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Audi future performance days 2015

The equipment and data specified in this document refer to the model range offered in Germany. Subject to change without notice; errors and omissions excepted.

*The fuel consumption and CO_2 emissions of all models named above and available on the German market can be found in the list in the last chapter of this basic information.

The ideal solution for every model: Audi pushing electrification

Audi is upping the pace of electric mobility. For every vehicle and drive concept, the company develops the best form of electrification – in terms of customer expectations, market conditions, costs, complexity and delight potential. New services such as rapid direct-current charging round off Audi's premium electric mobility.

Audi possesses broad-based expertise in electric mobility. The brand unveiled its first plug-in hybrid model as far back as 1989, and it began working on fuel-cell drive at the start of the millennium. In conjunction with its partners, Audi is getting involved in a variety of future technologies. One of the results is the dynamic technology study Audi A7 h-tron quattro* with fuel-cell drive and a peak performance of 228 kW. Audi is poised to go into volume production with fuel cells as soon as the market and the public infrastructure justify this move.

Maximum flexibility: modular-principle batteries

At its high-voltage competence center near Ingolstadt, the Company is developing complete battery systems that follow a modular basic principle, regardless of the format of the individual cell. With this strategy, Audi is giving itself the flexibility to respond swiftly to developments in the market. If the battery still has around 75 percent of its capacity after propelling the customer's vehicle for 160,000 kilometers *(99,419.4 miles)*, it can enjoy a new lease of life as a stationary energy store. This concept, which is just being trialed, emphasizes the holistic approach of the brand with the four rings.

The brand with the four rings is also powering ahead with the range of models: The A3 e-tron Sportback* will shortly be joined by the powerful Q7 e-tron 3.0 TDI quattro*, equally with plug-in hybrid drive. Its technical highlights include a heat pump that regulates the interior climate very efficiently, thus extending the electric range. The predictive efficiency assistant evaluates information from the car's immediate vicinity to pave the way for a hybrid driving strategy based on anticipating the road ahead.

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In 2018 a sport SUV with all-electric drive will follow – its precursor, the Audi e-tron quattro concept that appeared at the 2015 Frankfurt Motor Show, has already demonstrated how thrilling electric mobility from Audi will be. The three electric motors have an output of up to 370 kW, providing the basis for e-quattro drive and electric torque vectoring for maximum dynamics and stability. The 95 kWh battery, located between the axles and therefore in the ideal position in terms of the center of gravity, makes a range of over 500 kilometers *(310.7 miles)* possible.

CharIN: direct-current charging at an output of 150 kW

It must also be possible to recharge all-electric-drive cars while out and about – for that reason Audi has teamed up with other manufacturers and partners to launch an initiative called CharIN (Charging Interface Initiative e. V.). It aims to establish a CCS (combined charging system) as a uniform charging interface and to set up a network of high-speed, direct-current quick-charging pillars along Germany's autobahns. Future electric cars from Audi will be able to plan their route intelligently; on longer trips they will keep the driver informed of where quick-charging pillars are currently free.

With an output of 150 kW, the large battery of the Audi e-tron quattro concept can be charged to 80 percent of its capacity in half an hour – enough to travel 400 kilometers *(248.5 miles)*. Charging it to 100 percent takes about 50 minutes. Audi is also introducing a convenient solution for its plug-in hybrid models in 2017, in this instance for the garage at home. This contactless form of alternating-current charging by induction is referred to as AWC (Audi wireless charging).

New technologies: The 48-volt subsidiary electrical system is coming

Among the new high-voltage electric cars, too, Audi is pressing ahead swiftly with electrifying its model range. The existing 12-volt electrical system and above all the new 48-volt subsidiary electrical system offer ample scope for making driving even more sporty, comfortable and efficient. New mild-hybrids with powerful belt alternator starters and new solutions delivering driving fun will soon become commonplace in the Audi model range. In about ten years, no single model offered by the brand outside the e-tron range will be without this technology.

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One particularly attractive development is the electrically driven compressor, which supports the engine's turbocharger whenever the energy in the exhaust gas does not suffice for a rapid torque buildup. The engine spontaneously develops abundant power thanks to the additional electric boost. The electrically driven compressor will soon be making its debut in a new model together with electromechanically active roll stabilization. Here, the stabilizers integrate electric motors that they can isolate from each other or combine, as required. This opens up new horizons of driveability, from ultra-comfortable to sportily firm. The system can also recuperate by converting kinetic energy into electrical energy.

Green power – an important factor in future mobility

Generally speaking, Audi views power generated by environmentally friendly means as a key factor in future mobility. Wind power is also used to run the Audi e-gas plant in Werlte (Emsland) – this plant uses the power-to-gas principle to convert water and CO_2 into synthetic methane, also known as Audi e-gas. This serves as the fuel for the Audi A3 Sportback g-tron* and the new A4 Avant g-tron*, which is appearing on the market in 2016. Green power is also the driving force behind other Audi e-fuels – the formulas of the future that Audi is developing through cooperation ventures.

Technology at the extremes: the Audi R18 e-tron quattro

Audi drives competition and is driven by competitiveness, too. The toughest testing environment for production is motorsport, in particular the Le Mans 24 Hours race and the World Endurance Championship. The Audi R18 e-tron quattro has enjoyed huge success in these events in recent years. Its concept allocates the drive concepts to separate axles – the combustion engine permanently propels the rear wheels, and the electric motor drives the front wheels for spurts of a few seconds at a time: quattro technology and electric drive forging a very special alliance.

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The electrification modular platform: new technologies with 12 and 48 volts

Audi is systematically driving forward the electrification of its cars – including below the new high-voltage models. The new mild hybrids are set to make inroads into the model range on a broad front – in ten years' time, Audi aims to offer all new models with this technology, with the exception of the e-tron lineup. The current 12-volt electrical system and, above all, the new 48-volt system offer many ways of making driving even sportier, more comfortable and more efficient.

Mild hybrid for beginners: high drive efficiency based on 12 volts
Audi offers a tailor-made solution for each new electrified model. A very efficient mild hybrid can already be implemented with the existing 12-volt electrical system. Its key components are a lithium-ion battery with 11 Ah capacity and a belt starter generator, which at the same time is used as a starter motor.

The belt starter generator paves the way for new functions. The start-stop phase can already begin at around 15 km/h *(9.3 mph)* residual speed. If the driver takes their foot off the accelerator at high speed, the car coasts for a short time with the engine switched off. With a maximum 5 kW the recuperation output is considerable – in addition, the generator can assist the combustion engine with up to 1 kW. As a result, the TDI or TFSI can be operated closer to its ideal load point. The belt starter generator based on 12 volts has the potential overall to reduce the fuel consumption by up to 0.4 liters per 100 kilometers *(588.0 US mpg)*.

More power, more recuperation: the 48-volt electrical system
This technology is even more compelling with the new 48-volt subsidiary electrical system, which is about to enter volume production at Audi. The lithium-ion battery provides 10 Ah electrical capacity; the belt starter generator, however, produces 12 kW, translating into fuel savings of up to 0.7 liters per 100 kilometers *(336.0 US mpg)*. With 48 volts, the same mild-hybrid functions can be implemented as with 12 volts, but to a greater extent – the coasting phase with the combustion engine switched off, for instance, can last up to 30 seconds.

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Apart from hybridization, the 48-volt electrical system, which Audi is pioneering within the Volkswagen Group, boasts many other advantages. Its higher voltage allows for much smaller cable-cross sections, which also reduces the weight of the cable harness along with power dissipation. Above all, though, it can provide four times as much power as the 12-volt electrical system and, as such, opens up the prospect of innovative, compelling technologies for the driveline and suspension.

Driving pleasure technology: the electrically driven compressor
One of these new solutions is the electrically driven compressor; Audi has already showcased this solution in various technology studies. The electrically driven compressor sits in a bypass in the intake tract behind the intercooler and is activated via a flap. It is switched in series behind the turbocharger and always assists the turbocharger if the exhaust provides insufficient energy for instant torque buildup.

Instead of the turbine wheel, the electrically driven compressor incorporates a small electric motor, which accelerates the compressor wheel to very high speeds in around 250 milliseconds with approximately 7 kW of power. The motor always develops its power without any perceptible delay whether while moving off or accelerating at low speeds. The electrically driven compressor eliminates the need for constant downshifting, keeping engine speeds low. Sporty drivers will appreciate the passing power and immediate delivery of power when exiting a curve.

The electrically driven compressor is ideal for many Audi model lines, for diesel and gasoline engines alike. It will soon be part of volume production in the TDI sector. Here and also with the TFSI engines, Audi will focus the usage of the electrically driven compressor on the six- and eight-cylinder engines.

Brand-new solutions: 48-volt systems in the suspension
When it comes to the suspension too, the higher voltage facilitates compelling technologies. Audi will shortly be launching the first of these as part of volume production – the electromechanical active roll stabilization (EAWS). Here a compact electric motor with a three-stage planetary gearbox separates the two halves of the stabilizer from each other.

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With a comfort-oriented driving style, the two halves are decoupled from each other, resulting in excellent ride comfort. In response to sportier gear changes, the tubes are interconnected and twisted against each other. With each electric motor developing 1.5 kW of peak output, they produce anything up to 1,200 Nm *(885.1 lb-ft)* of torque.

The effect is taut, sporty handling: the car rolls less into the bends, the tendency to understeer reduced, lateral acceleration increased. The front and rear stabilizer can be adjusted independently of each other. As such, the control unit can make the handling even sportier on request.

Another of the system's strengths is recuperation. If the wheels on one axle are deflected to greatly differing extents on bumps in the road, they excite the stabilizer – its motor now operates as a generator and converts each impulse into electrical energy. Thanks to this effect, the electromechanical active roll stabilization only has to develop minimal power overall. With moderate gear changes on a very bumpy road, the power requirements can even be virtually zero.

Compared with conventional hydraulically switched stabilizers, the 48-volt-based system from Audi offers major advantages. It can develop more power, it works faster and more efficiently, and it is activated even at low speeds. The absence of oil also means the electromechanical active roll stabilization is maintenance-free and environmentally friendly.

eROT: electromechanical dampers recover energy

A second 48-volt project, which Audi uses to recover energy in the suspension, is still at the prototype stage. It is known under the working title eROT – an electromechanical rotary damper replaces today's hydraulic damper.

In terms of the basic principle, eROT is not unlike the electromechanical active roll stabilization: a strong lever arm absorbs the forces that are induced on the wheel carrier with a sporty driving style and on a bumpy road. Via a series of gears, it transmits this force to an electric motor, which converts it into electricity.

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The recuperation output is 150 watts on average on German roads – from 3 watts on a freshly tarmacked freeway to 613 watts on a poorly maintained country road. This corresponds to a CO_2 saving of three grams per kilometer *(4.8 g/mi)* under customer driving conditions.

The eROT system responds quickly and with minimal inertia. It is used to recover energy and acts as an actively controllable shock absorber. In doing so, it eliminates the mutual independence of the rebound and compression stage, which limits the effectiveness of modern hydraulic dampers. Thanks to eROT, Audi is able to tailor the compression stage to comfortable-soft characteristics without having to make compromises with the desired rebound damping setting. The system's horizontal position constitutes another advantage – the elimination of the upright dampers frees up additional installation space.

Gradual rollout: the electrification modular platform from Audi

In around ten years' time, Audi will equip all new models – with the exception of the e-tron range based on high voltage – with the new mild-hybridization features. A rollout plan maps out the desired route. In 2016, the 48-volt subsidiary electrical system will be launched in a new model, which will also feature the electrically driven compressor and the electromechanical active roll stabilization on-board. The increased voltage promotes above all dynamism and driving pleasure. The generator still works on the basis of 12 volts, a DC/DC converter interconnects the 12-volt electrical system and the 48-volt subsidiary electrical system.

The next expansion stage is planned for 2017 when the mild hybrid will be rolled out on the basis of 48 volts. The 12-volt system is now linked via a powerful DC/DC converter to the 48-volt system, which is then promoted to become the main electrical system and is powered by a 48-volt belt starter generator. The requisite lithium-ion battery is roughly as big as a large lead battery. Air cooling is sufficient for thermal management. The mild hybrid based on 12 volts is set to follow at around the same time.

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Over the medium term, Audi intends to convert auxiliaries such as pumps and superchargers for the engine, transmission and air conditioning system to 48 volts. Today they are driven hydraulically or by the combustion engine – however, if they are operated electrically, they can be controlled even more effectively according to demand; they would also be lighter and more compact. The same applies to large static convenience consumers such as window heating or sound systems. Small consumers such as control units or lights will, however, remain in the 12-volt system well into the future.

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The battery technology

Audi covers every key area in developing high-voltage batteries for its plug-in hybrid models and electric cars. Its expertise spans cell development, the arranging of the cells into modules, the operating strategies during driving operation, and use of the battery after the end of its service life in the car. The emphasis is on lithium-ion battery systems, which are put together using a flexible, modular concept.

At the competence center for high-voltage battery technology at Gaimersheim, just outside the main plant in Ingolstadt, Audi specialists are working on the traction batteries for future electric mobility. Whether for a plug-in hybrid car (PHEV, plug-in-electric vehicle) or a purely electric car, the battery structure without exception follows a uniform modular concept. This gives the Company the flexibility to respond swiftly to future requirements in the marketplace. The modular strategy also means the batteries can be used across all models and brands throughout the entire Volkswagen Group.

The module as central factor
The decisive factor for Audi is the battery module – a sturdy cuboid aluminum housing slightly smaller than a shoe box. The module weighs around 13 kilograms *(28.7 lb)* and within the battery system is mounted on a cooling plate through which cooling fluid circulates. It can accommodate three types of cell: round cells such as those used in the R8 e-tron 2.0*, prismatic cells – each of them about half the size of a paperback book – or long, flat pouch cells.

The prismatic cells have separate aluminum housings, so they are more robust than pouch cells. Their outer skin is made from aluminum-coated polymer and this in turn brings weight advantages. In terms of the performance of the battery system, the individual strengths and weaknesses of both concepts cancel each other out. The two suppliers with which Audi works have each specialized in a particular design.

The strength that prismatic and pouch cells have in common is the dense packaging. They both use 75 percent of the available volume, a much higher figure than round cells (50 percent), which also require more complex contacting.

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Round cells are generally only suitable for all-electric vehicles; while they store a high amount of energy compared to the other designs, their power output is comparatively low.

Pouch cells and prismatic cells are more versatile. With minor changes to their exterior dimensions, they can be configured specifically for maximum power output, maximum energy or a combination of both, making them ideal for a plug-in hybrid vehicle. The key criterion is the coating thickness of the electrodes – the thinner these are, the greater the contact surface between electrolyte and active material; the resulting high charge transfer assures a corresponding performance density. Conversely, high coating thicknesses for the electrodes produce a high energy density.

Worldwide, the development of lithium-ion battery technology is advancing very rapidly. Over the past three years Audi has succeeded in increasing the current capacity of prismatic cells by 50 percent – from 25 ampere hours per cell to 37 Ah. Energy density has increased by a similar degree. Pouch cells now achieve up to 550 watt hours per liter of volume, and Audi expects them to reach about 750 Wh/l by 2025. An important incidental effect is that battery costs have fallen by around half in the past five years. That is making electric mobility affordable for more and more customers.

Development in the competence center

Audi is helping to push forward developments with meticulous attention to detail. Together with Volkswagen Group Research, the brand with the four rings is also getting involved in long-term projects that are investigating innovative cell chemistry. At the special high-voltage competence center near Ingolstadt, the focus is on the development of complete systems: packaging, cooling, validation and, in partnership with body development, integration into the automobile. It is above all working on the battery system’s rigidity and its behavior in a crash situation – Audi is testing loads at up to 150 times the force of gravity.

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Design is opening up interesting fresh scope specifically for future electric cars. Audi gave a foretaste of this at the 2015 Frankfurt Motor Show. In the Audi e-tron quattro concept, the 95 kWh battery takes the form of a large, flat block beneath the passenger compartment, ideally positioned in terms of center of gravity between the axles. There is no longer a center tunnel in the body. This model points the way forward – as a precursor of the all-electric-drive sport SUV from Audi.

New lease of life for used batteries

Audi designs its batteries for high service lives of more than 150,000 kilometers *(93,205.7 miles)* and at least eight years in operation. Even then, these batteries still possess a large portion of their nominal capacity – too high for them to be recycled. Under a venture with the motto “From Road to Grid”, the Company is therefore currently working on a concept to convert old batteries into stationary energy stores.

A first test setup located near Ingolstadt recently started supplying the grid. A container for four traction batteries of various sizes works in tandem with a photovoltaic system that is capable of supplying up to 20 kW of power on sunny days. A second container houses the connection and control technology: Its power electronics convert the direct current from the batteries into alternating current at a standard voltage of 400 V. When the batteries have been run down to ten percent of their capacity, they are sent for recycling.

Audi’s innovative storage platforms are suitable as a power source for quick-charging stations with an output of more than 250 kW. Alternatively they can serve as buffers for renewables such as wind and solar power – whether as part of the grid or as home installations. Audi has already drawn up plans for larger systems with a capacity of around 500 kWh.

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The range of systems for electric driving

From the e-tron connect app to the future option of rapid charging, Audi offers its customers convenient ways of enjoying electric mobility. The brand with the four rings is successively expanding its range of e-tron systems.

One of the offerings already on the market is the Audi A3 e-tron connect app. Customers can use it on their smartphone or via the Audi web portal to call up data on the vehicle status – such as level of charge, electric range and location – along with statistical information on past trips.

With the “Audi connect security & convenience” package and the special Audi connect e-tron services, other important vehicle functions can be controlled remotely via the Audi MMI connect app. These include locking and unlocking, the optional auxiliary heating, and charging. On the Q7 e-tron 3.0 TDI quattro*, these services are integrated into the Audi MMI connect app.

German e-tron customers can choose renewable energy for the power supplied to the charging point in their garage at home. Audi offers this power in partnership with the energy provider Lichtblick. It comes one hundred percent from hydroelectric power stations in Germany, Austria and Switzerland. When charged with green power, the plug-in hybrid models then run with zero emissions when in electric mode. There are similar arrangements available through local partners in many export markets.

Audi offers an individual installation service if desired: An electrical engineer will inspect the domestic electrics, make any necessary modifications and fit an industrial power socket to enable the car to be charged at maximum power. The customer can also choose to have a charging dock fitted. This box, mounted on the wall, is a convenient way to store the charging plug. Fully charging both the A3 Sportback e-tron* and the Q7 e-tron 3.0 TDI quattro takes around two and a half hours. The 17.3 kWh battery of the SUV has twice the capacity of that of the premium compact model, but it also achieves double the charging power.

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Since January 2015, Audi and Volkswagen car customers have been able to fill up on power and fuel throughout Germany with the “Charge&Fuel Card”. This card gives access to over 10,800 gas stations and 1,200 public charging stations nationwide run by the charging pillar operators Ladenetz, RWE and EnBW – and the network is due to expand rapidly in 2016. The card is issued by Audi Financial Services and can be obtained from any e-tron Audi partner.

Drivers of business vehicles in particular will appreciate the convenience of a one-stop system for settling expenses and the attractive, clear tariffs. Until the end of 2015 customers can charge their car at no cost; thereafter, one kilowatt hour of energy will cost around 26.4 cents for the A3 Sportback e-tron* (95 cents per hour’s charging a battery with 3.6 kW capacity). There are no card fees.

Quick, convenient and clean charging will remain a key feature of the e-tron range of systems. Audi is making advances on all fronts: with plans for wireless AC inductive charging (Audi wireless charging, AWC), with AC charging at up to 22 kW and with rapid DC charging.

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Fast charging and Audi wireless charging

Progress in charging technology is crucial to the success of electromobility. Whether charging with direct or alternating current, the new solutions from Audi for all-electric cars and plug-in hybrids will be extremely convenient for customers. There will also be wireless options. Market launch is scheduled to begin in 2017.

Up to 150 kW of power – fast charging with direct current

Direct current charging with 150 kW of power is the next step. With this technology, a sporty SUV such as the Audi e-tron quattro concept would be able to charge its large 95 kWh battery to 80% capacity in less than half an hour, enough for a cruising range of around 400 kilometers *(248.5 mi)*. A full charge – enough for more than 500 kilometers *(310.7 mi)* – would take around 50 minutes.

Audi and other German manufacturers use the Combined Charging System (CCS). It enables electric cars to be charged with direct current (DC) and alternating current (AC) using the standard Combo 2 connector. The official charging solution of the European Union, which is based on the CCS standard, has already been ratified. To further promote these standards worldwide, Audi co-founded the Charging Interface Initiative (CharIN) with BMW, Daimler, Opel, Porsche and Volkswagen, connector manufacturers Mennekes and PhoenixContact, and the TÜV SÜD inspection authority in May 2015. In China and Japan, where other standards already exist (GB/T and CHAdeMO, respectively), country-specific requirements will be accommodated. Installation of CCS charging stations has already begun in Europe and the United States. The majority of stations currently available on the market support DC charging with 50 kW.

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With a high-performance fast-charging infrastructure along transport axes, all-electric cars would be suitable for universal use. Current efforts are geared toward ensuring the establishment and operation of a fast-charging infrastructure with at least 150 kW by the market launch of the first all-electric sport SUV from Audi. The Audi e-tron quattro concept introduced at the IAA in Frankfurt was equipped with the CCS charging interface. The new standard allows for charging with up to 350 kW.

Audi considers it very important to offer the customers of its all-electric models a very convenient and capable charging system. This also requires cooling of the charging connector while connected to the charging station. This is the only way to continuously transfer the full power without thermally overloading the pins. In real-world driving, DC fast charging represents significant value-added for customers, particularly for long trips.

Audi wireless charging – wireless charging with alternating current
DC fast charging is virtually impossible in the private infrastructure due to the limited grid power. AWC (Audi wireless charging) is an inductive AC charging technology Audi is developing as an alternative that also makes home charging extremely convenient. The company hopes to launch AWC in 2017.

With AWC, the energy is transferred via a floor charging plate connected to the electric grid. The plate has an integrated primary coil and an inverter (AC/AC converter). Connected to a 16 ampere, single-phase outlet, the first-generation system offers a charging power of 3.6 kW, with higher powers of up to 11 kW possible in the next version.

When the customer approaches to within a few meters of the charging plate with his Audi e-tron, the plate establishes radio contact with the car. The driver then sees the precise position of the floor plate on the display. Charging can begin immediately after proper positioning or according to a timer. With the piloted parking systems Audi is currently developing for production use, the car handles positioning itself. The driver can get out of the car and then initiate the parking procedure remotely via her smartphone.

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Prior to charging, an integrated electric motor in the floor plate raises the primary coil. This minimizes the distance between it and the secondary coil, which is integrated into the front section of the Audi e-tron floor pan, regardless of the specific vehicle. The floor plate's alternating electromagnetic field induces an alternating current in the car's secondary coil across the air gap. An AC/DC converter inverts the current, which is then fed into the high-voltage electrical system. There it charges the battery and powers additional consumers such as the heating or air conditioning as needed. The driver can interrupt the charging process at any time, and charging stops automatically when the battery is full.

Because the alternating field is only generated when a car is over the plate and the coil is active, there is no risk to people or animals. The small air gap prevents the magnetic field from interfering with electronic devices.

The first generation of the AWC technology is ideal for use in home garages or office building parking garages. A later version can be integrated in a modified form into the public infrastructure, such as into the asphalt of roads and parking lots.

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Fuel cell technology

Dramatic, highly efficient and clean: Audi is taking a unique approach typical of the brand when it comes to fuel cell technology. Here again the energy chain is based on sustainably generated electricity.

At its power-to-gas plant in Werlte, Lower Saxony, Audi uses electricity generated by wind power to break water down into oxygen and hydrogen by means of electrolysis. The pure hydrogen is all it takes to power cars like the Audi A7 Sportback h-tron quattro*.

The A7 Sportback h-tron quattro technology demonstrator clearly illustrates how dramatically Audi is bringing fuel cell technology to the road. It is the first fuel cell car with quattro drive – and thus with a decisive advantage over its two-wheel-drive competitors with respect to traction, stability and handling. Separate electric motors drive the front and rear axles, respectively. With a peak output of 170 kW and maximum torque of 540 Nm *(398.3 lb-ft)* of torque, the e-quattro drive provides for sporty performance with a top speed of 200 km/h *(124.3 mph)*.

The lithium-ion battery of the Audi A7 Sportback h-tron quattro also uses the energy recovered and stored during braking to provide extra boost when the driver firmly presses the pedal on the right. The battery has a capacity of 8.8 kWh and can be charged at a power outlet. The recirculation fan in the fuel cell also enhances the efficiency of the technology demonstrator by returning unconsumed hydrogen to the anode.

As part of its efforts to further develop fuel cell technology, Audi acquired a package of important patents from the Canadian company Ballard Power Systems Inc. in early 2015 that will form the basis for the development of the next generation of fuel cells. All brands in the Volkswagen Group will benefit from this know-how, and the Group will continue to collaborate with Ballard.

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Audi is also working with Volkswagen and other partners on the future of the fuel cell as part of the HyMotion 5 project. The focus here is on new materials for the bipolar plates separating the individual cells in the stack. These will make the fuel cell significantly lighter, smaller, more robust and more powerful. Additional strengths are easy cold starting, long service life, spontaneous response and low hydrogen consumption. The price should also drop because the proportion of costly components such as platinum in the fuel cell will decrease.

Audi has been working on fuel cell concepts for more than ten years now.
The first technology demonstrator was the compact A2H2 in 2004, which was already equipped with a polymer electrolyte membrane fuel cell (PEM) – the ideal in this technology. It had a 110 kW electric motor, and a nickel-metal hydride battery served as a buffer. The Audi Q5 HFC (Hybrid Fuel Cell) followed in 2009. Its PEM fuel cell had an output of 90 kW and was supported by a compact lithium-ion battery.

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Audi e-fuels

Audi is designing the mobility of the future in which environmentally friendly produced electricity plays a key role. It not only powers the electric motors in the e-tron models, it is also the powerhouse behind certain Audi e-fuels: climate-friendly alternative fuels for combustion engines. Audi produces fuels that do not depend on petroleum, that bind as much CO_2 during their production as they emit during combustion. They are known as Audi e-gas, Audi e-diesel, Audi e-gasoline and Audi e-ethanol. With Audi e-gas, Audi already offers A3 g-tron* customers climate-neutral mobility.

In 2013, the Audi e-gas plant in Werlte (Emsland) came on stream. With help from wind power, the Audi e-gas, a synthetic methane, is produced from water and carbon dioxide. The process is performed in two major process steps: electrolysis and methanation. In the first step, the plant uses renewably generated electricity to split water into hydrogen and oxygen. Over the medium term, the hydrogen can also be used to power fuel-cell vehicles such as the Audi A7 Sportback h-tron quattro*.

The absence of any universal hydrogen infrastructure at present means the focus at the moment is on the second process step: the hydrogen is then reacted with CO_2, which comes from a nearby waste biogas plant, to produce synthetic methane, or Audi e-gas. Chemically, it is nearly identical to fossil-based natural gas, so it can be distributed throughout Germany over the natural gas grid to CNG filling stations and be used in Audi g-tron models.

New e-gas model: the Audi A4 Avant g-tron

Every year the Audi e-gas plant produces up to 1,000 tons of e-gas, binding up to 2,800 tons of CO_2 in the process. This quantity enables 1,500 Audi g-tron models to drive 15,000 kilometers *(9,320.6 mi)* each a year with no carbon footprint. The company offers the Audi e-gas fuel card which can be used as a means of payment. This fuel card is also used as an accounting tool – Audi pumps the amount of gas refueled by customers as e-gas back into the natural gas grid.

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The Audi A3 Sportback g-tron, which went on sale in early 2014, will be joined by the new A4 Avant g-tron* at the end of 2016. The usage of e-gas is also ongoing in other markets.

The Audi e-gas plant in Werlte demonstrates just how well the power-to-gas concept – the conversion of electricity into fuel – works. It now already has several imitators in the German power industry, with other major players running their own power-to-gas plants. These allow the increasingly frequent surpluses of renewable energy to be stored, thus making a valuable contribution to the energy transition.

At the same time, the Audi e-gas plant helps stabilize the public power grid in northern Germany, which is supplied with large amounts of wind energy. As a series of tests conducted by electricity grid operator TenneT TSO GmbH showed, it is able to react very quickly and reliably and iron out fluctuations in the power grid. As a result, it has been qualified to take part in the secondary balancing energy market, which the grid operators run to stabilize the power grid.

Audi is convinced of the potential of the power-to-gas principle and is cooperating with other partners from the energy sector to cover the increasing demand for fuel. One of these cooperation partners is the Thüga group, a network of municipal power utilities. It also runs a power-to-gas plant in Frankfurt am Main, which is testing, among other things, the addition of hydrogen to the natural gas grid.

e-gas by biological means: Audi partner Viessmann

Viessmann GmbH is another Audi partner. The heating specialist from Allendorf in the state of Hesse provides its expertise from the electricity and gas sector and is operating the first power-to-gas plant involving biological methanation in Germany. Another example is the cleantech company Electrochea in Copenhagen, which aims to bring biological methanation into the megawatt class. The conversion of hydrogen into methane takes place in both instances not as in Werlte by means of a thermochemical, catalytic process, but in a biological process: special microorganisms are fed by the hydrogen and CO_2, producing the Audi e-gas in the process.

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Power-to-liquid: Audi e-diesel

A production plant for Audi e-diesel started pilot operation in Dresden-Reick at the end of 2014. Here too, the Audi e-fuels formula applies: fuel production binds exactly the same amount of CO_2 that is emitted again when running the car. The local energy technology company sunfire is Audi's project partner here. The plant works in accordance with the power-to-liquid principle (PtL) and utilizes green electricity as the primary energy. The raw materials are water and carbon dioxide, which a biogas plant provides. Part of the CO_2 will be extracted in future from the ambient air by means of direct-air-capturing – a technology of Audi's Zurich-based partner Climeworks.

The efficiency of the overall process at around 70 percent is very high compared with other processes for manufacturing synthetic liquid fuels. In the first step, water heated up to form steam is broken down into hydrogen and oxygen by means of high-temperature electrolysis. In two further steps, the hydrogen reacts with the CO_2 in synthesis reactors – again under pressure and at high temperature. The result is known as blue crude, which – similar to crude oil – can be refined to create the end product Aud e-diesel. The synthetic fuel is free from sulfur and aromatics; its high cetane number makes it readily ignitable.

Highly pure designer fuel: Audi e-gasoline

Audi is currently developing Audi e-gasoline, another CO_2-neutral future fuel based on renewable raw materials. Global Bioenergies S.A. operates a pilot plant near Reims (France) to produce isobutene. The Fraunhofer Center for Chemical-Biotechnological Processes (CPB) in Leuna (Saxony-Anhalt) converts the gaseous isobutene using hydrogen into liquid iso-octane, a high quality designer fuel. It contains no sulfur or benzene, and, as such, it burns very cleanly.

Global Bioenergies has built a demonstration plant in Leuna that will begin producing larger quantities of iso-octane in 2016. Over the medium term, the project partners aim to modify the process so that it requires no biomass, instead requiring just water, hydrogen from renewable sources, CO_2 and sunlight.

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High yield per square meter: Audi e-ethanol

Another project is underway in Hobbs (New Mexico, USA). Here Audi has been running with the U.S. biotechnology company Joule a research plant for producing high-purity e-ethanol and e-diesel since 2012. Special microorganisms use sunlight, carbon dioxide, and salt or brackish water to produce liquid fuels. The end product of this bio-technologically optimized photosynthesis process comes in the form of alkanes – important components of diesel fuel and ethanol. Even today the specific yields per area of the demonstration plant are eight times higher than with the production of bioethanol from corn, which is widespread in the United States, and still three times higher than with sugar-beet based bioethanol, which is mainly produced in Brazil. Further increases are expected.

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Great class, low emissions – the Audi Q7 e-tron 3.0 TDI quattro

With the Q7 e-tron quattro*, Audi presents the world's first plug-in hybrid model with a six-cylinder TDI engine and quattro drive. The SUV sets standards thanks to 275 kW (373 hp) of system power and 700 Nm *(516.3 lb-ft)* of system torque: It sprints from 0 to 100 km/h *(62.1 mph)* in 6.2 seconds and consumes not more than a best-in-segment 1.8 liters of fuel per 100 kilometers *(130.7 US mpg)* in the New European Driving Cycle (NEDC).

The 3.0 TDI, a highly efficient, latest-generation V6 diesel engine, delivers 190 kW (258 hp) of power and 600 Nm *(442.5 b-ft)* of torque.

The electric motor produces 94 kW of power and 350 Nm *(258.1 lb-ft)* of torque. Together with a decoupler, it is integrated into the eight-speed tiptronic. The automatic transmission boasts high efficiency and low weight. During fast cornering, the quattro permanent all-wheel drive works closely with the wheel-selective torque control, an intelligent software feature. This brakes the inside wheels ever so slightly, thus further enhancing the car's agility and stability.

56 kilometer *(34.8 mi)* electric range: best value in the segment
The lithium-ion battery comprises 168 prismatic cells and is liquid-cooled. With a capacity of 17.3 kWh, it allows a 56 kilometer *(34.8 mi)* range in electric mode in the NEDC – like the fuel consumption another record in the segment. The total range with the TDI engine is 1,320 kilometers *(820.2 mi)*.

The new multi-phase charging technology allows charging with 7.2 kW of power. A full charge on an industrial outlet thus takes less than two-and-half hours. Audi also offers a package of special e-tron services, from switching to green electricity (Audi Energy) to the "Audi Charge&Fuel Card". With the e-tron services in the Audi connect portfolio, drivers can use their smartphones to control such functions as charging and heating or cooling.

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Maximum efficiency: hybrid management

The hybrid management system controls the operating states of the Audi Q7 e-tron quattro intelligently, flexibly and with high efficiency. The driver can choose between three modes. “EV” mode prioritizes electric driving, while in “hybrid” mode the decision regarding the drive type is left largely to the hybrid management system. In “battery hold” mode it saves the available electric energy for a later time.

Depending on the driving situation, the SUV can boost, coast and recuperate. During everyday driving, most braking operations use the electric motor, which then works as a generator. The Audi Q7 e-tron quattro normally starts off purely on electric power. When switching into hybrid mode and for boosting, the driver has to depress the active accelerator (another Audi innovation) beyond a certain point of resistance. The position of this pressure point varies depending on the charge state.

According to the standard applicable for plug-in hybrids, the Audi Q7 e-tron quattro consumes just 1.8 liters of fuel *(130.7 US mpg)* in the NEDC, corresponding to 48 grams CO_2 per km *(77.2 g/mi)*. The combined system outputs 275 kW (373 hp) and delivers 700 Nm *(516.3 lb-ft)* of torque. The SUV thus accelerates from 0 to 100 km/h *(62.1 mph)* in 6.2 seconds and reaches a top speed of 230 km/h *(142.9 mph)*.

Global first: the heat pump

One important efficiency component is the specially developed thermal management system with a heat pump. This makes it possible for the waste heat from the electrical drive components to be made available to the interior of the Q7 e-tron quattro. It heats and cools the interior quickly and effectively. At the same time, the fact that it uses so little energy significantly increases the electric range compared with a conventional electric heating system. Audi is the first manufacturer worldwide to use this technology in a production plug-in hybrid and is consequently setting new standards in the areas of interior comfort and climate control efficiency.

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In the Audi Q7 e-tron quattro, the likewise standard MMI navigation plus works closely with the hybrid management system. This makes it possible to use navigation data and real-time traffic information to compute an ideal driving strategy at the start of the trip – even for longer distances.

Underway, the predictive efficiency assistant provides precise near-field information to help the driver save fuel. Using navigation and camera data as well as the information from the radar sensors of the optional adaptive cruise control (ACC), it generates a detailed image of the route up to three kilometers *(1.9 mi)* ahead. On approaching speed limit signs, town signs, bends, traffic circles and intersections, the system visually signals the driver well in advance to release the accelerator pedal. At the same time, the active accelerator pulses once against the sole of his or her foot.

Extremely versatile: chassis

As an all-rounder for leisure, family, sports and business, the Audi Q7 e-tron quattro also effortlessly masters easy terrain. Hill descent control and an off-road mode for the electronic stabilization control ESC are standard. A tilt angle display is standard with the optional air springs.

The Audi Q7 e-tron quattro combines comfort with great sporting talent. The electromechanical power steering is sensitive and conserves energy. The five-link suspensions front and rear are very light and contribute greatly to the outstanding handling characteristics. The low center of gravity and relatively low curb weight also play major roles here. This is due largely to the body with its numerous components of hot-shaped steel and aluminum.

Even the base version of the spacious plug-in hybrid SUV is impressively comfortable. Audi offers an adaptive air suspension with controlled damping as an option. The driver can adjust its characteristic via the standard Audi drive select dynamic handling system. It offers up to seven modes and incorporates such things as the engine management system, engine sound, automatic transmission, steering assistance, cruise control, adaptive cruise control (ACC), Matrix LED headlights and ambient lighting.

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Making their world premiere in a diesel engine are the active engine mounts in the Audi Q7 e-tron 3.0 TDI quattro. Utilizing electromagnetic oscillation coil actuators to induce phase-offset counter oscillations, they largely eliminate vibrations. The engine mounts are always active when the combustion engine is running.

Specific details: design

5.05 meters *(16.6 ft)* in length, the Q7 e-tron quattro combines a powerful, masculine design with elegant understatement. The striking emphasis of the wheels and the edges over the wheels – the “quattro blisters” – clearly illustrate the Audi genes. The tailgate wraps around the steeply raked D-pillars – typical of the brand’s Q models. Hybrid models feature a special design for the sculpted Singleframe grille, the air inlets and the 19- and 20-inch wheels. Customers can also order illuminated door sill trims with the e-tron logo.

Elegance and quality: interior

The Audi Q7 e-tron quattro offers the most spacious interior in its segment. The rear seats have adjustable backrests and can be moved fore/aft as desired. The lithium-ion battery takes up little space. Luggage compartment capacity is 650 liters *(23.0 cu ft)* and can be expanded to a maximum of 1,835 liters *(64.8 cu ft)*. A power tailgate is standard; gesture control is available as an option.

Interior design elements such as the wrap-around – the long arc around the driver and front passenger – the trim strips and the row of air vents emphasize the generous width. The two-part trim areas allow many individual combinations; the range of upholstery corresponds to the luxury class. The workmanship is of the accustomed high standard.

Tailored: controls & displays

The Audi virtual cockpit is standard in the Q7 e-tron quattro. The all-digital instrument cluster with its 12.3-inch display presents all key information in top-quality graphics. The driver can call up various levels of information: The Audi virtual cockpit shows the power meter, energy flow, range and battery charge state.

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Audi has expanded the infotainment to include essential e-tron displays. For example, fuel economy statistics and a graphic display of the electric range is shown on the navigation map. The driver can program times for charging as well as preheating or cooling and adapt them to his or her requirements, such as departure time, so as to save resources and costs.

This is made possible by the second-generation modular infotainment platform, which uses the high computing power of the Tegra 30 chip from Audi's partner Nvidia. This chip makes the standard MMI navigation plus extremely powerful. Operation is by voice, with the multifunction steering wheel or with the brand new MMI all-in-touch, the touchpad with haptic feedback.

Audi connect, which is also standard, connects the Q7 e-tron quattro to the internet via the fast LTE standard. With the Audi MMI connect app, the smartphone can be used to remotely control charging and interior heating or cooling, call up the battery status and display data about past trips. Passengers can surf the web and send emails with their mobile devices via the Wi-Fi hotspot. Also indicative of the brand's power to innovate are the supplemental components: the Audi tablet for the Rear Seat Entertainment, the sound systems from Bang & Olufsen or Bose with 3D sound and the Audi phone box, which easily connects the cell phone with the car and charges it inductively.

Comfort and safety: driver assistance systems

The Audi Q7 e-tron quattro also sets standards in assistance systems. Besides the predictive efficiency assistant, other useful systems for everyday driving include the collision avoidance assist, turn assist, cross traffic assist rear and trailer maneuver assist. The adaptive cruise control including traffic jam assist takes over the braking, acceleration and steering from the driver on well-paved roads at speeds of up to 65 km/h *(40.4 mph)* as long as traffic is slow-moving.

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Power from gas:
The new Audi A4 Avant g-tron

Sporty, versatile and completely CO_2-neutral, if desired: Scheduled to launch in late 2016, the A4 Avant g-tron* is yet another offer from Audi for the sustainable mobility of the future. It follows the A3 Sportback g-tron* as the brand's second model to use natural gas or climate-friendly Audi e-gas.

The A4 Avant g-tron is simultaneously sporty, efficient and extremely economical. The engine is based on the new 2.0 TFSI featuring an advanced, highly efficient combustion process developed by Audi. The turbocharged power plant produces 125 kW (170 hp). Maximum torque of 270 Nm *(199.1 lb-ft)* is available at approx. 1,650 rpm. The pistons and valves have been specially modified for gas operation and allow for an optimal compression ratio. An electronic controller reduces the high pressure of the gas flowing from the tank from as much as 200 bar to a working pressure of 5 to 10 bar in the engine. This pressure control function is performed dynamically and precisely in response to the power requested by the driver. The correct pressure is always present in the gas line and at the injector valves – low pressure for efficient driving in the lower speed range, and higher pressure for more power and torque.

In the NEDC, the Audi A4 Avant g-tron consumes less than four kilograms CNG (compressed natural gas) per 100 kilometers *(8.8 lb)*, corresponding to customer fuel costs of roughly four euros (as of: October 2015). CO_2 emissions are less than 100 grams per km *(160.9 g/mile)*. The tank capacity of 19 kilograms *(41.9 lb)* of gas allows for a range of over 500 kilometers *(310.7 mi)*. When the amount of gas remaining drops below approx. 0.6 kilograms *(1.3 lb)* – analogous to a residual pressure of 10 bar – the control unit switches to gasoline operation. The bi-fuel A4 Avant g-tron can cover an additional 450 kilometers *(279.6 mi)* in this mode. The potential overall range is comparable to that of a car with a TDI engine.

The filler necks for gas and gasoline are located under a common tank flap. After refueling, and whenever it is very cold, the engine is started with gasoline initially, then switched over to natural gas operation as quickly as possible. Two displays in the instrument cluster keep the driver up-to-date on the fill levels of the tanks.

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The driver information system shows the fuel consumption in the active operating mode.

Audi installs the four cylindrical CNG tanks as a compact module in the rear end of the Avant. They are optimized for the available space, and each is specifically sized. Sheet steel shells with tensioning straps hold the cylinders and protect them against damage, such as curbs. The complete CNG tank module, which also includes the 25 liter *(6.6 US gal)* gasoline tank, is fitted to the body during production of the A4 Avant. The spare wheel well in the body is eliminated. The battery also moves from the luggage compartment to the engine compartment. The loading floor is even with the loading lip, thus offering a full-fledged luggage compartment.

The CNG tanks with an operating pressure of 200 bar at 15 degrees Celsius follow the Audi lightweight construction philosophy. Thanks to their innovative layout, they weigh 56 percent less than comparable steel cylinders. Their inner layer is a gas-tight matrix of polyamide. The second layer, a composite winding of carbon fiber-reinforced polymer (CFRP) and glass fiber-reinforced polymer (GFRP), provides for maximum strength. The third layer is pure GFRP and serves primarily as a visual inspection aid, turning milky white where damaged. Before being installed in a car, each tank is tested at 300 bar during production. The actual bursting pressure is much higher still and far exceeds the legal requirements.

With Audi e-gas, the A4 Avant g-tron is CO_2-neutral in operation. e-gas is a synthetic methane produced from water and CO_2 with the help of green electricity in multiple power-to-gas plants. Audi operates the world’s first industrial-scale power-to-gas plant in Werlte, but now also procures e-gas from other facilities. With power-to-gas technology, the brand with the four rings is making it possible to store excess renewable energy – a valuable contribution to the energy transition. The company and its partners are intensively driving the development of various synthetic fuels known as Audi e-fuels, including by means of new biological production processes.

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The driver can buy fuel using the Audi e-gas refueling card familiar from the Audi A3 Sportback g-tron, which serves as both a payment and balancing instrument. Based on the information transferred during payment, Audi feeds e-gas corresponding to the amount of gas purchased by the customer back into the natural gas network. In this way Audi achieves completely CO_2-neutral mobility.

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The Audi A7 Sportback h-tron quattro

It sprints from 0 to 100 km/h *(62.1 mph)* in 7.9 seconds and reaches a top speed of 200 km/h *(124.3 mph)*. It can cover more than 500 kilometers *(310.7 mi)* on a single tank, with nothing more than a few drops of water leaving the tailpipe. The A7 Sportback h-tron quattro* uses a 170 kW electric drive system with a fuel cell as the energy source. Each of the two electric motors drive the wheels of one axle. The Audi technical concept car is a true quattro and thus unique among fuel cell automobiles.

The Audi A7 Sportback h-tron quattro joins the Audi e-tron and g-tron lineup of alternative-drive models and features another technology of the future: The “h” in its name denotes the chemical element hydrogen.

Like the engine of a conventional A7 Sportback, the fuel cell of the Audi technical concept car is mounted in the front. It comprises over 300 individual cells that together form a stack. The core of each of these individual cells is a polymer membrane. There is a platinum-based catalyst on both sides of the membrane. Hydrogen is supplied to the anode, where it is broken down into protons and electrons. The protons migrate through the membrane to the cathode, where they react with oxygen present in air to form water vapor. Meanwhile, outside the stack the electrons supply the electrical power – depending on load point, the individual cell voltage is roughly 0.6 to 0.8 volts.

The fuel cell operates in the high-voltage range. The most important auxiliaries include a coolant pump and the recirculation fan – a turbo compressor that forces air into the cells, returning unconsumed hydrogen back to the anode and thus increasing efficiency. These components have a high-voltage electric drive and are powered by the fuel cell. Because the exhaust system transports only water, it can be made of lightweight polymer.

There is a separate cooling circuit for cooling the fuel cell. The unit, which operates at a temperature of approximately 80 degrees Celsius, places higher demands on the vehicle cooling than an equivalent combustion engine, but achieves superior efficiency of as high as 60 percent – nearly double that of a typical combustion engine.

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Cold starting is possible at temperatures down to -28 degrees Celsius. A heat exchanger and a thermoelectric, self-regulating auxiliary heating element maintain pleasant temperatures in the cabin.

Battery under the luggage compartment: the plug-in hybrid concept
A special feature of the A7 Sportback h-tron quattro is its plug-in hybrid concept – this represents a logical evolution from the Audi A2H2 and Q5 HFC test cars. The technology demonstrator is equipped with an 8.8 kWh lithium-ion battery taken from the Audi A3 Sportback e-tron*. It is located beneath the luggage compartment and has a separate cooling circuit for thermal management.

The high-performance battery makes the ideal partner to the fuel cell. It can store energy recovered from brake applications and supply considerable power for full-load boosting. On battery power, the Audi A7 Sportback h-tron quattro covers as much as 50 kilometers *(31.1 mi)*. Depending on voltage and amperage, a full charge takes between two and four hours.

The battery operates at a different voltage level than the fuel cell. For that reason, there is a DC converter (DC/DC) between the two components. This tri-port converter is located behind the stack. The power electronics in the front and rear of the vehicle convert the direct current from the fuel cell and battery into alternating current for the two electric motors.

Fascinatingly innovative: quattro drive with no mechanical parts
The Audi A7 Sportback h-tron quattro is the first fuel cell car with quattro drive – more specifically with an e-quattro drive – that has no mechanical connecting parts. The front electric motor drives the front wheels; the unit in the back the rear wheels. Torque at both axles can be electronically controlled in the event of slip and steplessly varied. The e-quattro concept requires precise coordination of the electric motors – the technology demonstrator offers the sporty, stable and high-traction drive of a production car with mechanical quattro drive.

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The electric motors, which together with the voltage converters are cooled by a low-temperature circuit, are permanently excited synchronous machines. Each of them has an output of 85 kW, or 114 kW if the voltage is temporarily raised. Maximum torque for each is 270 Nm *(199.1 lb-ft)*. The electric motors' housings incorporate planetary gear trains with a single transmission ratio of 7.6:1.
A mechanical parking lock and a differential function round off the system.

Driving in the Audi A7 Sportback h-tron quattro offers the full performance of electric drive in conjunction with the advantages of the new e-quattro. The silent thrust is available in full from the start. At full load, the fuel cell reaches maximum output within one second, more dynamically than a combustion engine because the entire drivetrain includes just a few mechanical parts.

With 540 Nm *(398.3 lb-ft)* of propulsive power at its disposal and tipping the scales at only around 1,950 kilograms *(4299.0 lb)*, the Audi A7 Sportbac h-tron quattro races from a standstill to 100 km/h *(62.1 mph)* in 7.9 seconds. Its top speed is 200 km/h *(124.3 mph)* – a top figure for its field of competitors. When the driver presses the EV button, the technology demonstrator drives solely on battery power. Switching from automatic transmission mode D to S increases the level of energy recovery when braking, so that the battery is charged up effectively during sporty driving. Braking is also generally all-electric. The four disk brakes only become involved if more forceful or emergency braking is required.

Range of over 500 km *(310.7 mi)*: the hydrogen tanks
The four hydrogen tanks of the Audi A7 Sportback h-tron quattro are located beneath the base of the trunk, in front of the rear axle, in the center tunnel. An outer skin made from carbon fiber reinforced polymer (CFRP) encases the inner aluminum shell. The tanks can store around five kilograms *(11.0 lb)* of hydrogen at a pressure of 700 bar – enough to drive over 500 kilometers *(310.7 mi)*. According to the NEDC, fuel consumption is roughly one kilogram *(2.2 lb)* of hydrogen per 100 kilometers *(62.1 mi)* – an amount with an energy content equivalent to 3.7 liters *(1.0 US gal)* of gasoline.

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The tank flap is in the right side section of the five-door coupe, concealing a filler connector for the hydrogen. Fully refueling with H_2 takes around three minutes, roughly the same as with a conventional automobile. The tanks communicate with the refueling system via an infrared interface, indicating the pressure and temperature levels in each tank for optimal refueling.

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The Audi e-tron quattro concept

Aerodynamically-optimized design with a drag coefficient of 0.25, a purely electric e-tron quattro drivetrain with up to 370 kW of power output – the Audi e-tron quattro concept is an all-electric, full-size class sport SUV. The technology study provides a firm glimpse at the production model to follow in 2018. And it is a statement about the future of electric mobility: It is sporty, efficient and suitable for everyday use.

Pure performance: Three electric motors
The Audi e-tron quattro concept uses the power of three electric motors: One electric motor drives the front axle, the two others act on the rear axle. Together they produce 320 kW. During boosting, the driver can even draw temporarily on 370 kW and more than 800 Nm *(590.0 lb-ft)* of torque. The concept study offers sports car-like performance. When the driver floors the right pedal, the Audi e-tron quattro concept sprints from a standstill to 100 km/h *(62.1 mph)* in 4.6 seconds and quickly reaches the electronically governed top speed of 210 km/h *(130.5 mph)*.

The concept with three electric motors which Audi is presenting for the first time makes the technology study an e-tron quattro. An intelligent drive management system controls the interplay between them as appropriate for the situation, while also maximizing efficiency. The driver decides on the degree of recuperation, the driving program S or D and the mode of the Audi drive select system. During sporty driving on a winding road, the Torque Control Manager actively distributes the power between the rear wheels as necessary. This torque vectoring provides for maximum dynamics and stability.

The large lithium-ion battery is integrated into the floor of the passenger compartment. It gives the Audi e-tron quattro concept a balanced axle load distribution and a low center of gravity – prerequisites for dynamic handling. The battery's capacity of 95 kWh enables a range of more than 500 kilometers *(310.7 mi)*.

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The Combined Charging System (CCS) enables charging with DC or AC electrical current. A full charge with DC electrical current at a charging column with an output of 150 kW takes just around 50 minutes. The study is also designed for use with Audi Wireless Charging (AWC) technology for contactless inductive charging. The charging process is very convenient. The Audi e-tron quattro concept uses a system for piloted parking that guides it to the proper position on the charging plate. When the sun is shining, a large solar roof provides electricity for the drive system battery.

The chassis also expresses the high-tech character of the concept study. The adaptive air suspension sport, which features controlled damping, lowers the body at higher speeds and thus reduces drag. The dynamic-all-wheel steering combines a dynamic steering system on the front axle with a steering system for the rear wheels.

Aerodynamic: the exterior design

The Audi e-tron quattro concept harmoniously combines the design with aerodynamics and the all-electric drivetrain. The five-door technology study is 4.88 meters *(16.0 ft)* long, 1.93 meters *(6.3 ft)* wide and just 1.54 meters *(5.1 ft)* high. Its coupe-like silhouette with the extremely flat greenhouse that tapers strongly toward the rear lends it a very dynamic appearance. The drag coefficient of 0.25 is the new benchmark in the SUV segment, where figures well over 0.30 are typical.

At speeds from 80 km/h *(49.7 mi)*, electrically actuated aerodynamic elements on the engine hood, the flanks and at the rear end direct the flow of air as needed to improve the flow through and around the vehicle. The vertical separating edges on the side panels and the fully enclosed floor plan with its newly designed microstructures also help to reduce drag. Cameras replace the exterior mirrors. Wind noise is low on board the car, and there are no engine noises in an electric car in any case. The fascination of electric driving unfolds in the silence.

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All primary lighting functions at the front of the car use Matrix laser technology. The bottom section houses a new, distinctive lighting signature comprising five lighting elements. Each of these combines an LED luminary with an extremely flat OLED element (organic light-emitting diode). The rear lights also comprise two sections. Each of the top zones features nine red OLED units for the tail light function, with three more below.

Spacious and comfortable: the interior

The package of the Audi e-tron quattro concept enables a spacious, comfortable interior for four persons and 615 liters *(21.7 cu ft)* of luggage. The interior has a light and open feel to it; its architecture melds harmoniously with the operating and display concept. All displays in the interior use OLED technology. The extremely thin films can be cut to any desired shape.

The concept study is equipped with all the technologies that Audi has developed for piloted driving: radar sensors, a video camera, ultrasonic sensors and a laser scanner. The data these supply come together in the central driver assistance controller (zFAS) in the luggage compartment. It computes a complete model of the car's surroundings in real time and makes this information available to all assistance systems and the systems for piloted driving. These technologies are also nearly ready for use in Audi production vehicles.

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Audi TT clubsport turbo

Wide add-on parts, a powerful rear wing and a power output of 441 kW (600 hp) – the Audi TT clubsport turbo impresses with its power and its spectacular design. The technical concept car, which debuted at the Wörthersee Tour 2015, combines a powerful TFSI engine with an electric biturbo for the first time. This means that it leaves its competitors in the dust after only a few meters.

The Audi TT clubsport turbo was inspired by the successful Audi 90 IMSA GTO race car of the late 1980s and is powered by an enhanced-output 2.5 TFSI engine. From 2,480 cc of displacement, the five-cylinder engine produces 441 kW (600 hp) of power and 650 Nm *(479.4 lb-ft)* of torque, with more than 600 Nm *(442.5 lb-ft)* available from 3,000 to 7,000 rpm. This means that the sonorous TFSI produces 176 kW (240 hp) and 260 Nm *(191.8 lb-ft)* per liter of displacement. Its exhaust system is designed for minimal back-pressure; a side pipe to the ambient air is located immediately after the racing-type muffler.

The Audi TT clubsport turbo show car has an unladen weight of just 1,396 kg *(3,077.7 lb)*. It needs just 3.6 seconds for the standard sprint from 0 to 100 km/h *(62.1 mph)*, and its top speed is 310 km/h *(192.6 mph)*. The TT clubsport turbo flaunts its strength over the first few meters of a sprint. Its electrically driven compressor lets it cover up to six meters *(19.7 ft)* more within the first 2.5 seconds than a comparable car without this new technology.

In the lower engine speed range, the electrically driven compressor increases torque by up to 130 Nm *(95.9 lb-ft)*. It revs up to maximum rpm rapidly and without any perceptible delay, and it continues to boost charge pressure when too little drive energy is left in the exhaust gas for the conventional turbocharger. This allows the conventional turbocharger to be designed more for high charge pressures and thus high engine output. The 2.5 TFSI develops its immense power with no perceptible lag, so it is available at a tap of the accelerator in any situation.

*The fuel consumption and CO_2 emissions of all models named above and available on the German market can be found in the list in the last chapter of this basic information.

Energy storage: the 48-volt electrical system

A dedicated 48-volt electrical sub-system – another key future technology from Audi – supplies electrical energy to the electrically driven compressor. A compact lithium-ion battery in the luggage compartment stores the energy generated by recuperation when coasting. A DC/DC converter provides the connection to the 12-volt electrical system. Power transmission is via a manual six-speed gearbox and quattro permanent all-wheel drive, whose multiplate clutch is mounted on the rear axle for better weight distribution. A coilover suspension system enables highly precise adjustment of the body's ride height and the compression and rebound of the shock absorbers as needed. An electric lifting function protects the equipment from damage by street curbs. Electronic Stabilization Control (ESC) and wheel-selective torque control round out the dynamic qualities of the suspension.

The wheels are size 9.5 J x 20. Their six twin-spoke design is finished in a two-color look – both in gloss turned finish and matt black – and the tires are size 275/30. Carbon-fiber ceramic brake disks are mounted behind all four wheels; they are very lightweight and wear-resistant. The front brake disks measure 370 mm (*14.6 in*) in diameter.

Widened by 14 centimeters *(5.5 in)* Characteristic add-on parts

The compact sports car takes a full stance on the road with track widths of 1,736 mm *(5.70 ft)* in front and 1,729 mm *(5.67 ft)* at the rear. 4.33 meters *(14.2 ft)* in length, it is 1.97 meters *(6.5 ft)* wide, including the exterior mirrors. Its angular fenders contribute their own, built-up shape to the car body. They take the characteristic design motif of the Audi TT to an extreme and accentuate the quattro drive. The fenders are open at the front and rear. Air from the car's slipstream flows through them to cool the brakes. The Singleframe grille and the large air inlets are also optimized for maximum air flow.

The manually adjustable rear wing is an updated version of that from the Audi Sport TT Cup race car. The wing is now 20 cm *(7.9 in)* wider, and the side flaps, which feature the four rings, were given a new geometry.

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The wing consists of carbon-fiber-reinforced polymer (CFRP) as do all other add-on parts: the air inlets and the large splitter at the front, the side panels and side sill trims as well as the voluminous diffuser at the rear. An assembly of ultra-high-strength titanium tubes makes the rear zone of the interior even more rigid and safe. Driver and passenger sit on lightweight racing bucket seats with four-point belts. The display and operating concept with the digital Audi virtual cockpit focuses on the driver, who can control all key driving parameters by using the four satellite buttons on the multifunction steering wheel.

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The Audi RS 5 TDI competition concept

The Audi RS 5 TDI competition concept uses a technology similar to that in the Audi TT clubsport concept. An electrically driven compressor provides for powerful, spontaneous thrust even at low engine speeds. It works together with a 3.0 liter, biturbo V6 TDI producing 320 kW (435 hp) and 800 Nm *(590.0 lb-ft)* of torque.

At the Sachsenring track in summer 2015, the technology platform set a new best lap time for cars with a diesel engine. The Audi RS 5 TDI competition concept rounded the 3.6 km *(2.2 mi)* race course in a time of 1 minute 35.35 seconds. Danish driver Nicki Thiim shaved 1.87 seconds off the previous record for diesel cars. In spring 2015, *sport auto* magazine tested the technology platform on the Hockenheimring, posting the best lap time the magazine had ever recorded for a car with a diesel engine.

The RS 5 TDI competition concept is based on a technical concept car that Audi presented in summer 2014 on the 25th anniversary of the TDI engine. Following extensive further development, the sport TDI with 320 kW (435 hp) and 800 Nm *(590.0 lb-ft)* of torque sprints from zero to 100 km/h *(62.1 mph)* in 4.0 seconds and to 200 km/h *(124.3 mph)* in less than 16 seconds.

A key innovation is that in addition to two exhaust-gas turbochargers, an electrically driven compressor is also used. A small electric motor with seven kW of power drives a turbine to a speed of up to 72,000 revolutions per minute within 250 milliseconds for extremely fast buildup of charge pressure. Typical exhaust-gas turbochargers take two to three times as long to reach a comparable turbine speed. Thanks to its electrically driven compressor technology, high charge pressure is available quickly in the RS 5 TDI competition concept in any driving situation. This is essential for excellent sporty engine response.

The compressor is powered via a 48 volt electrical sub-system – a key component of the Audi electrification strategy. It enables the rapid transmission of larger amounts of electrical energy and is thus ideally suited for supplying power to the compressor.

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The Audi RS 5 TDI competition concept is 241 kg *(531.3 lb)* lighter than the model upon which it is based. Targeted lightweight design measures have reduced the car's weight: The engine hood consists of carbon-fiber-reinforced polymer (CFRP), the doors are made of aluminum and the exhaust system is largely made of titanium. Inside, it features CFRP racing bucket seats, and the rear bench seat has been eliminated as part of an interior concept that is based on lightweight design. Thin glass and polymer windows are used as well.

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The Audi R18 e-tron quattro

The Audi R18 e-tron quattro is testimony to just how dynamic electromobility is at Audi. The hybrid drive of the three-times 24 Hours of Le Mans winner is designed for motorsport conditions, the most grueling test environment for production development.

Motorsport is an integral part of the Audi DNA – for 35 years the brand with the four rings has been testing new technologies while competing on the track. The 24 Hours of Le Mans and the FIA World Endurance Championship WEC are decisive test environments. It is here that the sport's regulators specifically promote technical innovations.

That also applies to the TDI engine, still the most efficient and most environmentally friendly powerplant in Audi's view. For this reason Audi's involvement in prototype motor racing with TDI engines stretches back to the 2006 season. The pace of volume-production development has been accelerated on the back of the insights gained on the track. The engines also fulfill the EU's most stringent emissions requirements. With the Le Mans prototypes, Audi has managed in ten years to reduce the fuel consumption by 40 percent while maintaining similar power output figures.

The brand with the four rings is convinced of the additional potential inherent in the TDI engine. In line with this philosophy, the amount of energy available in the Audi R18 e-tron quattro will once again be reduced between 2015 and 2016. The WEC regulations have also been structured in such a way that hybrid systems play an ever-increasing role. Here too, racing helps accelerate the development of future volume-production technology.

Under these conditions, the Audi R18 e-tron quattro consistently plays to its strengths. Its concept separates the drives on each axle – the combustion engine permanently drives the rear wheels, while the electric motor temporarily powers the front wheels. The V6 TDI develops more than 410 kW (around 558 hp) from four liters of displacement, with torque of over 850 Nm *(626.9 lb-ft)*.

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A special layout permits short gas paths: the exhaust end is in the inner V of the cylinder banks, which has a 120 degree angle to keep the center of gravity low. The large turbocharger assists the instant torque buildup with its variable geometry.

A clutch with linings made out of carbon-fiber-reinforced polymer (CFRP) forwards the power from the diesel engine to a sequential, electrically operated seven-speed transmission. Like the engine, it is designed as a self-supporting unit, with its housing made of CFRP with titanium inserts. As such, the transmission along with the aluminum crankcase of the TDI contribute to the systematic lightweight construction concept. The torque is transferred to the rear wheels via a locking differential.

Compared to its predecessor, many components of the current Audi R18 e-tron quattro have been substantially fine-tuned, including the hybrid system. At the 24 Hours of Le Mans it managed to recover four instead of two megajoules per lap, i.e. twice the amount of energy. The energy recovered during braking is fed for a short period into a flywheel accumulator, which can store up to 700 kilojoules. The accumulator, which is located on the left next to the driver in the cockpit, combines high energy density with high charging output.

When accelerating out of the bend, the energy reaches a water-cooled electric motor with integrated power electronics. It drives the front wheels with more than 200 kW (272 hp) – for a few seconds the Audi racing car is turned into the e-quattro. The driver can adjust all the important parameters of the hybrid system via buttons on the steering wheel. A great many factors are at work here, such as the current race tactics and strategy, the condition of the brakes and tires, or the quality of road grip.

The one-piece monocoque of the sport prototype is made out of a CFRP matrix with an aluminum honeycomb core and features Cylon side panels to prevent intrusions. It fulfills all the relevant crash and safety standards and is extremely light – under the regulations, the minimum weight of the R18 e-tron quattro is just 870 kilograms *(1,918.0 lb)*.

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The aerodynamics of the 4.65-meter-long *(15.3 ft)* racing car combines maximum downforce with minimal drag. The headlights combine Matrix LED technology with the laser light from Audi. The airflow through the side cases, the arrangement of the radiators and the engine cover are also designed for maximum low-loss airflow through and around the vehicle.

The Audi R18 e-tron quattro features electric power steering. A double wishbone suspension guides the rear and front wheels. At the front axle, the springs and dampers are operated via compression struts, while tension struts provide the same function on the rear axle. Monoblock alloy brake calipers work together with the CFRP brake discs; the tire format is 31/71-18 all round.

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Fuel consumption of the models named above:

Audi A3 e-tron Sportback:
Combined fuel consumption in l/100 km: 1.7 – 1.5** *(138.4 – 156.8 US mpg)*;
Combined electric power consumption in kWh/100 km: 12.4 – 11.4**;
Combined CO_2 emissions in g/km: 39 – 35 *(62.8 – 56.3)*

Audi Q7 e-tron 3.0 TDI quattro:
Combined fuel consumption in l/100 km: 1.9 – 1.8** *(123.8 – 130.7 US mpg)*;
Combined electrical power consumption in kWh/100 km: 19.0 – 18.1**;
Combined CO_2 emissions in g/km: 50 – 48** *(80.5 – 77.2 g/mi)*

Audi A4 Avant g-tron:
This vehicle is not yet on sale. It does not yet have type approval and is therefore not subject to Directive 1999/94/EC.

Audi A3 Sportback g-tron:
CNG consumption in kg/100 km: 3.6 – 3.3 *(7.9 - 7.3 lb)***;
Combined fuel consumption in l/100 km: 5.5 – 5.1** *(42.8 – 46.1 US mpg)*;
Combined CO_2 emissions in g/km (CNG): 98 – 89** *(157.7 – 143.2 g/mi)*;
Combined CO_2 emissions in g/km: 128 – 117** *(206.0 – 188.3 g/mi)*

Audi R8 e-tron:
This vehicle is not yet on sale. It does not yet have type approval and is therefore not subject to Directive 1999/94/EC.

**Fuel consumption, CO_2 emission figures and efficiency classes given in ranges depend on the tire/wheel sets used.

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