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PRESS INFORMATION

Audi e-tron:
Charging concepts and battery technology

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

Simple – fast – safe:
Audi e-tron charging technologies

The Audi e-tron heralds the dawning of a new era for the brand with the four rings as it transforms from a classic carmaker to a systems supplier for mobility. Thanks to a comprehensive range of charging options with intelligent solutions for home and on the move, customers can enjoy fully electric driving without having to compromise. The large lithium-ion battery in the Audi e-tron provides for a range of more than 400 kilometers *(248.5 mi)* in the WLTP driving cycle. When charged at a fast charging station with up to 150 kW, the electric SUV is ready for the next long stage of its journey in approximately half an hour.

At home: AC charging

The Audi e-tron will typically be recharged most often at home. And each charging cycle costs the owner just a few seconds of time, i.e. the time required to connect and disconnect the charging cable. In most cases, the electric SUV is charged overnight and then sets off the next morning with a fully charged battery and a range of more than 400 kilometers *(248.5 mi)* according to the WLTP test cycle.

Audi offers various solutions for charging at home: The standard compact charging system enables charging with an output of up to 11 kW. The optional connect charging system doubles the output to 22 kW provided the Audi e-tron is equipped with a second charger. In combination with a home energy management system, it also enables intelligent charging functions.

Customers buying an Audi e-tron can check online which options are available in their garage using the e-tron Pre-Check online on the Audi homepage. This provides an initial assessment of whether the home's electrical system is suitable for the charging process and how it will influence the Audi e-tron charging process, particularly with respect to charging time. Home-Check provides customers with even more information. The local Audi dealer searches a vast network for a qualified electrician who will investigate the home charging options and even install the necessary technology, if desired. In Germany and a few other European countries, the home electrical system generally offers sufficient output for three-phase AC charging via a conventional industrial outlet with 400 volts and up to 11 or 22 kW.

Standard: the compact charging system
The Audi e-tron comes standard with the compact mobile charging system. It can be used directly with a standard outlet and does not require installation by an electrician. It includes two different power cables: one for a 230-volt household outlet with a charging output of up to 2.3 kW and one for a 400-volt three-phase outlet with up to 11 kW. With the latter, the battery of the Audi e-tron can be fully recharged in roughly 8.5 hours. The cable includes an integrated module with LED lights to indicate the charge status. The display module can be inserted easily into the optional charging clip, a wall-mounted holder provided by Audi for installation in the garage.

Intelligent option: the connect charging system
Audi will also offer the optional connect charging system. This enables charging with an output of up to 22 kW, so that a full charge takes roughly just 4.5 hours. The second on-board charger required for this will be available as an option at some point in 2019. The lockable charging clip is standard. To prevent unauthorized charging, the charging system can be locked with a PIN, a particularly sensible solution when used in a carport, for example.

With the connect charging system, the Audi e-tron can always be charged with the maximum output possible with the home electrical system and the car. The system also considers the power requirements of other consumers in the household and adjusts accordingly to prevent overloading the home electrical system and thus tripping the breaker. This presumes that the home is equipped with a home energy management system (HEMS), to which the charging system connects via the home's WiFi network. Audi is collaborating here with two partners, SMA Solar Technology and the Hager Group.

In combination with the connect charging system and an appropriately equipped HEMS, the Audi e-tron also takes advantage of variable electricity rates. It can charge the battery when electricity is less expensive while simultaneously considering the customer's mobility requirements, such as departure time and charge level. The connect charging system gets the necessary rate information either from the HEMS or from information the customer enters into the myAudi portal. If the home is equipped with a photovoltaic system, the customer can also optimize the charging process to prefer the electricity generated by the system for charging the Audi e-tron. The electric SUV does this by considering either forecast phases of sunshine or the current flow of electricity at the home's connection point to the public grid.

Furthermore, the connect charging system also enables customers to view their individual charging statistics and charging progress in the myAudi portal and in the myAudi app. Besides charging times and the amount of electricity charged, the system also provides detailed information about the corresponding costs. If supported in the HEMS, the customer can also see how much self-generated solar power is being used for the car. This data is stored on a secured server, and the portal offers both analysis and export functions. Communication with the charging system takes place via the home network and the customer's internet connection.

Remote control via app: charging and heating/cooling
The myAudi smartphone app provides for convenient operation from the couch. Customers can use the app to plan, control and monitor the charging and heating/cooling of the Audi e-tron as if they were actually in the car. They can set a departure time, for example, so that the Audi e-tron is charged and/or heated/cooled at the desired time. Customers can even choose to heat or cool certain zones in the car. On cold winter days, for example, they can turn on the seat heating or the heated steering wheel. The app also displays charging and driving data. Communication with the car is via the integrated LTE module, which is standard equipment in the Audi e-tron.

On the move: DC and AC charging

Drivers who charge their Audi e-tron overnight and set off the next morning with a full battery don't have to worry about stopping at a charging station during their normal daily drive. The range of more than 400 kilometers *(248.5 mi)* in the realistic WLTP cycle enables fully electric driving without compromise. On longer journeys the Audi e-tron can be charged with direct (DC) or alternating (AC) current. Smart solutions ensure that charging can be performed quickly and easily.

Fast charging with up to 150 kW: along the main European transport routes
For lengthy trips – driving to a vacation destination, for instance – fast-charging is essential. That's why the Volkswagen Group with Audi and Porsche, the BMW Group, Daimler AG and the Ford Motor Company have founded the joint venture Ionity. The Audi e-tron can charge with up to 150 kW at Ionity's high-output DC charging stations. It is then ready to set off on the next long stage of its journey after approximately 30 minutes. Plans call for 400 such high-power charging (HPC) stations at intervals of 120 kilometers (74.6 mi) along European highways and main transportation corridors by 2020.

The HPC network and all of the carmakers involved use the European charging standard Combined Charging System (CCS). It combines a seven-pole AC connection and a two-pole DC connection. The openness of the system and the Europe-wide availability will help to significantly improve acceptance of electric cars.

Charging with up to 22 kW: at public AC charging stations
In addition to charging with direct current at DC charging stations, the Audi e-tron can also be charged on the move with alternating current at AC chargers, with up to 11 kW standard and optionally with 22 kW. The latter is possible if the electric SUV is equipped with the optional second charger. The car is connected to the charging station using the standard mode 3 charging cable. Roughly 95 percent of all charging points in Europe currently conform to this standard.

Clever route planning: via app and in the car
Longer trips can be planned either in the myAudi app or directly in the car. In both cases the customer is shown the appropriate route with the required charging points in order to reach their destination. The navigation system considers not only the battery's charge but also the traffic situation and includes the required charging time in its arrival time calculation. The system includes the locations throughout Europe of DC charging stations, at which the Audi e-tron can be charged with direct current, as well as most AC stations for charging with alternating current. The route planning includes charging station information such as output and – provided the chargers are so configured – even whether they are currently occupied or out of service. While driving, detailed information about the remaining range is displayed in the Audi virtual cockpit and in the top MMI touch response display. Charging planning is continuously updated to the prevailing conditions. For example, an alternative suggestion is made if a targeted DC fast charging station can no longer be reached. Charge planning is mirrored seamlessly between the display in the car and in the myAudi smartphone app. During an active charge process, it displays the charging time remaining and the battery's current charge status. Customers can also opt to receive push notifications as soon as they can continue their journey.

Safe and convenient: the e-tron Charging Service and Plug & Charge
At market launch, Audi's new e-tron Charging Service will give e-tron customers access to around 80 percent of all public charging stations in Europe. Whether it's AC or DC, 11 kW or 150 kW – just one RFID card, the e-tron Charging Service Card, is all customers need to start the charging process. Data transfer is based on RFID (Radio Frequency Identification) radio technology. Many charging stations can also be activated by scanning a QR code with a smartphone. Customers have to register for the service in the myAudi portal and conclude an individual charging contract. There will be different rate plans for the various countries, taking into account customer needs such as energy and minute quotas.

Each charging process will be billed automatically and without any physical form of payment. Customers can use the myAudi portal to view their current charging history at any time, review their latest bills and manage their contract. Independent of this, customers can also use charging stations that are not included in the e-tron Charging Service portfolio. In these cases the customers settle directly with the respective provider.

From 2019 onward, charging will be even more convenient for Audi customers. This is when the function Plug & Charge will be introduced. It enables the Audi e-tron to authenticate itself at charging stations via state-of-the-art cryptographic procedures, after which it is authorized – a card will no longer be necessary. This requires a valid charging contract with the e-tron Charging Service. All Audi e-tron models rolling off the assembly line from mid-2019 will support this function as standard. Customers can also use Plug & Charge privately to unlock their connect charging system. This would then eliminate the need to enter a PIN to protect against unauthorized use.

In the spotlight: the charging process

Each Audi e-tron charging process begins with a little show: At the push of a button, the motorized charging flap in the driver-side fender opens toward the front to reveal the connector illuminated by a white LED. Next to it is a second LED that indicates the status. A pulsing green light, for example, means charging is active; a steady green light means charging is complete. When the plug is disconnected, the charging flap closes automatically within five seconds. Together with the optional second charger, Audi provides an additional connector on the passenger side used only for AC charging.

Green electricity: from production to the car

Production of the Audi e-tron at the Brussels plant will be CO_2-neutral. The Belgian inspection and certification organization Vinçotte certified the Audi Brussels location as such in early 2018. The plant has sourced green electricity since 2012 and has the largest photovoltaic system in the region. Over 3,000 MWh of energy per year are generated on a rooftop area of 37,000 m^2 *(398,264.7 sq ft)* – enough to fully charge some 33,000 Audi e-tron models. The company thus avoids CO_2 emissions totaling 17,000 metric tons. Audi Brussels also reduces emissions by sourcing biogas for the site's heat supply. The plant covers more than 95 percent of its energy requirement with renewable energies, which reduces CO_2 emissions by as much as 40,000 metric tons per year overall.

The Ionity network, which Audi is helping to build, will also operate its fast charging stations in Europe primarily with green electricity. In addition, Audi will provide market-based green electricity offers for charging at home in collaboration with local energy suppliers. Customers who have installed a photovoltaic system on the roof of their homes can – in combination with the connect charging system and a compatible home energy management system – charge their Audi e-tron preferentially with the self-generated solar electricity.

Powerful storage: the high-voltage lithium-ion battery

The lithium-ion battery in the floor of the Audi e-tron stores 95 kWh of energy and is designed for a long service life. In the realistic WLTP driving cycle, the electric SUV achieves a range of more than 400 kilometers *(248.5 mi)*. The battery's sophisticated thermal management is what allows the Audi e-tron to charge with an output of up to 150 kW at DC fast charging stations.

Key data: 95 kWh of energy, 36 modules, 432 lithium-ion cells

The battery of the Audi e-tron can store 95 kWh of energy at a nominal voltage of 396 volts. It comprises 36 cell modules in a square aluminum housing, each of which is roughly the size of a shoebox. Each module contains twelve pouch cells having a flexible outer skin of aluminum-coated polymer. They guarantee a long service life as well as high energy and power density. They can also reproducibly discharge and charge electricity over a broad temperature and charge status window. And they can be packed tightly so as to make the best possible use of the volume available in the high-voltage battery system. In the future, Audi will use both technically equivalent prismatic cells in its modular concept, also in terms of a multiple supplier strategy.

Compact block: the battery system and its management

The battery system forms a wide, flat block located in the ideal position from a center of gravity perspective beneath the occupant cell and between the axles. At 2.28 meters *(7.5 ft)* long, 1.63 meters *(5.3 ft)* wide and 34 centimeters *(13.4 in)* high, it roughly has the contours of a double bed. Above the rear section of the first level, known as the First Floor, is a second, smaller level with cell modules. This is located beneath the rear seat of the Audi e-tron. The total weight of the system including the housing pan with intricate crash structures is roughly 700 kilograms *(1543.2 lb)*.

The battery and all of its parameters, such as charge status, power output and thermal management, is managed by the external battery management controller (BMC). This is located in the occupant cell on the right A-pillar of the Audi e-tron. The BMC communicates with both the controllers of the electric motors and the cell module controllers (CMC), each of which monitors the currents, voltage and temperature of the modules.

The battery junction box (BJB), into which the high-voltage relays and fuses are integrated, is the electrical interface to the vehicle. Enclosed in a die-cast aluminum housing, it is located in the front section of the battery system. Data exchange between the CMCs, the BJB and the BMC is via a separate bus system.

The thermal management system of the Audi e-tron comprises four circuits that can be connected in various ways as required to heat and cool the interior and the electrical units. They can also work as a highly efficient heat pump. Beside the battery, they also connect the electric motors together with their rotors, the power electronics and the charger. Thanks to the intelligent thermal management, the battery is kept within its optimal efficiency range of 25 to 35 ° Celsius in all situations, from a cold start in winter to fast highway driving on hot summer days. This also contributes to the long service life.

The high-performance thermal management system offers Audi e-tron drivers numerous advantages. There is no decrease in performance even if they repeatedly request high loads. Drivers can also charge the battery at one of the new DC fast charging stations in the Ionity network with an output of up to 150 kW. The coolant dissipates the heat from electrical power loss. If the battery is still cold when charging in winter, it is heated with warm coolant.

To charge the high-voltage battery as quickly and gently as possible, the Audi e-tron communicates during the charging process with the Ionity charging station, whose cable is also cooled. If the battery is nearly empty upon arrival, it can be charged under optimal conditions to roughly 80 capacity in approximately 30 minutes with 150 kW. Once this mark is exceeded, the charging process slows to protect the lithium-ion battery and avoid shortening its service life.

Particularly efficient: the cooling system
The cooling system for the battery is attached to the outside of the housing beneath the cell chamber. It is made of flat, extruded aluminum sections divided into tiny chambers known as microports. A newly developed, thermally conductive adhesive joins the cooling unit to the battery housing. The contact between the cell modules and the housing is provided by the gap filler, a likewise thermally conductive gel injected into the space beneath each cell module. In what is a particularly efficient solution, the gel evenly transfers the waste heat produced by the cells to the coolant via the battery housing.

The developers also placed the utmost importance on safety when it came to the battery system housing. Its strong circumferential frame comprises extruded sections and cast nodes. A framework structure, which is likewise made up of extruded sections, divides the interior of the housing like a typecase so that each cell module is in its own compartment. A aluminum plate protects the battery against damage from below, such as stone chipping or curbs.

Reinforcement for the body: the battery housing
The aluminum battery housing in an Audi Space Frame design comprises 47 percent extruded aluminum sections, 36 percent aluminum panels and 17 percent diecast aluminum parts. 35 bolts connect it to the body for shear and torque rigidity. This increases the body's torsional rigidity by 27 percent and contributes to the high level of the safety of the Audi e-tron, as does the cooling system bonded to the outside of the battery housing.

The battery system is assembled at the Audi plant in Brussels. The company has developed numerous new fabrication technologies for this, from automatic placement of the cell modules in their receptacles to injection of the gap filler. The battery can be easily separated from the car for maintenance and repair work. The fuse box is connected using a direct plug connection, and the master controller is easily accessible.

Extensive expertise: battery development at Audi
Audi has extensive expertise in high-voltage battery technology. Numerous specialists at a dedicated competence center in Ingolstadt are working on the traction batteries. Whether designed for a plug-in hybrid model or a fully electric car, all batteries follow a standard module concept with respect to structure. This gives Audi maximum flexibility to respond swiftly to any developments in the marketplace.

At the battery technology center, the focus is on the development of the complete systems: their packaging, cooling, protection and integration into the car. Important topics here are the rigidity of the battery system, its behavior in the event of a crash and its electromagnetic compatibility (EMC). The center is therefore equipped with high-performance test benches and its own EMC test hall.

Charging technology glossary

Alternating current
Alternating current (AC) comes out of the conventional Schuko sockets in the home. They deliver a constant current of 10 amperes and 16 amperes for short durations. With a voltage of 230 volts, output is limited to 2.3 or 3.6 kW, respectively. In an AC line, the electrons continuously change direction with a frequency of 50 Hz, i.e. 50 times per second. This back and forth is called the phase. 230 volt alternating current is single phase.

Three phase power
Three-phase power is a three-phase alternating current whose phases are offset by 120 degrees. This enables a continuous flow of power and the development of strong rotating magnetic fields. Electrical utilities around the world operate their grids with three-phase power because it is easy to transform. In the home, larger consumers such as kitchen stoves are connected to the red, five-pole three-phase outlets with a voltage of 400 volts. The current is usually 16 or 32 amperes, and the corresponding output 11 or 22 kW, respectively.

Direct current
With direct current (DC), the electricity always flows from the positive pole to the negative pole without every changing polarity. Regular and rechargeable batteries like those in a cell phone provide direct current. Electronic devices such as televisions, which may be equipped with internal converters for different voltage levels, are operated with direct current. Direct current also enables the low-loss transmission of very high powers across long distances. The lithium-ion battery in the Audi e-tron also delivers direct current while discharging and requires the same when charging.

AC charging
Whether at home or at a charging station, output when charging an electric car with alternating current via the type 2 plug commonly found in Europe is generally limited to 22 kW or in some cases 43 kW. The AC charger in the car is therefore also a limiting factor. Its inverter, which converts the three-phase current into direct current for the battery, can only process a certain output, which is measured in kW. The higher this is, the more waste heat it produces, which reduces the efficiency. To keep such losses as low as possible, the three-phase charger in the Audi e-tron is integrated into the low-temperature cooling circuit.

DC charging

The AC charger in the car is irrelevant when charging with direct current. The electricity flows from the DC charger integrated into the pillar through the CCS (Combined Charging System) directly into the battery. This enables high powers, although heat is also produced here due to internal resistances in the battery. Audi cools the high-voltage battery during charging to achieve charging outputs of up to 150 kW at DC fast charging stations, such as those in the Ionity network. With all lithium-ion batteries, charging speed slows dramatically above a charge level of roughly 80 percent. Fast DC charging is also referred to as high-power charging (HPC).

Power electronics

The high-voltage battery delivers direct current; the electric motors use three-phase power, which is why every electric motor is connected to a power electronics module that converts the electricity. With a volume of 5.5 liters *(0.2 cu ft)* and weighing 8 kilograms *(17.6 lb)*, the power electronics modules of the Audi e-tron are very compact. Both include a process for controlling the electric motor and are integrated into the thermal management system for the electrical units. They are extremely dynamic, reading sensor data 10,000 times per second and outputting current values for the electric motors.

Asynchronous motor

A three-phase asynchronous motor comprises two major parts: the outer, fixed stator and the rotor contained therein. The stator is a laminated core into which coils of copper wire are inserted, usually in three windings to which the three phases of the three-phase current are connected. When a voltage is applied to them, a (rotating) magnetic field is produced. This field moves in a circle and induces another magnetic field in the bars of the rotor. The rotor moves with the field, but with a slight difference in speed, i.e. asynchronously. If the rotor turns more slowly than the rotating magnetic field, the electric motor in the car works as a traction motor. In the opposite case it becomes a generator and converts kinetic energy into electrical energy.

Heat pump

A heat pump can heat and cool very efficiently by absorbing heat from the environment. In the Audi e-tron, it uses the waste heat from the electrical components to transport as much as 3 kW of thermal energy. The heat pump is not a separate physical component, but rather the demand-driven connection of the coolant circuit and the low-temperature cooling circuit.