

## **EfficientDynamics**

**– the intelligent route to lower emissions.**

The BMW Group is presenting a raft of innovations in its current model range aimed at drastically reducing emissions. Underpinning these innovations is a clear development strategy dedicated to securing individual mobility for the future.



**BMW Group**





Visionary technological developments have played a role in the success of the BMW Group ever since the company was founded over 90 years ago. Reliable prognoses on future market requirements and the timely introduction of tailor-made solutions have secured BMW a sustained and pre-eminent position among the world's leading car manufacturers. A development strategy initiated by the BMW Group back in the 1990s has yielded a constant flow of product innovations which have quickly fulfilled their brief of ensuring sustainable use of natural resources. The name of this strategy says it all: EfficientDynamics.

The substance behind the buzzword is provided by a unique development concept designed to cut fuel

consumption and CO<sub>2</sub> emissions levels. This is based on the conviction that excellent driving dynamics and impressive cost-effectiveness need not be mutually exclusive. With its principle of efficient dynamics, the BMW Group has therefore placed two equal-priority goals at the centre-point of each new car development project: optimising the use of resources and raising performance characteristics vis-à-vis the outgoing model. The result is that the BMW Group today produces premium models which top the rankings in terms of both their inspirational handling properties and their efficiency – and thus their environmental compatibility. This strategy includes the aim of offering premium-segment customers highly efficient models in every class of car.

**The BMW Group supports the drive for environmental protection.**

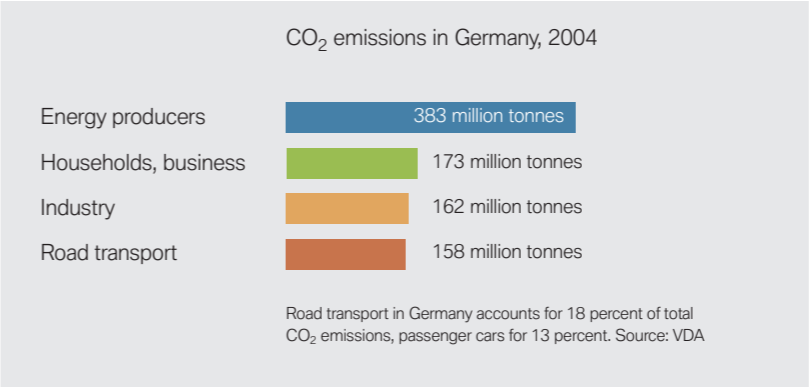
Reductions in fuel consumption are directly linked to cuts in CO<sub>2</sub> emissions. For example, the combustion of one litre of petrol per 100 kilometres releases approximately 23.8 grams of CO<sub>2</sub> per kilometre, and a vehicle burning 5.0 litres of petrol per 100 kilometres therefore emits approximately 119 g/km of CO<sub>2</sub>. The values for diesel vehicles are slightly higher: burning one litre of diesel per

purpose-fully to play its part in fulfilling the voluntary agreement made by the European Automobile Manufacturers Association (ACEA). The common goal of all the ACEA members is to cut European fleet average CO<sub>2</sub> emissions for new passenger cars to 140 g per kilometre by the end of 2008. This means capping the average fuel consumption of all vehicles produced by European manufacturers at 5.9 litres of petrol – or 5.3 litres of diesel – per 100 kilometres. Added to which, with its EfficientDynamics development strategy, the BMW Group is toeing the line set out in the 1997 Kyoto Protocol. As part of the United Nations Framework Convention on Climate Change, this Protocol targets a reduction in CO<sub>2</sub> emissions to at least

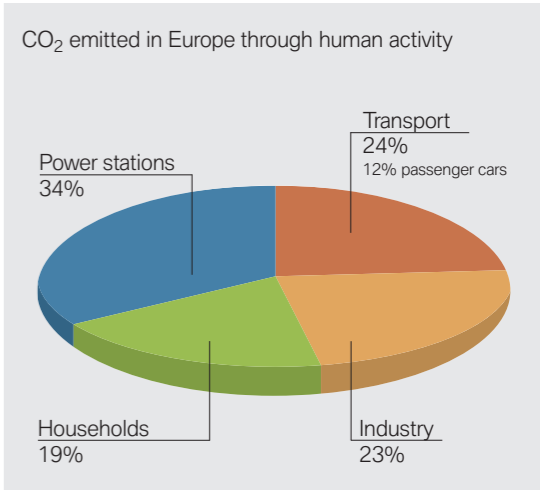
The best output/fuel consumption combination in their respective segments: the MINI Cooper D (above) and BMW 318d



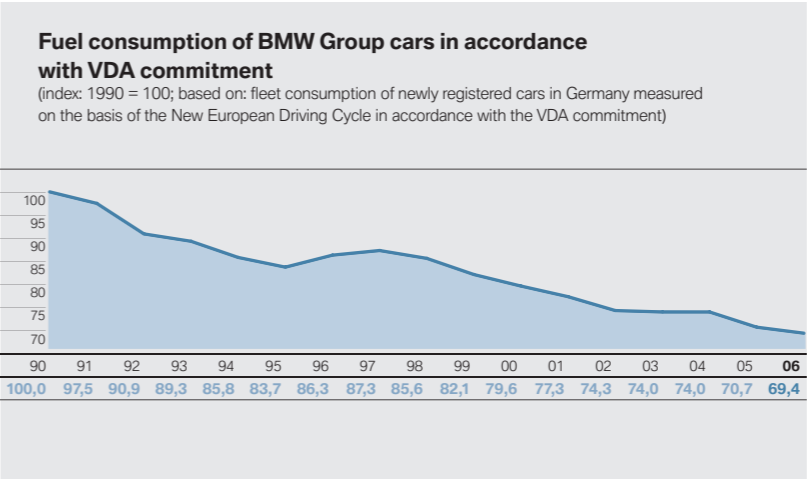
The four-cylinder diesel engine with Variable Twin Turbo in the BMW 123d



100 kilometres generates approximately 26.5 g of CO<sub>2</sub> per kilometre, meaning that average consumption of 5.0 litres per 100 kilometres yields a CO<sub>2</sub> value of some 132 g/km. As far as its commitment to preserving fossil fuel resources is concerned, by 2005 the BMW Group had achieved a dramatic 30 percent reduction in fleet consumption levels in Germany when measured against its 1990 model range. For the same period, the Association of the German Automotive Industry (VDA) had pledged to lower fuel consumption by 25 percent, a target the BMW Group met in exemplary style as early as 2002. And the BMW Group is working just as



five percent below their 1990 levels by 2012. The BMW Group has made a wide-reaching reduction in the CO<sub>2</sub> emissions caused by human activity a key target in its drive to ensure the responsible use of resources, and is thus all the more committed to developing concepts demonstrating maximum efficiency in order to meet this aim. An important element of these efforts is the objective examination of scientifically proven facts on CO<sub>2</sub> emissions and associated climate change. In Europe private transportation accounts for 12 percent of CO<sub>2</sub> emissions. The automotive industry has no direct influence on the remaining 88 percent.





X-ray view:  
the BMW Concept X3  
EfficientDynamics

Aside from these considerations, there is no question for the BMW Group that the carmakers have a duty to do everything in their power to reduce CO<sub>2</sub> emissions within their sphere of influence. Taking responsibility in this way also makes a statement that society as a whole is working to reduce levels of CO<sub>2</sub> emissions.

The BMW Group has been pushing forward a whole series of product-based fuel-saving technologies for many years now under the banner of EfficientDynamics.

vehicle, the optimisation of aerodynamics and intelligent lightweight construction techniques. In the medium term it also embraces the use of hybrid powertrains while, looking further ahead, the switchover to practically zero-emission hydrogen as an energy source of the future is also very much established on the EfficientDynamics radar. By contrast to some of the concepts offered by other carmakers, EfficientDynamics is not restricted to individual special-purpose models. Instead, as a fixed and standard feature, its impact is gradually spreading throughout the company's entire fleet. EfficientDynamics has brought an extensive package of innovations into series production through the model years 2007 and 2008. The vehicles equipped with these measures have seen fuel consumption drop by up to 23 percent and output rise by as much as 20 kW. These impressive figures see the BMW Group setting new standards as a front-runner in refined yet environmentally compatible transportation, without compromising on driving pleasure. This package of innovations has enabled the BMW 1 Series and 5 Series models to claim "best in segment" honours in terms of both efficiency and dynamics. As far as environmental considerations are concerned, a diesel BMW now stands comparison with a hybrid-powered vehicle, while displaying a clear edge over hybrid drive systems on country roads and motorways.



The BMW 520d Touring  
with four-cylinder diesel  
engine: the first car in its  
class with CO<sub>2</sub> emissions  
as low as 140 g/km

**A long-term concept with sustained impact.**  
In essence EfficientDynamics encompasses engine-related technological innovations, the intelligent management of energy flows within the



EfficientDynamics – a development strategy ensuring optimum use of fuel



### The perfect combination: impressive dynamics, low emissions.

There is no question of the EfficientDynamics development strategy being an expression merely of a short-term shift in priorities. On the contrary, what makes EfficientDynamics particularly impressive is that it has determined the long-term direction of the BMW Group's development work for many years now. By setting the right course in the past, the BMW Group is today in the position to deliver solutions aimed at preserving resources. When applied to the product range itself, this means that current model-year BMW vehicles come with a range of fuel-saving measures whose development was set in train some five years ago and which have now made it into series production. These models therefore boast a level of efficiency which many rivals will only achieve in several years' time. For example, the BMW 120d is a star performer in the compact car segment in terms of fuel efficiency and emissions, burning just 4.8 litres per 100 kilometres, developing 177 hp/130 kW and emitting 128 g of CO<sub>2</sub> per kilometre. The BMW Group also occupies a leading position in the small car segment as far as economy and emissions are concerned. Indeed, powered by a 110 hp/80 kW four-cylinder engine the MINI Cooper D burns a meagre 3.9 litres of diesel per 100 kilometres, allowing it to record a spectacularly low CO<sub>2</sub> output of 104 grams per kilometre. And the new MINI Cooper D Clubman is not a great deal thirstier, requiring only 4.1 litres of fuel per 100 kilometres. Its CO<sub>2</sub> emissions stand at 109 g/km. By 2008 the fuel consumption of the BMW 320i, meanwhile, will be a full 36 percent



lower than in 1983. At the same time, its exhaust emissions quality has improved by a stunning 95 percent. Another milestone is furnished by the 2008 BMW 520d, the first car in its class to push its CO<sub>2</sub> emissions down below 140 g per kilometre.

Fitted with a four-cylinder diesel engine developing 177 hp/130 kW, the Saloon produces average fuel economy of 5.1 litres per 100 kilometres and CO<sub>2</sub> emissions of 136 g per kilometre. Through the gradual introduction of the latest efficiency-enhancing measures across all model series, overall CO<sub>2</sub> levels will drop significantly once again in the near future. In model year 2008, 40 percent of all new BMW Group vehicles in Europe will record CO<sub>2</sub> figures below the challenging 140 g/km level.



The MINI Cooper D Clubman: average fuel consumption of 4.1 litres/100 km, CO<sub>2</sub> emissions of 109 g/km



### Efficient petrol engines.

Given its status as the global leader in engine innovation, it is natural that the significant advances in efficiency achieved by the BMW Group can be traced back primarily to further developments in drive system technology. Among the key landmarks set since the 1990s has been VANOS fully variable intake camshaft adjustment, extended in 1998 to include fully variable exhaust camshaft adjustment (double-VANOS). This was followed in 2001 by a technological leap forward with the introduction of VALVETRONIC fully variable valve control. For the first time since the invention of the petrol engine, the throttle butterfly was now rendered superfluous. The result was a drop in fuel consumption of up to ten percent in the EU test cycle. The all-aluminium petrol engine crankcase fitted for the first time in a series-produced vehicle in 1994 represented substantial progress in weight reduction technology, and thus also enabled a cut in fuel consumption. Nine years later this innovative casing was also fitted in a six-cylinder diesel engine. The launch of the new BMW 3 Series range in 2004 then marked the arrival of the first six-cylinder in-line engine with a magnesium-aluminium composite crankcase. This new construction is 24 percent lighter than a comparable aluminium casing.

The four-cylinder petrol engine with second-generation direct injection (High Precision Injection)



High Precision Injection, a second-generation petrol direct injection system, saw BMW revolutionise fuel supply for petrol engines in its model year 2007 cars. This first ever jet-guided petrol direct injection system for a volume-produced vehicle enables low-consumption lean-burn operation to be maintained over a particularly broad engine speed range and produces clear fuel savings in everyday conditions. The principle of High Precision Injection is based on advanced piezo injectors, which spray precisely-calculated and extremely small amounts of fuel directly around the spark plug. High



Precision Injection lends the four and six-cylinder units enhanced free-revving characteristics in lean-burn operation when measured against first-generation petrol direct injection. The lean-burn engine in the BMW 116i, for instance, boasts 5 kW greater output than its predecessor unit, but also a cut in fuel consumption of 23 percent.

### Powerful diesel engines.

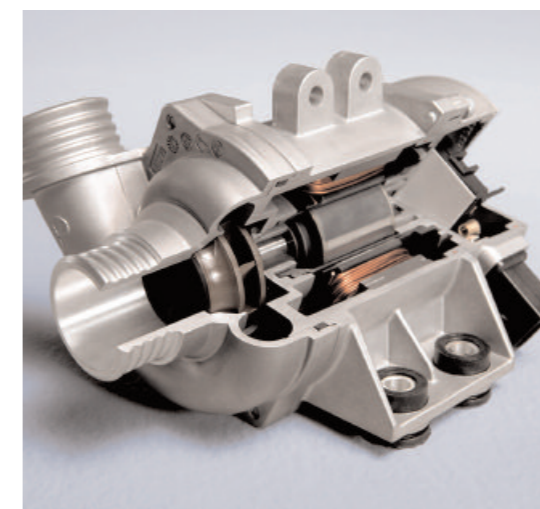
The fusion of greater output with reduced fuel consumption has made its presence felt to equal effect in diesel engine development. The BMW Group has achieved outstanding fuel economy results through consistent improvements in the diesel injection process, in particular. Early progress was made in 1988 with the arrival of electronic by-wire diesel injection. Then, ten years later, BMW introduced common-rail diesel injection at 1,350 bar, and this process was upgraded to run at 1,600 bar in 2001. BMW took this technology to the next level with piezo injectors, the latest generation of which – in model year 2008 cars – injects the diesel into the combustion chambers at 2,000 bar and with exceptional precision.

The precisely calculated fuel calculation and high efficiency of the combustion process allows the 204 hp/150 kW four-cylinder engine in the BMW 123d, for example, to earn top marks for its muscular power development and impressive economy. The torquey compact class model burns 5.2 litres of diesel per 100 kilometres in the EU test cycle and records a CO<sub>2</sub> figure of 138 g per kilometre. The further development of the turbocharger with variable turbine geometry (VTG) – as fitted in the BMW 525d, for example has delivered further benefits. The 525d pumps out 197 hp/145 kW yet is 17 percent more economical than its predecessor. The BMW 535d is also considerably quicker over the ground and a good deal more economical, its new six-cylinder Variable Twin Turbo diesel engine developing an extra 10 kW of output and lowering fuel consumption by 15 percent.

### Energy-saving auxiliary units.

In order to open up further potential for fuel savings, the BMW Group has extended its EfficientDynamics programme to cover auxiliary units. These are regulated according to need, reducing the amount of electric energy they require to operate. As a result the alternator has to convert less primary energy for power generation, and fuel consumption is reduced. At the same time a larger slice of the drive energy is available to be transformed into driving dynamics. The innovative electric coolant pump, for example, uses only a tenth of the energy soaked up by comparable units running constantly at full capacity. In cold starts, it begins work after the engine has been switched on, enabling the unit to reach its operating temperature more quickly. An electromagnetic coupling, meanwhile, allows the air conditioning compressor to be decoupled from the belt drive as soon as the

Temperature-controlled electric coolant pump



system is switched off, saving energy. Added to which, EfficientDynamics spans a highly effective package of additional efficiency-enhancing measures which are fitted as standard and tailored specifically to the individual models. These include systems such as the Auto Start-Stop function and Optimum Gear Shift Indicator, which give the driver the tools to actively cut fuel consumption.

### Optimum Gear Shift Indicator.

Another system the BMW Group is offering customers as a means of promoting an environmentally aware driving style is the Optimum Gear Shift Indicator. This technology gives the driver recommendations on which gear to select in order to maximise fuel economy. The driver is advised of the ideal time to change gear by an illuminated arrow symbol in the instrument cluster signalling the optimum gear. The system calculates which gear to recommend based on load and acceleration. In this way it recognises when the driver wants to accelerate and only gives a shift recommendation at higher revs.

### The Auto Start-Stop function.

As part of the EfficientDynamics strategy, the BMW Group has introduced the Auto Start-Stop function for all four-cylinder BMW 1 Series and 3 Series



models with manual gearbox, as well as for the MINI. When this function is active, the engine is automatically switched off when the car comes to a halt at a junction or in traffic congestion. It is then restarted again in a split-second when the driver presses the clutch pedal. This allows periods spent at idle to be virtually eliminated, leading to substantial reductions in fuel consumption particularly in city traffic.



### Brake Energy Regeneration.

In a conventional vehicle power supply a significant amount of energy goes to waste because the battery remains under permanent charge in all engine operating conditions and regardless of whether this is actually required. Intelligent alternator control in many BMW models now sees power generation concentrated during the car's overrun and braking phases. This Brake Energy Regeneration system is a prime example of the thinking behind EfficientDynamics. As soon as the driver takes his foot off the accelerator and the engine moves into overrun, the energy released is used to boost the onboard power supply. Energy is thus generated without using any extra fuel and is stored in the battery. When the driver accelerates, on the other hand, the alternator is cut off from the engine. This means that a higher proportion of the energy contained in the fuel is available for conversion into driving dynamics when the driver requests it. A parallel for the idea behind this intelligent energy management can be found in the workings of storage power stations. There, economical energy is stored temporarily during the night in "upper" reservoirs and then called up again during the day when demand is greatest. When applied to Brake Energy Regeneration this principle allows the identification of driving phases with low energy needs, during which power can be stored temporarily in the battery. This energy can then be

released into the vehicle power supply as and when it is needed.

### Need-based Electric Power Steering.

Not many drivers are aware that the steering servo of their cars also uses up energy. In conventional steering systems with mechanical-hydraulic power assistance, this assistance is supplied via a pump, which uses energy to permanently build up pressure – even when no power assistance is required. Electric Power Steering, on the other hand, only uses energy when the driver is actually steering. When driving in a straight line or if the steering angle through a corner remains unchanged, the system's motor is not active. This is another example of technology contributing to efficient energy management.



EPAS electro-mechanical power steering in the new MINI

The BMW 135i Coupé: EfficientDynamics for top performance



### Active adjustment of aerodynamics to the driving situation.

The faster a car is travelling, the greater the effects of drag on fuel consumption. Even the design of the car's air intakes has an impact on its aerodynamics. The control of the cooling air flaps is thus one of the key factors when it comes to raising efficiency. These are opened or closed automatically according to the situation, the engine being supplied with all the cooling air it needs. The car's aerodynamics are enhanced when the flaps are closed.



Intelligent lightweight construction: the BMW 6 Series

### Lightweight construction wherever possible.

Alongside the innovations in and around the engine and auxiliary units, the EfficientDynamics development principle also focuses on the optimisation of vehicle weight. Clever use of materials (plastics, higher-strength steels and light metals such as magnesium and aluminium) allows the increase in weight of new models to be kept in check and, ideally, even reversed. And all while consistently improving safety and comfort. New, extremely lightweight materials have allowed steady reductions in the fuel consumption of all models over the years. However, tough requirements are placed on the use of these materials. At the same time as ensuring a significant drop in weight, they must be able to at least match the performance of conventional materials in all other departments.

### Many innovations for many models.

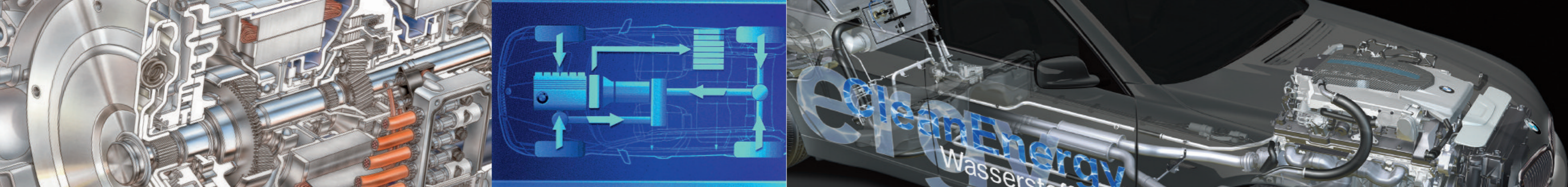
In order to generate serious savings as part of its EfficientDynamics strategy, the BMW Group engineers check every detail of every model. Other prominent innovations of recent times include the highly efficient, quick-shifting automatic gearbox, tyres with low rolling resistance, the introduction of special energy-conserving transmission oil and optimised heat management for the final drive.

The measures developed to raise efficiency are channelled gradually into all model series. This approach, coupled with the fact that these innovations are included in the cars as standard, ensures that a large number of customers benefit at an early stage from the advances achieved in the area of fuel consumption optimisation. It also increases the overall effect of the measures in terms of reducing the CO<sub>2</sub> produced by road transportation.

A line-up of extremely economical engines and this package of efficiency-enhancing measures will be offered in the high-volume 1 Series, 3 Series and 5 Series ranges in model year 2008. Two different aims can then be ticked off. The number of models made by the BMW Group with CO<sub>2</sub> emissions of 140 g/km and under will swell to comfortably in excess of 20 and the proportion of exceptionally efficient vehicles sold will also rise. It will thus become even easier in the future for customers to find an extremely economical and low-emission car which meets their individual requirements in terms of dynamics and spaciousness. As this development shows, the strategy pursued by the BMW Group is aimed at achieving the greatest possible overall impact when it comes to cutting CO<sub>2</sub> emissions.



The package of efficiency-enhancing measures is being introduced gradually into all model series



The BMW Group is continuing its efforts – with the help of its EfficientDynamics strategy – to achieve the largest possible cuts in fuel consumption and emissions across all segments. These endeavours are not restricted to the German and European car markets alone. However, for the time being, the full range of EfficientDynamics measures for petrol-engined vehicles will only be available in those markets where sulphur-free fuel is on sale – i.e. in Europe, New Zealand and Japan. In the USA and large parts of Asia, on the other hand, engines with VALVETRONIC will remain the most efficient solution until fuel of sufficient quality is widely available. These powerplants also benefit from a constant process of further development. In this way, the goal of efficient dynamics is achieved in all markets as far as conditions allow.

#### Innovative hybrid powertrain.

The BMW Group is aiming to integrate hybrid drive systems into its product portfolio in the medium term. This promises to deliver an additional cut in CO<sub>2</sub> emissions through the combination of electric motors and combustion engines along with the extra efficiency boost provided by the intensive utilisation of braking energy (converted into electric power). However, this is dependent on hybrid

technology attaining a degree of development which allows it to meet customers' expectations of a premium car in every way. The BMW Group is currently working on a new generation of hybrid drive systems as part of an equal cooperation with DaimlerChrysler and General Motors. One product of this meeting of minds, the "two-mode active transmission", sees the full integration of electric motors and a gearbox with fixed and variable gear ratios into the gearbox housing. With this technology on board, vehicles of the future could be powered by either the electric motor or the petrol engine alone, or by both drive units at the same time. This hybrid drive system breaks new ground in raising efficiency both in city traffic and over longer-distance journeys between towns, and the target is to cut fuel consumption by as much as 20 percent.

A separate jointly-run project with the Mercedes Car Group is focusing on putting together an innovative mild hybrid module for rear-wheel-drive premium segment passenger cars. The BMW Group is thus assembling a far-reaching modular system for hybrid technology in order to offer customers an optimum hybrid solution tailored to each individual model ("best of hybrid").

#### Hydrogen: a long-term pillar of EfficientDynamics.

In its efforts to ensure a sustainable future for passenger cars, the BMW Group is pursuing its vision of CO<sub>2</sub>-free motoring by concentrating on the use of hydrogen produced through regenerative processes. Water vapour is practically the only substance emitted by a vehicle powered by a hydrogen combustion engine.

In 2006 BMW produced a small series of the world's first hydrogen-powered luxury saloon: the BMW Hydrogen 7. Driven by a "dual-fuel" combustion engine – which can burn both hydrogen and conventional petrol – the BMW Hydrogen 7 develops output of 260 hp/191 kW and peak torque reaching 390 Newton metres at 4,300 rpm in both operating modes. The CO<sub>2</sub> emissions of this innovative car when burning hydrogen are just five grams per kilometre.

#### Sustainability is a recurring theme of the BMW Group corporate strategy.

In its pioneering role as a technological leader, the BMW Group was quick to declare social and environmental responsibility as key elements of its corporate strategy. Environmental protection was established as a fixture of the corporate organisation as early as the 1970s. The company employed a range of effective environment management systems to minimise the environmental impact of its production activities and maximise the preservation of resources. Regular audits ensure that environmental standards are observed within the company.

Today sustainable sound financial management is anchored as a guiding principle in the corporate strategy and culture at BMW.

The BMW Group has earned high praise from financial analysts for its corporate sustainability. For example, in 2005 and 2006 it was named as a "Supersector Leader" in the Dow Jones Sustainability Index World, making it the leading automotive company from a sustainability perspective. The BMW Group is the only automotive company to have enjoyed an uninterrupted top-three listing in the Dow Jones Sustainability Index since it was established in 1999. As a worldwide market leader in the premium segment and a key driver of technological progress, the BMW Group plays a standout role in securing mobility into the future.

The EfficientDynamics development strategy demonstrates how technological leadership can be

used to promote sustainability and achieve widespread effectiveness. The innovative power of the BMW Group will therefore continue to help safeguard individual mobility in the future through further reductions in fuel consumption and emissions levels. And in so doing it will also continue to make Sheer Driving Pleasure a reality for as many motorists as possible.

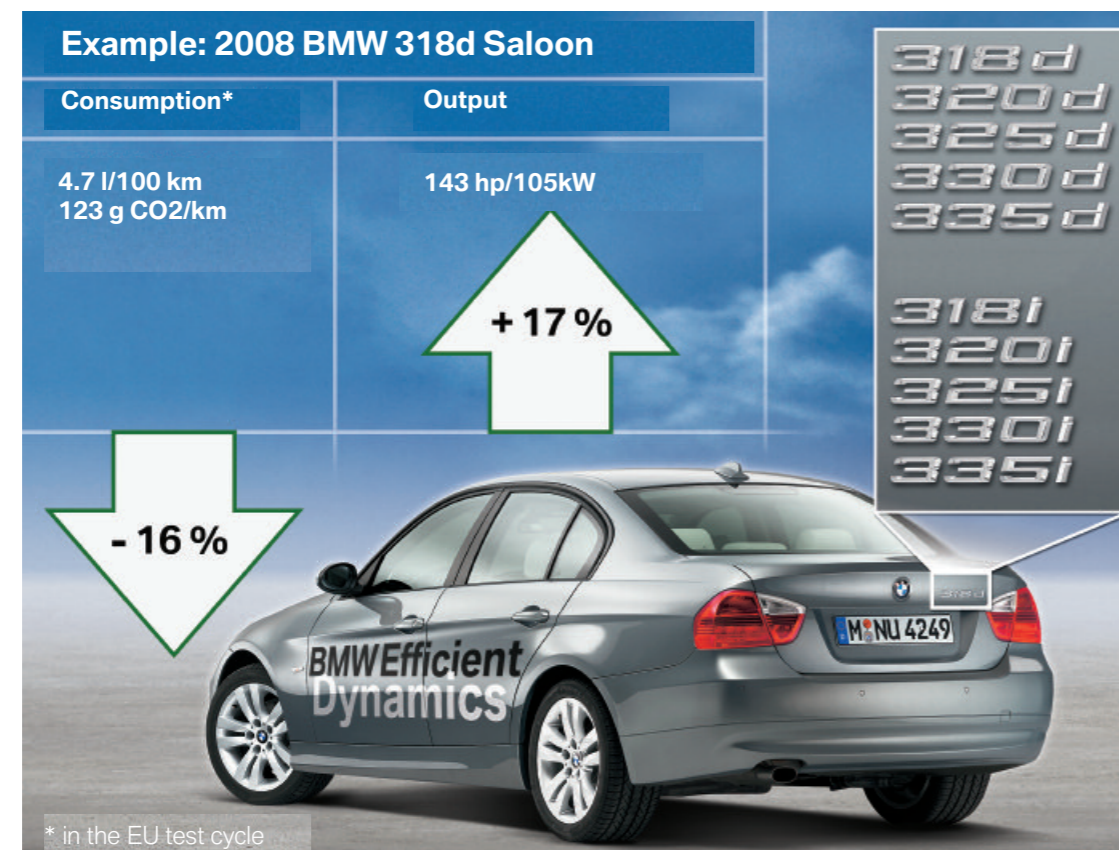


The BMW Hydrogen 7 in Berlin's government district



Refuelling the BMW Hydrogen 7

EfficientDynamics:  
enhancing  
performance and  
lowering fuel  
consumption  
compared with  
the previous  
model





A long-term  
view anchored in  
technology that can be  
used today:  
the BMW Hydrogen 7



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Further information is available  
on the Internet at  
<http://www.bmw.de/efficientdynamics>  
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