-joint tiebar axle with spring struts, compensation of lateral forces, anti-dive		
Suspension, rear		Independent, central-arm axle, separate springs and dampers, anti-squat and anti-dive		
Brakes, front		Swing-calliper disc brakes	Swing-calliper disc brakes	Frame-calliper disc brakes
Diameter	mm	300 x 24	330 x 24	348 x 30
Brakes, rear		Swing-calliper disc brakes	Swing-calliper disc brakes	Frame-calliper disc brakes
Diameter	mm	300 x 20	300 x 20	324 x 20
Driving stability systems		Dynamic Stability Control (DSC) with additional functions including Traction Mode (DTC), ABS and Dynamic Brake Control (DBC)		
Steering		Electric Power Steering (EPS)		
Transmission		Six-speed manual (Six-speed Sport Automatic and seven-speed Sport Automatic with double clutch on the BMW Z4 sDrive 35i as an option)		
Tyres, front		225/45 R17 91W RSC	225/45 R17 91W RSC	225/45 R17 91W RSC
Rims, front		8J x 17 light-alloy	8J x 17 light-alloy	8J x 17 light-alloy
Tyres, rear		225/45 R17 91W RSC	225/45 R17 91W RSC	245/45 R17 91W RSC
Rims, rear		8J x 17 light-alloy	8J x 17 light-alloy	8,5J x 17 light-alloy
Performance, Fuel Consumption				
Acceleration 0–100 km/h	sec	6.6	5.8	5.2
Top speed	km/h	242	250	250
Fuel consumption to EU, combined	ltr/100 km	8.5	8.5	9.4
CO_2 emissions	g/km	199	199	219

5. Even More Spontaneous, Even More Efficient: The New 3.0 Litre Straight-Six Gasoline Engine with BMW TwinPower Turbo, High Precision Injection and VALVETRONIC.

Spectacular power and outstanding efficiency–these are the characteristic highlights of BMW's cutting-edge turbo engines going back in their history to the year 2006. And now this story of success is entering a new era with BMW's new straight-six gasoline engine featuring BMW TwinPower Turbo, High Precision Injection and VALVETRONIC continuing the story of extra-dynamic power and performance with outstandingly good fuel economy and CO_2 management in a truly fascinating manner.

This 3.0-litre 225 kW/306 hp power unit conceived for the global market is yet a further achievement of BMW Efficient Dynamics. More than any other engine before, this revolutionary power unit offers a unique range of highlights in technology created in the course of this development strategy and now ideally matched to one another for a supreme standard of fast-revving running qualities, a never-ending surge of power, and supreme all-round economy.

The new straight-six is the first engine in the world to feature the unique combination of turbocharging, direct fuel injection and VALVETRONIC fully-variable valve management developed by BMW. The turbocharging process follows the twin-scroll principle already applied successfully by the BMW Group and now consistently enhanced for use in a particularly powerful straight-six engine.

The combination of this turbocharger technology exclusive to BMW with High Precision Injection and VALVETRONIC exceeds even the response and efficiency standard established by BMW's Twin Turbo gasoline engine introduced in 2006 and in the meantime to be admired in a number of model series. Depending on the model, fuel consumption and CO_2 emissions are reduced in the new straight-six by up to 9 per cent beyond the supreme standard already achieved so far.

Response optimised yet again, fuel economy even greater.
VALVETRONIC already plays a leading role worldwide in numerous BMW power units, enhancing efficiency to an even higher level. The big advantage of this unique system is infinite valve lift control on the intake valves, making the conventional throttle butterfly used in former engine generations superfluous.

VALVETRONIC reduces power losses in the charge cycle to an absolute minimum and optimises engine response, since the supply of air required for the combustion process is masterminded within the engine itself and not outside the power unit, avoiding the inevitable inaccuracy in volume in such a case. This ensures particularly efficient use of the energy contained in the fuel, generating a very “beefy” torque curve and giving the engine optimum response.

The significantly better response of a VALVETRONIC power unit results in particular from the fact that under-pressure in the part load range is only about 50 millibar, while in a conventional engine under-pressure is up to 800 millibar.

Introducing the new straight-six power unit, BMW’s engineers have refined the system and all its functions by means of a new adjuster with its own integrated sensor ensuring even faster valve control and timing. Inertia of the new adjuster is only one-tenth of the former level of inertia on the “old” model, further improving engine response and behaviour.

Responding directly and spontaneously to the gas pedal, the new straight-six is definitely the leader in terms of fast and efficient engine control. Maximum torque of 400 Newton-metres or 295 lb-ft comes at just 1,200 rpm – an improvement provided not only by optimised VALVETRONIC valve management, but also by the newly developed turbocharger. Indeed, the turbocharger ensures a particularly quick and spontaneous build-up of power through its structure and configuration alone, with three cylinders each flowing through separate ducts both in the exhaust manifold and the turbocharger for a particularly low level of exhaust counter-pressure at low engine speeds.

Thanks to this dual flow configuration, the gas flowing through the exhaust manifold is able to build up even greater dynamic momentum, turning the turbocharger blades powerfully even at low speeds.

Twin-scroll technology therefore combines the benefits and effects of two turbochargers within one system. And so the principle of twin-scroll technology now adjusted to the high standard of power and motoring comfort rightly expected of a BMW straight-six consistently continues the process of BMW turbocharged engine development.

High Precision Injection with new injection nozzles.
VALVETRONIC is fully integrated in the cylinder head for the first time in BMW’s new straight-six gasoline engine. This intelligent and extremely compact configuration allows the combination of VALVETRONIC with High Precision Injection, where the injection nozzles are placed in the middle between the valves and therefore in the immediate vicinity of the spark plug in the cylinder head.

High Precision Injection in the new six-cylinder delivers fuel into the combustion chambers at an even higher injection pressure of up to 200 bar over a wide range of running conditions through innovative multi-nozzle valves. This, in turn, ensures extremely precise dosage of the fuel delivered and a particularly clean combustion process. A further advantage is that the cooler air/fuel mixture resulting from the direct injection of fuel allows a higher compression ratio than on a turbocharged engine with intake manifold injection, again benefiting the superior power and performance of this outstanding straight-six.

Displacing 2,979 cc, the new engine develops maximum output of 225 kW/306 hp at a speed of 5,800 rpm. Another thrilling feature is the engine's superior torque and pulling force comparable to that of a far larger eight-cylinder but at the same time benefiting from much lower weight and significantly lower fuel consumption and emissions. The engine is indeed far lighter than a comparably powerful eight-cylinder and is even 4 kilos lighter than the straight-six turbocharged engine already so popular in the market.

Depending on the model, the new straight-six gasoline engine is combined with a wide range of features and technologies from BMW EfficientDynamics. Supplementing the outstanding efficiency of the new power unit ensured right from the start, technologies such as Brake Energy Regeneration, on-demand management of ancillary units such as the electrical coolant pump, the electrical steering assistance pump and the on-demand a/c compressor, as well as consistent lightweight technology, optimised aerodynamics including active air flap management and tyres with minimum roll resistance for optimised fuel economy and emission management serve to enhance the qualities of the engine yet again.

As yet a further significant feature, the new straight-six may also be equipped in future with the BMW Auto Start Stop function already used successfully on the brand's current four-cylinder models. In cars featuring a manual gearbox, in turn, a gearshift point indicator facilitates the choice of the ideal gear for maximum fuel economy.

The new six-cylinder is the first turbocharged power unit to come with a map-controlled oil pump serving through its reduced consumption of energy to once again enhance the car's efficiency. And since the new straight-six with its turbocharger, High Precision Injection and VALVETRONIC does not require sulphur-free fuel, it may be used the world over, naturally fulfilling the EU 5 emission standard in Europe and ULEV II in the USA.

The new straight-six with BMW TwinPower Turbo will be making its production debut in the BMW 5 Series Gran Turismo.

5.1 Specifications of the New Straight-Six Diesel Engine with BMW TwinPower Turbo.

Feature/size	Unit	Straight-six gasoline engine with BMW TwinPower Turbo and High Precision Injection	For comparison: Straight-six gasoline engine with Twin Turbo and High Precision Injection
Fuel		Gasoline (RON 91–100)	Gasoline (RON 91–100)
Max output	kW/hp	225/306	225/306
at	rpm	5,800	5,800
Max torque	Nm/lb-ft	400/295	400/295
at	rpm	1,200–5,000	1,300–5,000
Max engine speed	rpm	7,000	7,000
Stroke	mm	89.6	89.6
Bore	mm	84.0	84.0
Capacity	cc	2,979	2,979
Distance between cylinders	mm	91	91
Cylinder arrangement		Straight-six	Straight-six
Valve plate diameter, intake	mm	32	31.4
Valve plate diameter, outlet	mm	28.0	28.0
Compression ratio		10.2 : 1	10.2 : 1
Fuel injection		Second-generation direct gasoline injection, jet-guided High Precision Injection; multi-nozzle injectors; λ = 1; up to 3 injections/stroke	Second-generation direct gasoline injection, jet-guided High Precision Injection; piezo-injectors; λ = 1; up to 3 injections/stroke
Max fuel injection pressure	bar	200	200
Turbocharger technology		One twin-scroll turbocharger (BMW TwinPower Turbo)	Two MHI turbochargers, parallel (BMW Twin Turbo)
Max charge pressure above atmospheric pressure	mbar	0.7	0.6
Mean com chamber pressure	bar	16.9	16.9
Peak com chamber pressure	bar	130	130
Engine weight to DIN 70020-GZ	kg	177	178
Min specific fuel consumption	g/kWh	245	248
Output per litre	kW/hp	75.5/102.7	75.5/102.7
Power-to-weight ratio versus engine weight, to DIN	kg/kW	0.79	0.79
Crankcase material		Aluminium	Aluminium
Water pump		Electrical	Electrical
Camshaft		Composite; hydroforming	Composite, hydroforming
Valve drive		Variable intake valve lift adjustment (VALVETRONIC) and infinite intake and outlet camshaft adjustment (dual-VANOS)	Infinite intake and outlet camshaft adjustment (dual-VANOS)

6. Incredible Torque, Outstanding Fuel Economy and Emission Control: The New 3.0 Litre Straight-Six Diesel Engine with BMW TwinPower Turbo and Piezo-Injectors with 2,000 Bar Injection Pressure.

Introducing a brand-new generation of straight-six diesel engines, BMW is increasing the brand's worldwide lead in the development of particularly efficient and powerful diesels. Following the 180 kW/245 hp diesel featuring a single turbocharger with variable turbine geometry presented for the first time in the new BMW 730d, this additional variant of the 3.0-litre also scheduled to make its first appearance in the BMW 7 Series delivers maximum output of 225 kW/306 hp and peak torque of 600 Newton-metres/442 lb-ft at just 1,500 rpm, thus taking on the top position as the world's most sporting and dynamic engine of its kind.

Apart from engine capacity of 2,993 cc, both representatives of BMW's new generation of diesels also share the same engine construction principle, optimised weight on the all-aluminium crankcase, as well as fuel supply by fourth-generation common-rail direct fuel injection.

On the new, even more powerful engine the injection pressure generated by the piezo-injectors is an even higher 2,000 bar. The second substantial change involves the turbocharging principle, BMW TwinPower Turbo technology being used consistently also on the brand's diesel engines. This technology incorporates two turbochargers varying in size, harmonised with one another and acting either individually or together as a team, depending on current load requirements.

The small turbocharger unit with variable turbine geometry used for the first time worldwide by BMW in this combination ensures a particularly powerful effect meeting even the most demanding requirements.

Setting a new standard in response, engine behaviour, consistent torque and high performance on a six-cylinder diesel.
To raise the new straight-six diesel to a particularly dynamic and sporting standard never seen before, the principle of Variable Twin Turbo technology featured for the first time on the former engine has been further enhanced and carried over to the new generation of power units. Together with the likewise optimised direct fuel injection, this combination ensured truly unique power and performance characteristics: The new engine delivers its enormous torque from just above idle speed, with 75 per cent of the peak torque being held

consistently in the broad range between 1,000 and 4,600 rpm. A further unique advantage of this engine is the unparalleled ratio between fuel consumption and the engine's superior power and performance.

In its response, torque curve and pulling force, the new six-cylinder diesel with BMW TwinPower Turbo technology is even able to match and, indeed, outperform the best eight-cylinders, while reducing both fuel consumption and emissions to a much lower level. And as a further point the new six-cylinder is more fuel-efficient than even many far smaller and less powerful diesels.

The low weight of the engine also contributes to its all-round efficiency and helps to enhance the car's agility on the road. The progress achieved over the former engine is borne out clearly by an increase in power by 15 kW/20 hp and an increase in torque by 20 Newton-metres/15 lb-ft on average fuel consumption down by approximately 4 per cent.

Engine built from the start for high efficiency and optimum combustion. Both the structure of the engine as such and the arrangement of the ancillary units are the same on both representatives of BMW's new generation of straight-six diesels. The newly developed crankcase is made of an extra-strong aluminium/silicon alloy, the compression height of the pistons, the design of the cooling ducts and the dimensions of the main and conrod bearings offering the ideal starting point for extra power and torque. The crankshaft made of high-strength steel, in turn, is particularly stiff and sturdy under all running conditions.

The fuel injectors positioned in the middle and vertically arranged valves keep the combustion process smooth, well-balanced and consistent, helping from the start to reduce emissions from the engine. Air is supplied to the cylinders by two intake ducts positioned next to each other and supplied with air by a compact air collector at the side. Again in the interest of minimum emissions, the intake duct providing the desired swirl effect is activated in an infinitely controlled electronic process.

The two outlet ducts flow into a joint pipe further downstream while the light-weight camshafts run in a camshaft bearing made of pressure-cast aluminium. Ceramic spark plugs optimise the engine's starting qualities as well as engine acoustics and vibrations in the process of warming up, at the same time helping to reduce both fuel consumption and emissions.

Agility enhanced, pedestrian safety optimised.
With its compact dimensions, lower height and the chain drive moved to the back, the new diesel also helps to fulfil current and future demands in terms of pedestrian safety. A further important point is that the risk of injury is reduced by the intake silencer giving way in height in a smooth deformation process beneath the cylinder head cover made of a special synthetic material.

As important ancillary units, the alternator, steering assistance pump and a/c compressor are all arranged on the left of the engine, leaving ample space at the right for the diesel particulates filter, the oxidation catalyst and the turbocharger system. And since all ancillaries are driven by one single belt, there is no need for a second belt and all the extra technology required. This again makes the power unit even more efficient by avoiding friction losses.

Common-rail direct injection with new piezo-injectors operating at a maximum pressure of 2,000 bar.
The fuel injection system specially developed for the new generation of six-cylinder diesel engines ensures exact dosage and precise management in the supply of fuel. Fuel injection is based on the latest generation of common-rail direct injection proven on both BMW's six-cylinder and four-cylinder diesels. Apart from the high-pressure pump, the fuel supply and injection pipes, the rail pressure sensor and the pressure control valve, the piezo-injectors themselves have also been upgraded to an even higher standard, operating on the new, particularly powerful diesel at a maximum injection pressure of 2,000 bar.

The new engine control unit comes with an even higher standard of performance and even larger memory capacity. It receives data from a variety of sensors positioned, for example, in the engine block, on the cylinder head, in the coolant and injection system, in the oil circuit, on the exhaust manifold, in the air supply, in the exhaust gas recirculation system, and around the exhaust pipes.

Variable Twin Turbo for the first time featuring variable turbine geometry on the small turbocharger unit.
The Variable Twin Turbo system made up of two turbochargers varying in size ensures a particularly direct and spontaneous build-up of power as well as a high level of consistent torque through all engine speeds.

The small turbocharger cuts in first at low engine speeds, developing its power-boosting effect spontaneously and without the slightest delay thanks to its low inertia, thus following even the slightest movement of the gas pedal. Then, with engine speed increasing, the second, larger turbocharger starts to develop its effect, helping to reach maximum engine torque of

600 Newton-metres/442 lb-ft at just 1,600 rpm. Interaction of the two turbochargers is controlled and masterminded by the particularly efficient high-performance engine electronics.

Thanks to the variable turbine geometry of the small turbocharger, the effect of the turbocharger system may be harmonised even more precisely to current driving conditions. Adjustment of turbine geometry activated as a function of load conditions and power requirements is now featured for the first time on an engine with Variable Twin Turbo technology, an electrical adjuster motor serving to set the turbine blades with extreme precision and minimum delay to current requirements. This ensures early and smooth operation of the larger turbocharger interacting with the smaller turbocharger at low speeds and helps to build up a high level of power and performance under full load. The new engine reaches its maximum output of 225 kW/306 hp at 4,400 rpm.

The newly conceived exhaust gas recirculation incorporates an exhaust pipe integrated in the cylinder head itself, a newly arranged intake pipe leading into the manifold, and particularly effective cooling. Optimised for maximum power, the stainless-steel exhaust gas cooler is positioned at the front of the engine and comes with a bypass flap limiting harmful emissions while the engine is warming up. The volume and temperature of exhaust gas may be determined precisely as a function of current running conditions and the temperature of the engine.

The outstanding efficiency and all-round economy of BMW's new six-cylinder diesel is further enhanced by EfficientDynamics featured as standard. In various combinations specific to each model, EfficientDynamics technologies such as Brake Energy Regeneration, on-demand control of ancillaries such as the coolant pump, the fuel pump and the a/c compressor, as well as active air flap control and tyres with minimum roll resistance, all provide the desired effect.

Diesel particulates filter and catalyst in the same housing.
The particulates filter and the oxidation catalyst interacting with the new straight-six diesel engine are housed in the same unit positioned directly behind the engine. Benefiting from the wide range of innovations, even this very sporting six-cylinder diesel is able to easily outperform the EU5 emission standard, the exhaust management system reducing not only diesel particulates, but also hydrocarbons and carbon monoxide very effectively.

The catalytic reaction is provided by the platinum and, respectively, palladium coating inside the exhaust management system. The diesel particulates filter does not require any maintenance at all throughout its entire lifecycle and works without additives. The regeneration phases required at regular intervals are initiated by a subsequent injection process activated by the engine control unit at regular intervals. Irrespective of the engine's running conditions and without

requiring any intervention by the driver, this reliably ensures that the filter remains free of residues and is not impaired in any way in its efficiency. With its high-tech management and control technology, the exhaust cleaning system provides optimum results completely by itself at all times.

6.1 Specifications of the New Straight-Six Diesel Engine with BMW TwinPower Turbo.

Feature	Unit	Straight-six diesel with BMW TwinPower Turbo and fourth-generation common-rail direct fuel injection	For comparison: Straight-six diesel with turbocharger and fourth-generation common-rail direct fuel injection	For comparison: Straight-six diesel with Variable Twin Turbo and third-generation common-rail direct fuel injection
Fuel		Diesel	Diesel	Diesel
Max output	kW/hp	225/306	180/245	210/286
at	rpm	4,400	4,000	4,400
Max torque	Nm/lb-ft	600/442	540/398	580/427
at	rpm	1,500	1,750	1,750
Max engine speed	rpm	5,600	5,000	5,000
Stroke	mm	90	90	90
Bore	mm	84	84	84
Capacity	cc	2,993	2,993	2,993
Distance between cylinders	mm	91	91	91
Cylinder arrangement		Straight-six	Straight-six	Straight-six
Valve plate diameter, intake	mm	27.2	27.2	27.4
Valve plate diameter, outlet	mm	24.6	24.6	25.9
Compression ratio		16.5 : 1	16.5 : 1	16.5 : 1
Fuel injection		Fourth-generation common-rail direct fuel injection, piezo-injectors; up to 5 individual injections	Fourth-generation common-rail direct fuel injection, piezo-injectors; up to 5 individual injections	Fourth-generation common-rail direct fuel injection, piezo-injectors; up to 5 individual injections
Max fuel injection pressure	bar	2,000	1,800	1,600
Turbocharger technology		Two exhaust gas turbochargers, two-stage turbocharging (BMW TwinPower Turbo), small turbocharger with variable intake geometry	One exhaust gas turbocharger with variable intake geometry	Two exhaust gas turbochargers, two-stage turbocharging (Variable Twin Turbo)
Max charge pressure above atmospheric pressure	mbar	2,050	1,650	1,980
Mean com chamber pressure	bar	25.2	22.7	24.4
Peak com chamber pressure	bar	180	180	180
Engine weight to DIN 70020-GZ	kg	196	182	193
Min specific fuel consumption	g/kWh	197	202	205
Output per litre	kW/hp	75.2/102.3	60.1/81.7	70.2/95.5
Power-to-weight ratio versus engine weight, to DIN	kg/kW	0.87	1.01	0.92
Crankcase material		Aluminium	Aluminium	Aluminium
Water pump		Mechanical	Mechanical	Mechanical
Camshaft		Composite	Composite	Composite
Valve drive		Four-valve, without variability	Four-valve, without variability	Four-valve, without variability

7. Innovative Efficient, Dynamic: BMW's New Eight-Speed Automatic Transmission.

Apart from power units making full use of the energy contained in the fuel, progressive, future-oriented drive technology also means the very latest and most up-to-date transmission with a particularly high standard of efficiency.

BMW's new eight-speed automatic transmission is an impressive example of how innovative power and consistent development lead to particular efficient solutions not only in the generation of power, but also in its transmission to the drive wheels.

Reflecting the supreme standard so typical of BMW, the new automatic transmission is able at the same time to enhance sheer driving pleasure in a premium car to an even higher standard. So the new eight-speed automatic transmission featured for the first time in the new 760i and the new BMW 760Li sets a new benchmark in terms of both efficiency, gearshift comfort and sportiness.

The new eight-speed automatic transmission excels through its innovative gearset configuration able to add further gears and cover an even wider range of gear increments than on the former six-speed automatic transmission without any negative effects on the size and dimensions of the transmission, the weight of the entire unit, and its inner efficiency. The eight forward gears and the reverse gear are provided by four simple gearsets and five shift elements. The innovative arrangement of these elements seen here for the first time worldwide on an eight-speed automatic transmission ensures that only two clutches are open at a time in each gear, thus reducing friction losses to a minimum under all conditions and in every situation.

Together with the larger range of gear increments and the high degree of efficiency, this is another reason for the outstanding qualities of the new transmission. The intelligent concept of BMW's new eight-speed automatic transmission therefore provides an ideal match for the BMW EfficientDynamics development strategy.

Introduction of the first eight-speed automatic transmission in the BMW 760i and the BMW 760Li hails the advent of a new generation of power transmission. The six-speed automatic transmissions offered by BMW today in all model series already set the benchmark in terms of gearshift comfort, reaction time, gearshift speed and efficiency. At the same time the existing transmissions, through their compact structure and consistent use in numerous vehicle segments and performance classes, offer a wide range of all-round benefits.

The topmost premise in developing the new generation of transmissions was therefore to retain the constructive benefits of the six-speed automatic transmission and reach even higher potentials in terms of comfort, performance and efficiency.

Optimum gearset configuration as the result of a revolutionary development process.
To achieve substantial progress over the proven generation of six-speed automatic transmissions BMW then initiated a development process striking out for new highlights in technology and, indeed, an entirely new philosophy. The starting point was the consideration that only a transmission offering an even wider range of gear increments would be able to provide the improvement of efficiency sought through the new transmission. Another objective was to keep the range of additional components as small as possible in order to optimise the inner efficiency of the system.

Looking for the optimum concept to fulfil these requirements, BMW decided to team up with ZF Friedrichshafen AG, the transmission specialist, as the Company's partner in the development process. Together, the two partners developed analytical methods serving to consider and compare all the pros and cons of all theoretically conceivable versions of a planetary transmission. To begin with both the number of gears and the structure of the new transmission system remained undecided, the objectives being to achieve maximum effectiveness and efficiency, compact dimensions and low weight.

Studies eventually led to the best solution offering the most positive balance of inner effectiveness within the transmission itself and overall efficiency in the vehicle: the new eight-speed automatic transmission. This new transmission comes with two additional gears and a gear increment range increased from six to seven, while the number of gearsets is up by only one to four and the number of clutches even remains the same.

Triple progress with two additional gears: gearshift dynamics up, comfort optimised, efficiency enhanced.
The larger range of gear increments offered by the new transmission allows the driver to keep the car far more often in the highest possible gear, with engine speed reduced by a significant margin. This not only optimises the economy of the respective model also at high speeds, but also enhances the running smoothness of the engine interacting with the eight-speed automatic transmission.

With the number of gears increased to eight, the steps in engine speed when shifting gears are smaller than before, despite the wider overall range of gear increments. Clearly, this makes the transmission even more sporting and dynamic, giving the car the athletic qualities so typical of a BMW. When accelerating, therefore, the harmonious flow of power from one gear to the next ensures a particularly smooth and consistent increase in road speed.

The smaller differences between gears serve furthermore to enhance the level of gearshift comfort, a change in gears involving only a minor change in engine speed.

Reaction and gearshift times even shorter than on the six-speed automatic transmission also serve to enhance the level of driving dynamics, with only one clutch being required to open up when shifting up or down one or two gears.

Direct transition to the appropriate gear path allows the driver to shift up or down by more than two gears at a time, again with extremely short reaction and gearshift times. The process of shifting back from eighth to second gear, for example, which is important when accelerating spontaneously, is also performed as one direct gearshift requiring the transmission to open only one clutch.

This configuration is of particular relevance for superior motoring in real style, enabling the driver to use the higher gears most suitable for supreme efficiency and running smoothness much more often than would otherwise be the case, at the same time benefitting from the car's maximum performance whenever required.

Flexible, up-to-date, focused on the future.
With the number of transmission components being increased only slightly versus the six-speed automatic transmission, the new eight-speed automatic offers an unusually high standard of inner efficiency, with gear mesh overlap exceeding 98 per cent in each gear. And with sixth gear offering a direct 1:1 ratio, there are no frictional losses of any kind.

Low weight almost identical to that of the six-speed automatic transmission likewise enhances the efficiency of the entire drivetrain, with the extra weight of an additional gearset being set off by the optimisation of weight elsewhere.

In all, the restriction of converter slip to the very lowest engine speed, the high degree of inner efficiency, low frictional losses due to the fact that only two clutches are open at a time, the longer transmission ratios in higher gears, and the improved suppression of vibrations as a further advantage when driving at low engine speeds, improve fuel economy overall by about 6 per cent versus the former six-speed automatic transmission.

The new eight-speed automatic transmission is not only the very best technology available today, but also a most future-oriented solution for transmitting engine power in a premium car. For this transmission may be combined with all kinds of engines varying in power and performance and may be used not only in cars with rear-wheel drive, but also in all-wheel-drive models. And in future it will also offer the option to integrate an Auto Start Stop function.

The functional qualities and benefits of the eight-speed automatic transmission are an ideal match for the power and performance characteristics of a modern BMW turbo engine offering substantial torque from the ground up at low engine speeds. This allows the driver to run the car much more frequently under very fuel-efficient loads and, when necessary, to shift back spontaneously for dynamic acceleration.

The advantages offered by the spontaneous and direct response of the engine, the high torque and pulling force typical not just of BMW's twelve-cylinder, but also of the eight-cylinder and the new straight-six with BMW TwinPower Turbo technology literally built into the transmission, come out most significantly with the eight-speed transmission unit.

The BMW 5 Series Gran Turismo will be the first car ever to combine this new transmission with both eight- and six-cylinder power units.

As yet another important benefit, the eight-speed automatic transmission may be combined with hybrid drive. It is therefore part of BMW's ActiveHybrid Technology combining an eight-cylinder gasoline engine with electric drive. This innovative drive concept will indeed be reaching production standard in the first BMW 7 Series hybrid model in the course of 2009.