BMW Group Innovation Days 2015: Drive technologies of the future.
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1. BMW Group Innovation Days 2015: Drive technologies of the future. (Introduction)

- The BMW Group presents pioneering drive technologies during a driving event at the Miramas proving grounds in southern France.
- The BMW Group's largest testing facility offers the ideal environment for the intensive, real-world testing of drive systems and driving dynamics.
- BMW eDrive technology from the BMW i cars continues to find its way into series production models from the BMW brand.
- The prototype of a BMW 2 Series Active Tourer with plug-in hybrid drive system demonstrates the high flexibility of BMW eDrive technology; first plug-in hybrid vehicle from BMW with a front/transverse-mounted combustion engine, high-voltage generator and road-linked all-wheel drive thanks to an electric drive system at the rear axle.
- Direct water injection enhances the efficiency of combustion engines at higher performance levels and also significantly reduces fuel consumption and emissions in key driving cycles for customers.
- Hydrogen fuel cell drive system is a future-focused variant of BMW eDrive technology allowing all-electric driving with a high operating range and short refuelling times. The BMW Group's many years of research and development work in this field are given fresh momentum by the collaboration with the Toyota Motor Corporation.

The integration of BMW eDrive technology into an increasing number of models from the BMW brand, the ongoing development of combustion engines with TwinPower Turbo technology and the concept of a Fuel Cell Electric Vehicle (FCEV) focused on the long term have helped the BMW Group prepare for the challenges of the future. Underpinning all these developments are flexible architectures and an increasing variety in drive system technology: efficient petrol and diesel engines, plug-in hybrid and battery-electric drive systems and, in the future, hydrogen fuel cells will provide effective technology for each individual segment and set of requirements.

The BMW Group test facility in Miramas: the ideal environment for testing innovative drive system and chassis technology.
For almost 30 years the Miramas proving grounds in southern France have played a central role in the development of BMW cars and motorcycles. With its stable climate and wide range of usage possibilities, the around

473-hectare site offers the perfect environment for the intensive testing of drive system and chassis technology. The Autodrome de Miramas was bought by BMW France in 1986 and has since been consistently extended and updated. As well as test tracks measuring a combined length of more than 50 kilometres (31 miles), Miramas now also features ultra-modern office and workshop facilities for the development and fine-tuning of new models and technological components.

At the heart of the testing facility is the erstwhile race circuit's five-kilometre (three-mile) asphalt oval. Added to which, a motorway ring for high-speed tests, various handling courses and hills, plus switchback bends, rough roads and off-road sections can all be used for individual trials and extended testing programmes. Among the special features of the site are a reproduction of a section of the Nürburgring. Renewal work on the Petit Ovale at Miramas included adding a carbon copy of the 'Ring's Caracciola-Kurve (aka Karussell) corner. The ultra-challenging section of the proving grounds has since provided the ultimate yardstick for the optimisation and fine tuning of chassis components and electronics control systems.

The BMW 2 Series Active Tourer plug-in hybrid prototype: BMW eDrive technology spreads to additional BMW brand models.
Electric mobility has added another new facet to the BMW model line-up. The BMW eDrive technology developed for BMW i cars is spreading its wings into other vehicle concepts as part of a plug-in hybrid drive system, highlighting its flexibility. And here we find it linking up with a front/transverse-mounted combustion engine for the first time. The BMW 2 Series Active Tourer plug-in hybrid prototype presented in Miramas is kitted out with a three-cylinder BMW TwinPower Turbo petrol engine driving the front wheels, a high-voltage generator mounted in the front structure and an electric motor sending its power to the rear wheels. The result is road-linked all-wheel drive similar to that of the BMW i8 plug-in hybrid sports car, but here arranged in a mirror image.

And so the high efficiency of the plug-in hybrid drive system, the ability to run on electric power alone and the instantaneous power delivery when the electric motor comes on stream are complemented by an all-wheel-drive system unmatched in this segment. The BMW 2 Series Active Tourer plug-in hybrid prototype can cover up to 38 kilometres on electric power alone, accelerate from 0 to 100 km/h in around 6.5 seconds and will achieve average fuel economy of approximately two litres per 100 kilometres, equating to CO_2 emissions of under 50 g/km, in the EU test cycle for plug-in hybrid vehicles.

Direct water injection: cooling effect ensures extra power and efficiency.

Following the premiere of water injection in the BMW M4 MotoGP Safety Car, direct water injection for turbocharged petrol engines is now making its debut in a member of the BMW Group's new generation of engines. This innovative technology, which increases efficiency by reducing temperatures in the combustion process, will be presented at the BMW Group Innovation Days 2015 in a BMW 1 Series model with a three-cylinder petrol engine.

The cooling effect triggered by direct water injection likewise imbues this unit with substantially increased performance and efficiency. Plus, fuel consumption is reduced when pushing on, in particular. The boost to efficiency is therefore significant – especially when the driver adopts a sportier style – and average fuel economy under everyday conditions benefits accordingly. Added to which, direct water injection reduces thermal stress on numerous engine components and minimises emissions.

Hydrogen fuel cell: pioneering combination with BMW eDrive, long-term option for zero-emission mobility.

The BMW Group has been conducting research and development work in the field of hydrogen fuel cell drive systems for over 15 years now. And a collaboration with the Toyota Motor Corporation launched in 2013 has further accelerated progress towards its goal of finalising approved components for a Fuel Cell Electric Vehicle (FCEV) by 2020. The fuel cell, which converts hydrogen into electric energy and water vapour, enables locally emission-free driving laced with the dynamics customers expect of a BMW – plus long-distance capability and short refuelling times. It therefore represents the ideal next layer of BMW eDrive technology.

The Innovation Days 2015 event will include, for the first time, driving presentations in which demonstration vehicles with a hydrogen fuel cell drive system will display the potential of this technology. Over the long term, the hydrogen fuel cell drive system will become an integral element of Efficient Dynamics technology, allowing the BMW Group to add further variety to a portfolio of drive systems which can be adapted flexibly to different vehicle concepts, customer requirements and legal stipulations around the world. Furthermore, the hydrogen fuel cell drive system also offers scope for integration into a bespoke vehicle architecture. Future FCEVs will therefore benefit from extensive freedom in the development of innovative design and space-related solutions, similar to that enabled by the LifeDrive architecture underpinning BMW i cars with eDrive.

Further information on official fuel consumption figures, specific CO2 emission values and the electric power consumption of new passenger cars is included in the following guideline: "Leitfaden über Kraftstoffverbrauch, die CO2-Emissionen und den Stromverbrauch neuer Personenkraftwagen" (Guideline for fuel consumption, CO2 emissions and electric power consumption of new passenger cars), which can be obtained from all dealerships, from the Deutsche Automobil Treuhand GmbH (DAT), Hellmuth-Hirth-Str. 1, 73760 Ostfildern-Scharnhausen and at http://www.dat.de/en/offers/publications/guideline-for-fuel-consumption.html. LeitfadenCO2 (GuidelineCO2) (PDF – 2.7 MB)

2. BMW eDrive in the pipeline for further BMW models: The BMW 2 Series Active Tourer plug-in hybrid prototype.

The advent of plug-in hybrid variants in various model series from the BMW brand is making all-electric driving with zero local emissions in a premium car a possibility for an ever-increasing number of target groups. The BMW eDrive technology initially developed for BMW i cars offers an extraordinary degree of freedom that allows it to be used across a broad range of vehicle concepts and segments. The BMW Group Innovation Days 2015 will host the debut appearance of a front/transverse-mounted combustion engine in combination with a high-voltage generator and an electric drive system acting on the rear wheels. In the prototype of a BMW 2 Series Active Tourer with plug-in hybrid system set for demonstration at the event, the front wheels are driven by a three-cylinder petrol engine and the rear wheels by an electric motor. The result is road-linked all-wheel drive – similar to that offered by the BMW i8 plug-in hybrid sports car, albeit with the positions of motor and engine reversed.

The BMW 2 Series Active Tourer plug-in hybrid thereby serves to widen the reach of BMW eDrive in the Sports Activity Tourer segment.

- BMW X5 xDrive40e: this Sports Activity Vehicle – the brand's first ever plug-in hybrid model – is due to be launched very shortly.
- BMW 3 Series with plug-in hybrid technology: the world's most successful premium sedan was already presented in electrified form as a prototype at last year's Innovation Days event. Further models with plug-in hybrid technology are set to follow in the core model series.

In the plug-in hybrid models developed to date by the BMW Group, the combustion engine and electric motor are combined with one another in a specific configuration for the model at hand. The signature qualities of BMW eDrive are present and correct in all models:

- Efficiency: substantial reduction in fuel consumption and emissions over conventionally powered models, while delivering comparable performance and greater power.
- Electric mobility: all-electric driving with zero local emissions in urban driving situations or when commuting.

- Driving dynamics: instantaneous power delivery thanks to a boost effect from the electric motor that assists the engine under high loads.
- Flexibility: the high-voltage battery can be recharged from conventional domestic power sockets, the BMW i Wallbox or at public charging stations.
- Unrestricted long-distance capability: intelligent drivetrain management governs the interaction between electric motor and engine with no loss of range.

BMW eDrive in the BMW 2 Series Active Tourer: all-electric mobility, sporty AWD driving experience, exemplary efficiency.

The BMW 2 Series Active Tourer plug-in hybrid prototype fuses BMW eDrive with a model-specific form of power transmission – based on the front-drive concept of the standard BMW 2 Series Active Tourer – which sees action for the first time. Following on from the four-cylinder petrol engine in the BMW 3 Series plug-in hybrid prototype, a front-mounted transverse three-cylinder petrol unit from the new Efficient Dynamics engine family now forms part of a plug-in hybrid system for the first time. The 1.5-litre BMW TwinPower Turbo engine generates an output of 100 kW/136 hp together with a peak torque of 220 Nm (162 lb-ft), with power relayed to the front wheels via a six-speed Steptronic transmission. The additional high-voltage generator on the front axle fulfils three different tasks: it boosts the combustion engine for brief periods with extra output of up to 15 kW and some 150 Nm (111 lb-ft) from rest, generates electric power while on the move (which is fed directly to the high-voltage battery), and enables the engine to be started and turned off very smoothly thanks to its higher output compared to conventional starters. The electric motor is located above the rear axle, together with its two-staged transmission and the power electronics. It sends output of up to 65 kW/88 hp and maximum torque of 165 Nm (122 lb-ft) through the rear wheels.

The on-demand, road-linked all-wheel drive provides qualities unmatched in this segment, with the power electronics distributing drive to the front wheels, rear wheels or all four wheels as required. As with the BMW i8, the intelligent drivetrain management and networking with the DSC (Dynamic Stability Control) system ensure safe and supremely assured handling characteristics at all times, together with optimised traction, highly dynamic acceleration and cornering, and maximum efficiency.

The BMW 2 Series Active Tourer plug-in hybrid prototype accelerates from 0 to 100 km/h in around 6.5 seconds. Its average fuel consumption in the EU test cycle for plug-in hybrid vehicles will be approximately two litres per

100 kilometres, which equates to CO_2 emissions of under 50 grams per kilometre. The range on electric power alone as measured in the EU test cycle will be 38 kilometres.

The pricing for the production version of the BMW 2 Series Active Tourer with plug-in hybrid drive has not yet been finalised. But thanks to its specific overall vehicle concept, prices at launch will be in the range of existing engine variants with comparable power outputs – just as they are for the electrified versions of the BMW X5 and BMW 3 Series. This means that customers do not have to pay a high premium for the technology.

Wide-ranging driving characteristics, unrestricted versatility.
The BMW 2 Series Active Tourer plug-in hybrid prototype comes with the same Driving Experience Control switch found in the conventionally powered model variants. The Comfort and Sport settings and Eco Pro mode can be activated at the push of a button. Not only does this influence the accelerator mapping and chassis functions, it also alters the shift characteristics of the Steptronic transmission. With Eco Pro mode engaged, drivers can also make use of the coasting function, while energy efficiency is further boosted by precisely gauged power control for electrically operated convenience functions, such as the air conditioning, seat heating and heated mirrors.

Furthermore, the driver is able to adjust the responses of the drivetrain management using the eDrive button on the centre console. There is a choice of three settings:

- Auto eDrive: this hybrid mode is activated as the default setting in Comfort mode every time the vehicle is started. The engine and electric motor combine to extremely efficient effect in this setting. Under normal loads, the vehicle initially sets off purely on electric power. Once the speed exceeds approximately 80 km/h (50 mph) or under strong acceleration, the engine cuts in automatically. When route guidance is activated, the system automatically calculates how to make the most efficient use of the energy generated by the electric motor and combustion engine, with all-electric driving prioritised over sections of the route where it makes most sense. In Comfort mode, the high-voltage battery is automatically recharged by the high-voltage generator to a charge up of around 15 percent.
- Max eDrive: in this setting, the vehicle is powered by the electric motor alone. Top speed is limited to around 130 km/h (81 mph), while the all-electric range is some 38 kilometres. Accelerator kickdown brings the combustion engine into play.

- Save Battery: This mode allows the energy stored in the high-voltage battery to be deliberately kept at a constant level or increased again up to 50 percent (when its charge drops below that mark) by efficiently raising the engine's load points and using energy recuperation. The stored energy can then be used for all-electric driving at a later stage in the journey, for example when driving through an urban area.

When Sport mode is selected with the Driving Experience Control switch, on the other hand, the combustion engine and electric motor operate in unison and are geared toward a sporty driving style. The high-voltage generator provides a boost effect at low engine revs and generates electricity that is stored directly in the high-voltage battery up to a charge level of around 50 percent.

Drivers can call on another special feature when they require a particularly strong hit of power, e.g. for a short-notice overtaking manoeuvre; moving the transmission's selector lever into the S gate has the effect of activating both power units, meaning that the drive system's maximum output is instantly on tap. At the same time, by contrast with Sport mode the high-voltage battery can be charged to 80 percent using this method.

The Driving Experience Control switch modes and the eDrive button settings can be combined in different ways. This gives the driver a significant amount of scope for varying the drivetrain management and vehicle set-up to suit their individual preferences. And the BMW 2 Series Active Tourer plug-in hybrid prototype also comes with a hybrid-specific energy management function built into the navigation system, which allows it to incorporate route topography, speed restrictions and the traffic situation, along with the high-voltage battery's available energy capacity, into drivetrain management.

BMW eDrive technology has been incorporated into the concept underpinning the versatile BMW 2 Series five-door model without compromising on either occupant comfort or the interior's flexibility of use. The high-voltage battery is housed in a space-saving position underneath the rear seat bench. The power electronics, including the charging generator, can be found next to the electric motor above the rear axle.

Unrestricted everyday usability and flexibility

The capacity of the main load compartment in the BMW 2 Series Active Tourer plug-in hybrid prototype is identical to that of its conventional siblings. And there is still a storage compartment underneath the load compartment floor, as well.

3. Extra power, improved real-world fuel economy: Direct water injection enhances efficiency.

With direct water injection for turbocharged petrol engines, the BMW Group has again succeeded in enhancing the capabilities of conventional engine technology through an ongoing process of refinement and improvement. The precisely controlled injection of water into the engine cylinders produces a cooling effect that boosts power and torque, particularly when operating at or near full throttle, while at the same time reducing fuel consumption and emissions.

Water injection made its debut in a modern-day BMW Group engine under the bonnet of the BMW M4 MotoGP Safety Car. Designed by BMW M GmbH – on the basis of the M4 high-performance sports car – for use in the world's top motorcycle racing series, it is powered by a modified version of the high-revving M TwinPower Turbo six-cylinder in-line engine that already develops maximum output of 317 kW/431 hp and peak torque of 550 Nm/405 lb-ft (combined fuel consumption: 8.8–8.3 l/100 km; combined CO_2 emissions: 204–194 g/km) in the standard BMW M4. Water injection provides the BMW M4 MotoGP Safety Car with extra power, torque and efficiency for its duties on the race track.

The BMW Group Innovation Days 2015 event marks the first presentation of this innovative technology in a prototype of a model from the BMW core brand powered by a latest-generation three-cylinder petrol engine. In this version of the system, most of the water is injected directly into the combustion chamber, rather than just into the intake manifold. In the prototype, which is based on a 5-door BMW 1 Series model, direct water injection offers an optimised balance between driving pleasure and fuel consumption in keeping with the principle of Efficient Dynamics.

Cooling effect enhances efficiency: up to ten percent more power, up to eight percent better real-world fuel economy.
Direct water injection allows the potential of turbocharging to be harnessed even more effectively. The water is injected as a fine spray into the intake manifold plenum chamber where it evaporates, extracting energy from its surroundings and reducing combustion temperatures in the engine by around 25° Celsius.

Particularly at full throttle, this cooling effect provides a big improvement in efficiency, while helping to improve the combustion process in various other ways as well:

- Efficiency: the cooling effect provided by water injection reduces temperatures sufficiently to avoid any need to inject additional fuel when operating at or near full throttle; the homogenous fuel/air mixture and improved full-load efficiency allow real-world fuel economy to be improved by up to eight percent.
- Emissions: reduced combustion temperatures lead to lower emissions.
- Reduced knock: lower temperatures reduce the risk of uncontrolled combustion (knock).
- Higher compression ratio: the reduced knock risk allows the compression ratio of the prototype model's three-cylinder engine to be increased from 9.5:1 to 11.0:1, optimising efficiency in the low and medium throttle range too.
- Performance: the earlier ignition point and higher boost pressure improve engine power and torque by up to 10 percent; the increased oxygen content of the cool induction air boosts power, too.
- Fuel compatibility: power output is optimised even when operating on low-octane fuel (RON 95); turbocharged engines with direct water injection can therefore be used anywhere in the world.
- Thermal load reduction: the cooling effect reduces the thermal load on pistons, valves, catalytic converter and turbocharger.

The benefits of direct water injection cooling can be utilised in various ways. Depending on vehicle type and engine, it is possible to prioritise either increased power or enhanced fuel economy.

On-board water recovery ensures everyday practicality.

The water injection system in the BMW M4 MotoGP Safety Car draws water from a five-litre tank in the boot. Under gruelling race conditions, when the vehicle spends a lot of time operating at full throttle, the water tank is topped up every time the vehicle is refuelled.

By contrast, the direct water injection system destined for future production models that is being presented at the BMW Innovation Days never requires topping up in everyday use. Unless the vehicle is operated in exceptional climatic conditions, the system is fully self-replenishing, thanks to on-board water recovery.

The water supply for water injection cooling is kept topped up by the continuous recovery of condensed water from the air conditioning system.

Every time the engine is switched off, all the water in the hose system is drained into the tank. This guards against system components icing up in sub-zero temperatures and prevents engine corrosion. The water tank itself is also located in a frost-protected position in the vehicle.

4. Long range, short refuelling times, zero emissions: Hydrogen fuel cell drive system points the way to the future of BMW eDrive technology.

As part of its research and predevelopment work in the area of drive technology, the BMW Group has focused on the use of hydrogen as an energy source for more than 30 years now. In 2006 the first luxury sedan for everyday use to be powered by a hydrogen combustion engine was unveiled – the BMW Hydrogen 7. And more than 15 years ago the BMW Group also began to direct its spotlight onto hydrogen fuel cell drive systems. A constant stream of significant advances – in terms of energy efficiency, performance capability and everyday practicality – have likewise been made with this technology, which converts hydrogen into power for an electric drive system, rather than burning it inside the engine.

The results of the research and development activities in the field of hydrogen fuel cell drive systems will be presented in driving demonstrations for the first time during the BMW Group Innovation Days 2015. The demonstration vehicle, based on a BMW 5 Series Gran Turismo, reveals a take on this form of propulsion in keeping with the brand's profile and character. It combines locally emission-free mobility with sporting dynamics, excellent ride comfort and long-distance capability. Its key features are as follows:

- Electric motor developing 180 kW/245 hp, power electronics and high-voltage battery for interim energy storage; developed as a variant of BMW eDrive technology for BMW i cars and BMW brand plug-in hybrid models.
- Hydrogen storage in the form of a tunnel tank between the front and rear axle; industry standard 700 bar CGH2 vessel technology and cryogenic pressure vessel technology (CCH2) patented by the BMW Group for storing gaseous hydrogen at low temperature and 350 bar pressure; operating range: over 500 kilometres (more than 300 miles).
- Fuel cells, housing and ancillary systems: initial results from the collaboration between the BMW Group and the Toyota Motor Corporation on Fuel Cell Electric Vehicle (FCEV) technology.

The strategic collaboration between the BMW Group and the Toyota Motor Company agreed at the beginning of 2013 has provided fresh momentum for the development of FCEV drive technology. The aim of the collaboration is to have an initial group of approved components ready by 2020. The successful introduction of FCEVs is dependent on the development of a hydrogen

infrastructure in the markets concerned. The two collaboration partners are supporting this process through jointly created technological standards which make fuel cell-powered vehicles easier to use and help to increase their reach and numbers.

Pioneering combination: BMW eDrive and fuel cell technology.
The hydrogen Fuel Cell Electric Vehicle (FCEV) represents a pioneering concept focusing on locally emission-free mobility combined with hallmark BMW dynamics and a high level of energy efficiency. The hydrogen fuel cell drive system combines the benefits of BMW eDrive technology with a host of qualities familiar from conventional combustion engines:

- All-electric, locally emission-free driving.
- BMW eDrive electric motor generates instantaneous power delivery and impressive dynamics.
- Power electronics, high-voltage battery and intelligent energy management based on the BMW Group's eDrive technology.
- Long-distance capability with an operating range of more than 500 kilometres (300 miles) thanks to the high energy density of the hydrogen carried on board.
- Fast and convenient refuelling in under five minutes.

Fuel cell technology therefore makes an ideal addition to both the BMW i models and, in the future, the series-produced models from the BMW brand fitted with tried-and-tested eDrive technology. It converts the gaseous hydrogen contained in the storage tank into electric power and water vapour. The vehicle's high-voltage battery serves as an energy storage unit and can therefore be considerably smaller – with a net capacity of around one kilowatt hour – than in battery-electric concepts. Storing hydrogen in a cryogenic pressure vessel can, depending on the type of vehicle, allow an operating range comparable with that of conventional vehicles powered by combustion engines. Filling up the hydrogen storage tank takes a similar amount of time as refuelling a petrol or diesel tank.

FCEV as an element of Efficient Dynamics: drive system portfolio and vehicle architecture offer high flexibility.
Our aim is to establish hydrogen fuel cell drive technology as an integral element of the BMW Group's Efficient Dynamics strategy for the long term. This would create a drive system portfolio of the greatest possible variety, which can be adapted flexibly to different vehicle concepts, customer desires and legal requirements around the world:

- Highly efficient combustion engines with BMW TwinPower Turbo technology.
- Intelligently controlled plug-in hybrid systems with BMW eDrive or Power eDrive technology enable low-emission electric driving very much in the BMW mould.
- Locally emission-free, battery-electric vehicles with a high-voltage battery like that of the BMW i3.
- Fuel Cell Electric Vehicle (FCEV) with hydrogen fuel cell technology and BMW eDrive electric drive system.

With this flexible drive system portfolio designed to provide efficient personal mobility, the BMW Group is ideally prepared for the global challenges of the medium and long term when it comes to reducing fuel consumption and emissions.

The integration of the hydrogen fuel cell drive system into the demonstration vehicles presented during the BMW Group Innovation Days 2015 is all part of the testing and validation process taking place as part of the ongoing development phase. The development of a series-produced FCEV provides the opportunity to integrate the variable drive system architecture into a bespoke vehicle architecture and so provide the perfect showcase for the qualities customers will most appreciate.