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August 2016

Connectivity TechDay

*The fuel consumption and emissions values of all models available on the German market and named in this text are listed on the last page of this document.

The future is connected – Audi is driving digitalization in the automobile

Intelligent networking is a key for the future of the automobile. Already a leader in this area, Audi continues to expand its lead – with the first car-to-x services from Audi connect, with new infotainment modules and the high-precision digital map from HERE for piloted driving. Audi customers will enjoy even more comfortable, safe and efficient mobility in the connected cars of tomorrow.

The term Audi connect covers all applications and developments that connect an Audi with its driver, the internet, the infrastructure and other automobiles. Audi is putting the pedal to the metal in this field of technology, completely integrating the car of tomorrow into the digital world of the customer. Audi launched its first digital information services, such as point-of-interest search or news, back in 2009. Numerous additional services have followed since then, including traffic information online and navigation with Google Earth and Google Street View. Remote functions used in combination with a smartphone or smartwatch have also been seamlessly integrated into the car for some time now. Audi developers are now working on the seamless connectivity between car and infrastructure as well as between the cars themselves.

Audi connect and swarm intelligence

The new Audi connect SIM makes online access child's play. It includes a flat-rate data plan for the Audi connect services and saves roaming charges when traveling in other European countries. The connect services emergency call and online roadside assistance cover key emergency and assistance functions. The Audi MMI connect app brings the customer's smartphone and the car even closer together with services such as online media streaming, calendar linking and the remote control of certain functions.

Now the company is launching the next stage of Audi connect. The first car-to-x services will be rolled out before the end of the year: traffic sign information and hazard information (for Europe) and traffic light information online (for the USA). The intelligent analysis of the data generated by the cars themselves gives rise step-by-step to a new form of swarm intelligence. With its help, Audi customers in the future will spend less time waiting at red lights, be warned in advance of hazards and experience safe piloted driving.

To be able to process this quickly expanding volume of data, Audi is investing in new hardware technologies, in particular with the Modular Infotainment Platform (MIB). The next version, MIB2+, supports the LTE Advanced wireless communication standard, and Audi is also exploring the LTE-V automotive standard. Cars can use this to interconnect directly and spontaneously.

Another important foundation for piloted driving besides a perfect online connection is the HERE HD Live Map. This map is generated by HERE, an independent company that has been acquired in equal parts by Audi, BMW and Daimler. The HERE HD Live Map is a high-precision digital map conceived as an independent, continuously extensible and updatable platform. Whether carmaker or supplier, municipal traffic manager or service provider: HERE is accessible to all.

Controls and displays

Audi is also setting new standards for controls and displays with solutions such as the Audi virtual cockpit, MMI touch/MMI all-in-touch and the natural speech voice control system. In the future, the latter will tap into the boundless knowledge of the cloud. The cockpit is also getting a complete overhaul with the Audi virtual dashboard. In addition to the Audi virtual cockpit, it includes two touch displays with haptic feedback that can assume a variety of functions.

The fully digital implementation of the Audi control concept creates the foundation for a system that adapts ideally to the use patterns of individual customers. With intelligent messages and personalized content, it becomes a personal assistant in the car.

Virtual reality

Audi is increasingly turning to high-tech simulation tools. With the Audi VR experience, customers can now virtually experience the car of their choice at the dealership. In three dimensions and from a 360-degree perspective. The new high-tech tool uses the original design data from Technical Development, where VR tools are also becoming increasingly important.

The Audi connect services

The term “Audi connect” refers to all applications and developments that connect Audi models to the driver, the internet, the infrastructure and other vehicles. A groundbreaking innovation in this field of technology is the new Audi connect SIM, which makes the use of connected functions even more convenient for the customer.

Audi connect is available for all Audi models and follows a uniform principle: The second generation of the Modular Infotainment Platform (MIB) – the technical basis for all infotainment features from Audi – includes an LTE/UTMS module. It establishes the connection to the internet with download speeds of up to 100 MBit/s. An integrated Wi-Fi hotspot enables passengers to surf, email and stream music and movies on their mobile devices. They also have access to a large number of customized Audi connect services.

One of these services is traffic information online, which provides real-time data about the current flow of traffic. If the selected route has good traffic flow, it appears in green in the display; if traffic is heavy or slow-moving it is shown in orange, and traffic jams are highlighted in red. In the latter case, the service indicates the delay due to the traffic jam and suggests the fastest alternate route. Traffic information online covers not only freeways, but also country roads and city streets. It covers most European countries.

The parking information service displays parking lots and parking garages at the current location, the destination or at any other location. Whenever possible, it also indicates the number of available spaces and parking fees. The address of the parking lot or garage can be used as the navigation destination, and its surroundings appear on the MMI monitor via Google Earth and Google Street View. The fuel prices service lists the gas stations with the lowest fuel prices and also considers the type of fuel required.

Flight, bus and train information from Audi connect can be used to check for departure times, train track and gate numbers and any delays. The user can also search for a specific flight number directly.

City events is a service that provides information on a multitude of events at the current location, a travel destination or a freely selectable location. Customers can filter according to various categories such as cultural or sporting events. Rounding out the range of Audi connect services in this area are news online, which can be adapted to personal interests, and travel and weather information.

Audi also integrates the Twitter online community service into Audi connect, preparing it in a vehicle-specific way. Along with the text-to-speech function, which is available in many other services as well, there is also a text function. This enables the driver to send out predefined text modules that can be combined with additional data such as the current position, if desired. In many Audi models, the driver can transfer emails from a smartphone to the car and have them read aloud or even dictate text messages (SMS) and send them out. A server in the cloud converts the sound file into a data packet.

Many Audi connect services and functions can be controlled via the natural speech voice control system, including the point-of-interest (POI) search. Here too, the system converts the voice command into a data packet and sends it to the Google search engine. POI send to car enables any destination to be selected in Google Maps or via the MMI connect app and forwarded to the car. Five free semi-annual updates of the navigation map are available for many Audi models equipped with MMI navigation plus.

In spring 2016, Audi rolled out another attractive innovation to Europe with the Audi connect SIM. This is what is known as an embedded SIM (e-SIM) that is permanently installed in the car. The Audi connect SIM is available for many Audi models that use the second-generation Modular Infotainment Platform (MIB2). These are currently the A3, A4, A5, Q2 and Q7 model series.

The new SIM card offers significant value, particularly to those customers who frequently travel to other European countries. In most countries, it autonomously accesses the respective provider, as needed. This eliminates annoying roaming fees and roaming confirmation procedures. With the Audi connect SIM, customers can use the Audi connect services with unlimited data from the date of purchase of their new car. For A3, A4, A5 and Q2 models equipped with MMI navigation plus, the service is free of charge for three years.

Customers can also purchase additional data packages for the Wi-Fi hotspot, independent of the integrated Audi connect services. If a customer selects a European package, the data transfer continues to function at the fixed price when crossing an international border, and thus when changing Internet provider. Data packages are available from the online shop of Audi's partner Cubic Telecom, a leading provider of global seamless connectivity solutions. Customers can reach the shop via their myAudi account. Once the appropriate packages have been enabled, they can be ordered directly from the car in the MMI system.

Customers may also continue to use their own SIM card in the car and establish Wi-Fi internet access through their own cellular provider. In this case, the Audi connect SIM is temporarily deactivated, and the data volume used for the Audi connect services is charged against the personal SIM card.

The Wi-Fi hotspot is a component of the optional navigation systems. It allows all passengers to surf the internet at attractive rates with up to eight mobile devices. The Wi-Fi hotspot also provides in-car access to the services Online Media Streaming, Web Radio, Aupeo! and Napster.

Audi connect safety & service

Audi is continuously expanding its online services. With Audi connect safety & service, customers can receive assistance in numerous situations. The new services are currently available in the A4, A5 and Q7 model series.

Audi connect safety & service includes the services emergency call, online roadside assistance and Audi service request. The data and voice connection runs via a separate wireless communication module independent of customer telephony that uses an embedded SIM card installed in the car at a crash-safe location.

The car autonomously makes an emergency call following a detected accident. It establishes a voice and data connection with the Audi Emergency Call Center and supplies important data such as GPS coordinates, direction of travel and number of occupants. Over a voice connection, a specially trained service employee asks the driver and passengers in their native language for further details about the severity of the accident so that arrangements for the best form of assistance can be set in motion without delay.

If the accident victims are not capable of voice communication, the service employee contacts the rescue coordination center, which dispatches an emergency ambulance to the accident scene. The driver or front passenger can also activate the emergency call manually using a switch in the roof module. Because the emergency call module has its own power source, it can still establish a voice connection even if the car’s electrical system has failed.

When an online roadside assistance call comes in, the Audi Service Center is sent the position and the relevant data on the car’s status. With Audi service request, the car sends service-relevant data to the workshop specified by the customer in the myAudi portal two weeks prior to scheduled maintenance. The service partner can then contact the customer to schedule an appointment.

The Audi connect safety & service package is available for all new models in the A4, A5 and Q7 families for a one-time fee of 250 euros and also includes the myCarManager remote services, which run via the Audi MMI connect app. The services are available in Germany and most European countries free of charge for a period of ten years (remote services: three years) from delivery of the new car. The costs arising for data and voice connections are included in the package price.

The Audi MMI connect app

The free Audi MMI connect app makes using the car even more attractive. It enables customers to use their smartphones to access information and for various functions from online media streaming to new remote services. The e-tron models Audi Q7 e-tron quattro* and A3 Sportback e-tron* can also use the app to charge the battery and operate the HVAC system remotely.

The current version of the Audi MMI connect app is available for download free of charge in the online portal myAudi and on the Apple and Google store platforms. Users can receive over 3,000 internet radio stations and store their favorites on their smartphones. The app also enables music stored locally on the smartphone to be played through the car's audio system.

Another function, online media streaming, offers access to the catalogs of Napster, Rhapsody and Aupeo!. Audi customers thus can choose from nearly 20 million MP3 music titles and several thousand audio books. As with all the other functions of the Audi MMI connect app, the files are transferred via Wi-Fi from the smartphone to the MMI navigation or MMI navigation plus infotainment system (depending on equipment and model).

New to the portfolio is the Calendar service, which transfers the smartphone's appointment calendar to the car. The user can then dial the number of person they are meeting directly and save it as a contact in the infotainment system. The location of the meeting can also be used as a navigation destination. The system will also read the place, time and subject of the appointment to the user, if desired.

Destinations from Google maps, points of interest (POI) and listings from the Travel service can be transferred from the cell phone to the car's navigation system using the app. The service Destination Sharing enables smartphone users to send navigation destinations to the car from numerous apps. The Share function sends the respective data to the Audi MMI connect app.

myCarManager

The vehicle-specific myCarManager services are particularly interesting. They provide access to information about the car and provide convenient remote control of basic functions via smartphone. These services are available for the new A4, A5 and Q7 model series. With the Audi MMI connect app, customers can use their smartphones to lock or unlock the doors and to program, start and stop the auxiliary heater. They can also view an up-to-date status report on the car that includes a range of information, from the amount of fuel in the tank to the oil level. The parking location and duration can also be displayed, and the app directs the driver back to his or her car. These remote functions can also be used with a smartwatch or the fourth-generation Apple TV. Audi attaches maximum importance to data security here. Communication therefore never passes directly between the smartphone and the car; there is always a secure Audi server in between.

Because locking and unlocking the doors requires additional authentication between the Audi server and the car, the car would not respond to a command from an unauthorized, third-party server. An extra PIN must be entered via the smartphone to enable all remote actions affecting the car. Customers define the PIN themselves in the myAudi portal, where they can also grant rights to up to five people. A maximum of five different cars can be managed via one account.

The Audi MMI connect app offers additional remote services in the USA. They alert owners via smartphone if their car is being moved in a way that is expressly prohibited in the owner's individual configuration. The geofencing alert is activated if the car leaves or enters a predefined zone, and curfew alert is triggered if the car is driven during an unauthorized time of day. Valet alert reports unauthorized use of the car in valet parking, and the speed alert informs the owner if the car is being driven above a predefined speed. If the car is stolen, the stolen vehicle locater helps to localize the car by sending position data to the police.

Audi connect e-tron services

The Audi MMI connect up offers customized functions for the Audi Q7 e-tron 3.0 TDI quattro* with plug-in hybrid drive: the Audi connect e-tron services. Owners can use them to view statistical trip data, check the battery charge and electric range, begin/end charging or to program multiple charging timers. They can also specify whether the interior should be heated or cooled prior to departure. The advantage of preheating/precooling while still plugged in is that the SUV can make full and efficient use of the energy stored in its batteries for driving, thus increasing electric range.

Similar, country-specific services are available for the Audi Q7 e-tron 2.0 TFSI quattro, which Audi sells in Asia. The same applies for the compact Audi A3 Sportback e-tron.

Audi’s semiconductor strategy

The Modular Infotainment Platform (MIB) exemplifies the strategy Audi is pursuing with respect to electronic hardware and semiconductors, in particular. They are the decisive key for the future: Nearly 90 percent of all automotive innovations are directly or indirectly associated with semiconductors. There are already between 6,000 and 8,000 processors working in the brand’s models today, and the trend is toward further growth. Semiconductors drive progress in all areas of electronic development – from electric mobility and piloted driving to connectivity and infotainment.

The Progressive SemiConductor Program
Audi initiated the Progressive SemiConductor Program (PSCP) in 2010. The goal of the interdisciplinary semiconductor strategy is to make the latest technologies available to Audi models early on to satisfy the changing expectations of customers in terms of ease of use, performance, reliability and safety.

Audi sets the highest standards for semiconductors installed in the automobile, especially in terms of their robustness, long-term quality and functionality over a broad temperature range. The company is able to quickly bring new technologies to the automobile thanks to its close collaboration with such leading companies as NVIDIA, Qualcomm, Analog Devices, NXP, ST Microelectronics, Renesas and Samsung Semiconductor.

The system component supplier is a key partner in the collaborative program. The Audi engineers with their long years of electronics development experience also speak directly with the semiconductor manufacturers. This intensive dialog leads to high efficiency and effectiveness, enabling innovations at short intervals that are approaching the high pace in the consumer electronics industry.

The autoSWIFT project

Audi is collaborating with leading German research and industrial partners in the autoSWIFT project to research and develop new approaches for faster development cycles in the automotive industry. Funded by the German Federal Ministry of Education and Research, the project is focused on faster innovation cycles for electronic systems along the automotive value-added chain. The cross-company and interdisciplinary joint development of automotive components is intended to enable the suitability of future technologies to be assessed during their development phase and incorporated into the product development processes sooner than before. This will bring the latest semiconductor technologies into harmony with the high quality standards of the automotive industry.

Control and display concepts

Audi repeatedly sets new standards with its control and display concepts. The latest highlights are the Audi virtual cockpit and the new MMI control concept – available in the Audi TT, R8, Q2, Q7, A3, A4 and A5 model series.

Audi virtual cockpit The Audi virtual cockpit comprises a TFT display with a 12.3-inch diagonal and a resolution of 1440 x 540 pixels. It displays exceptionally sharp and highly detailed graphics. Working in the background for the cockpit is a high-performance Tegra 30 processor supplied by Audi's partner NVIDIA. The fully digital display enables a wide range of information to be presented clearly and directly in the driver's field of view. This includes the classic values for speed and rpm, but also navigation, communication and entertainment information.

The driver can switch between two views by pressing a button on the steering wheel. In Infotainment mode, a central window dominates the view. It offers plenty of room for the navigation map or for lists in the Phone, Radio and Media areas. The tachometer and speedometer are displayed as small dial instruments on the right and left. In a second, classic view, they appear about as large as analog instruments, and the middle window is smaller. For the S and RS models as well as for the Audi R8, there is a third screen with a dynamic emphasis. It is dominated by the tachometer and provides additional technical information. The driver operates the Audi virtual cockpit from the multifunction steering wheel. Using switches on the left spoke, the driver pages through the menus for the on-board computer, audio system, and – depending on the installed features – the phone and navigation system. Located on the right side of the steering wheel are the volume roller, the voice control button, telephone express controls and the skip function for quickly changing the radio station or song.

In keeping with MMI logic, Audi modifies the color scheme of the display according to the base menu being used – orange for the Media menu and green for the Phone menu, for instance. At the lower edge are permanent displays of outside temperature, time of day and odometer readings as well as warning and information symbols.

MMI control concept
The latest generation of the MMI control concept makes it very easy for users to control the many different functions in the new Audi models. The controls follow a flat hierarchy designed for a minimum of steps. The MMI terminals are configured differently depending on the model; Audi uses the top model in the new Q7.

In the Audi Q7, the newly developed MMI all-in-touch terminal on the center tunnel console is the control center. The driver can enter characters on the large touchpad or perform multi-finger gestures to zoom in on the map, for example. Each input is confirmed by acoustic and tactile feedback – with a click that is also felt on the finger. This lets the driver stay focused on the road.

In Asian markets, the system also recognizes the highly complex characters of the national languages. It can understand more than 29,000 Chinese characters (Hanzi), roughly 7,300 Korean and 6,700 Japanese characters. The MMI also understands the phonetic Romanizations commonly used in these countries. These types of alphabets include Chinese Pinyin, Hangul in Korea and Hiragana, Kanji and Katakana in Japan.

All MMI system functions can be accessed using the high-precision rotary pushbutton that works according to the joystick principle. It can be pushed in four directions to access the menu structure and quick access functions. Two rocker switches call up the main functions directly. In the Audi Q7, A5 and A4, there are also eight freely programmable buttons that the driver can use to store personal favorites, such as navigation destinations, telephone numbers or radio stations.

Audi has set another benchmark with the innovative MMI search function, which is the central starting point of the new control concept. It makes it easier to find music tracks and input phone contacts and navigation destinations. MMI search uses intelligent search algorithms significantly reduce the number of operating steps. The driver or passengers can enter individual letters by “writing” them directly on the touchpad with their finger. The first results appear after just a few letters. Here, the system considers the car’s current location and recent activities such as phone calls or destinations. When searching for a place to eat, for instance, the driver only has to enter the name of the restaurant and the first letters of the city and a list with hits appears.

The driver can use two supplemental menus to select relevant functions of each main group according to the context, which are then intelligently linked. In Radio mode, for instance, the driver can select the frequency band in the function menu, and traffic information can be called up from the Map menu. With these context-dependent options and settings, the driver can get directions to a specified destination, display nearby parking or save a destination to the Favorites list.

Control by natural language
One highlight is the newly developed, user-friendly and intuitive voice control system. The driver no longer has to be constrained to the use of rigidly defined voice commands – in many languages the system understands formulations from everyday speech. So, hundreds of variants are possible for each function. In the Phone menu, for example, the driver can call a contact just by saying “I want to talk to Peter Miller.” or “Connect me with Peter Miller.” In Navigation, commands such as “Where can I refuel?” or “Take me to Ingolstadt, Ettinger Strasse 35.” are sufficient. The intuitive voice control system is also available in the Radio and Media menus.

Infotainment

Advancements in infotainment pose new challenges for carmakers. It must be possible to use an increasing number of functions intuitively, simply and without diverting attention from the road. Audi is meeting these challenges with groundbreaking technologies.

The MIB2
The MIB2 (second-generation Modular Infotainment Platform) is the foundation for infotainment in all Audi production models. It uses an NVIDIA T 30 processor, a quad-core chip from the Tegra 3 series. With a clock speed of over 1 GHz and a fast graphics card, it can drive two displays. The Tegra 30 processor works together with a 3D graphics program from the specialist company Rightware to display spectacular three-dimensional images.

Personal route assist
Self-learning personal route assist is currently available in the new Audi Q7, the A4 and the A5. When this function is active, the navigation systems learns which routes the customer frequently takes to which destinations and links this information with the parking location and the time of day. The system thus learns from the driver's behavior and on this basis makes suggestions for optimized route planning for the next trip – even if route guidance is inactive. The navigation system builds the three most likely destinations into the calculation, taking account of both the arrival time and current traffic levels. It is therefore possible to suggest that the customer activate the navigation system to learn of potential alternate routes.

Audi phone box with wireless charging
The Audi phone box in the center armrest wirelessly connects a cell phone to the car's antenna by near-field coupling to ensure optimal reception quality. With wireless charging based on the Qi standard, the current flows inductively from a coil in the base of the box to a receiver coil in the smartphone.

Audi smartphone interface

The Audi smartphone interface brings Apple Car Play and Android Auto into the car. When a customer connects an iOS or Android cell phone (iOS 7.1 or higher, Android 5.0 Lollipop or higher) to the USB port, smartphone content such as navigation, telephone, music and selected third-party apps are made available. They can be conveniently operated by MMI or voice control. Audi has designed both applications especially for use in the car. The core content here is online music with access to an enormous range of music from Google Play Music and iTunes. There are also navigation and notification functions as well as schedule reminders. Third-party apps like Pandora, Spotify and WhatsApp will further expand the range of functions.

Sound systems with 3D sound

Sophisticated hi-fi fans have the choice of two optional systems from Bose and Bang & Olufsen in the Audi Q7, A4 and A5. Both offer the new 3D sound. Two (Bose) or four (Bang & Olufsen) additional speakers in the A-pillars add the spatial dimension of height. The 3D technology creates an unprecedented sound experience in the car. An intelligent program calculates information for the third dimension from conventional stereo or 5.1 recordings and prepares it for the speakers in the A-pillars. While Bose uses its own algorithms (Bose Advanced Staging Technology), the Bang & Olufsen system employs a procedure developed by Audi together with the Fraunhofer Institute for Integrated Circuits (IIS) in Erlangen.

The heart of the Bose 3D sound system is a 558 watt 15-channel amplifier. It drives 19 speakers, some of which have LED light guides in their surrounds.

The Bang & Olufsen Advanced Sound System with 3D sound integrates up to 23 speakers. A subwoofer, 25 cm *(9.8 in)* in diameter, generates the bass, while two acoustic lenses made of solid aluminum create the treble tones. They extend from the instrument panel when the system is started. The particularly efficient amplifier provides 1,920 watts of power.

Audi tablet

The Audi tablet with its high-resolution 10.1-inch screen is a flexible Rear Seat Entertainment system. The tablet is currently available in the new A4 and Q7 models. Connected to MMI navigation plus via Wi-Fi, it affords access to the Radio, Media, Navigation and Car menus. The data transfer runs in both directions – rear passengers might send a planned route to the driver, for instance or, conversely, the driver could start a radio or media program for them from MMI navigation plus. The sound is output either over the vehicle sound system or through the passengers' headphones.

The Audi tablet, which uses the Android operating system including its available apps, supports NFC technology (NFC = Near Field Communication) for transmitting data from the smartphone by proximity. It has 32 gigabytes of internal memory and can be expanded by a microSD card for additional memory. The technical core is the Tegra 4 processor from NVIDIA. The integrated full HD camera can be used to make a video call with Skype.

After the trip, the user can take the Audi tablet from the car for operation offline or on an external Wi-Fi network. The Audi tablet's anodized frame is milled from solid aluminum. Together with its rechargeable battery, it is logically designed for use in the car. It can also handle high or very low temperatures without problems; the tilt-adjustable bracket on the back of the front seat is collision-proof and removable if required.

Connectivity of the future

The brand with the four rings is hard at work on the Audi connect technologies of the future, which means even greater interconnectivity with other cars and the traffic infrastructure. Customers reap the benefits of greater safety and convenience. At the same time, the connect technologies are the foundation for greater efficiency, both with respect to fuel consumption and in terms of travel time and route guidance. To handle the rapidly expanding volume of data, Audi is investing in powerful wireless communications technologies with LTE Advanced and LTE-V.

The second generation of the modular infotainment platform (MIB) is used in many of the new production models from Audi. The next version, MIB2+, will enable new infotainment functions.

MIB2+ offers significantly more computing performance to support multiple high-resolution displays. It also merges onboard and online information, making the car more a part of the cloud than ever before. The integration of wireless communication into the car continues to play a decisive role here. With the MIB2+, this is based on the new LTE Advanced standard. On the one hand, this allows for improved convenience functions, such as faster transfer of online content or better call quality. It also is a prerequisite for the implementation of car-to-x services and, in the longer term, for the realization of swarm intelligence and automated driving.

The scalable concept of the modular infotainment platform (MIB) makes it possible to update the hardware at short intervals. It lets Audi react quickly and flexibly to the fast pace of innovation in consumer electronics and optimally exploit the potential of new generations of chips. The domain architecture that Audi uses in the MIB is a promising approach for the overall electrical/electronics architecture in the car. In the medium term, a few intelligently networked domain computers will replace the countless controllers to form a central computing unit.

LTE Advanced
With the MIB2+, Audi is the world's first carmaker to support the latest standard, LTE Advanced (LTE = Long Term Evolution). With LTE Advanced, MIB2+ achieves maximum transmission rates of 300 MBit/s for download and 50 Mbit/s for upload, making it around three times faster than the previous MIB2. Upgrading of the cellular phone network has already begun in many countries.

Another strength of the MIB2+ is mobile telephony using VoLTE (Voice over LTE), in which data packets are transported via the IP protocol. This new technology improves voice quality, accelerates phone connections and enables simultaneous use of high-resolution, online voice telephony and high-speed data transmission. If network conditions are poor, the Audi wireless communications module can use multiple frequency blocks in the LTE Advanced network simultaneously (carrier aggregation) to establish a fast data connection.

The LTE standard – and in the future LTE Advanced – also plays an important role for Audi's car-to-x services. In the medium term, it will be used to transfer most of the information being sent to the car via wireless networks, such as information about construction zones. This information flows into the new HERE HD Live Map, a digital map serving as the basis for the piloted driving of the future.

With car-to-x technology, there are strong market-specific preferences with respect to the base technology. The American market, for example, uses the 802.11 p standard, which has already been specified and which Audi has already successfully tested. In other markets such as China, the 5G standard will likely establish itself.

LTE-V
The "V" in LTE-V stands for vehicular, i.e. the specific applications in vehicles. The new LTE-V technology very quickly establishes direct connections between the data transfer modules in automobiles. This innovative ad-hoc communication enables cars to communicate with one another even in regions without wireless coverage.

The LTE-V module in the car has two operating modes: In Coverage mode is active when the car is located close enough to a base station. Here the network manages the communication between the users by allocating each defined resources with respect to time and frequency spectrum. A fire truck on a call, for example, sends its position reports with high priority. LTE-V management call also interconnect a group of vehicles in such a way that they form an intelligent local swarm. This enables the leading vehicle to warn those following about the end of a traffic jam, for instance.

The second mode is Out of Coverage. It serves as a fallback level for when cars are too far from a base station to synchronize with it. The station can supply coverage to an area several kilometers in diameter. Cars still exchange information in this mode, but without coordination by the base station.

The fast connection establishment predestines this new technology for the transfer of time-critical information. Besides warnings, this also includes such aspects as the future “platooning”: piloted cars driving in a close-headway formation on highways. The vehicles in the convoy can use LTE-V to continuously adjust the ideal gap between them so that they can drive very efficiently while also helping to prevent accidents.

Audi is working to establish the updated LTE standard in close collaboration with its partners, including the wireless technology company Huawei. Deutsche Telekom, which is making available the frequencies in the gigahertz spectrum, and the Chinese company have set up a test site on the A9 autobahn near Ingolstadt. This is a subproject of the “Digital Test Bed A9” trial sponsored by the German Federal Ministry of Transport and Digital Infrastructure. The objective is to test piloted and connected driving in real-world traffic. Audi is involved in multiple projects in this field.

Practical testing has already been completed. Four LTE-V base stations were installed along an 11 kilometer stretch of highway between the Lenting and Manching exits. The communications modules in the cars were provided by Huawei. In collaboration with BMW and Toyota, Audi used two test platforms to test how well cars from different manufacturers could share data among themselves – with a variety of requirements and under real-world conditions. The results are currently being analyzed.

The next step will be to standardize the LTE-V technology and protocols worldwide in order to gain as many users as possible. The new technology could reach market maturity before the end of this decade. Audi experts further expect that LTE-V will not only make its way to the car, but also to smartphones. That would open up additional, entirely new connectivity possibilities, such as car-to-pedestrian communication. This would allow information about the pedestrian's location to be shared in real time.

Control and display concepts of tomorrow

Audi showed how the control concept of the future might look with the Audi e-tron quattro concept technology study. Now the brand with the four rings is evolving the Audi virtual cockpit into the Audi virtual dashboard. This comprises multiple OLED displays, each of which assumes different tasks. The fully digital control concept lays the foundation for a system that adapts to the use patterns of individual customers, providing intelligent hints to support them as a discrete assistant.

With its fully digital cockpit, the Audi e-tron quattro concept provides a glimpse of how the control and display concept might look in the future. In the new, starkly reduced Audi virtual dashboard, a total of three displays are responsible for the display and control of all functions and information. Positioned in the driver's direct field of view is the curved OLED of the Audi virtual cockpit with a 14.1-inch diagonal and 2240 x 720-pixel resolution. In the base menu, it displays the speed, charge status of the traction battery and range. The Audi virtual cockpit curved OLED is controlled intuitively using the multifunction steering wheel.

The slightly curved surface of the large central display ensures that the driver can always read the displays without glare. The free form of the contour is one of the strengths of the AMOLED technology used here (AMOLED = Active Matrix Organic Light Emitting Diodes). It uses extremely thin films.

Two touch displays are found in the center console. The upper screen shows classic infotainment content for controlling navigation and media functions, while the lower screen is used for text input and to operate the automatic air conditioning system. In addition, on the multifunctional display, individual favorites can be defined whose functions can later be called up quickly.

All key functions are integrated into these two displays. This makes it possible to personalize contents and update and extend functions at a later time. The fully digital Audi control concept lays the foundation for a system that adapts to the use patterns of individual customers. Its intelligent messages and personalized content make it a kind of personal assistant in the car.

New touchscreen technology
The new type of MMI operation with MMI touch response recognizes touch gestures and adapts them for the car. The system provides haptic feedback that can be clearly felt on the finger when the driver scrolls through lists or adjusts the air conditioning system, for example. Buttons are selected and actuated by a gentle press on the display. This avoids inadvertent operating errors.

Operation is simple and safe; the wrist rests comfortably on the wide gear selector lever. The MMI touch response system thus combines the advantages of a configurable display with the haptic feedback of conventional switches and dials.

Online voice control
Audi is also entering a new dimension in voice control, which is also known as the SDS (speech dialog system). MIB2+ expands the system to include a hybrid solution that incorporates and if need be compares both on-board and online solutions. Online and offline voice control thus augment one another seamlessly.

In online recognition, the driver's speech input is sent as a data packet to voice recognition software in the cloud over the cellular phone network.
If the on-board and the online recognition systems both provide a response, the dialog manager compares them. In choosing the more plausible response, it uses such criteria as the car's location and previous user queries.

The new voice control system understands many expressions from everyday speech, thus extending the voice control spectrum. Along with point of interest (POI) searches, it includes additional functions such as weather, news and online radio.

Seamless connect experience
In the future, the entire control and display concept will learn about individual customers with their habits and preferences, and actively assist them. For instance, the navigation system might recommend before the trip begins that the driver start out early if traffic is beginning to build up, so that the desired destination can be reached on time. During the drive, the latest supplemental information – such as traffic and hazard messages – is displayed via the 3D map in the driver's direct field of view. Information on the surroundings as well as the location of nearby charging stations for Audi e-tron models can also be displayed. In the future, the HERE database will be supplying this information. Customers will also have a way of always keeping their cars up-to-date. They soon will be able to use their personal myAudi account to extend functionalities or acquire them after car purchase.

Personal intelligent assistant (PIA)

The best control concept is one that adjusts to driver, saving him or her as many actions as possible and automatically carries out routine commands. PIA, the personal intelligent assistant, adheres to this motto.

The concept of the PIA predevelopment project is to link data intelligently: data from the internet, driver data, data about the current and upcoming traffic situation as well as data from the car. PIA also reacts to voice input, and thanks to intelligent algorithms can interact with the user autonomously and adaptively.

Possible usage scenarios for PIA could be the following driver behavior patterns and activities: What navigation destination does the driver enter most frequently and on which days? What music and which Audi connect service does the driver choose at what time? How does the driver set the air conditioning and seat heating depending on the weather? How much distance does the driver leave between the vehicle ahead on the highway? What parking spot does the driver use at what time of day and in what type of weather? Does the driver prefer an underground garage when its raining? Whom does the driver call most often and at what time?

PIA continuously learns more about the preferences and habits of the user from this type of information. Audi uses machine learning technology here. PIA therefore is constantly developing and with the help of this artificial intelligence, gleans more detailed knowledge with every kilometer driven. PIA can adjust the functions of the car to the patterns of behavior and needs of the driver, and actively make recommendations. Heavy traffic on a rainy Friday afternoon might mean: air conditioner on Defrost, turn on traffic information, soft music, defensive characteristics for assistance systems, engine and suspension, plus suggesting a call home to let the family know that the driver is going to be late.

A server in the secure Audi cloud hosts and processes the PIA data. Customers can view and manage these data at any time via their myAudi account. They can delete or edit data, such as following a change of address, and have the data automatically transferred to additional cars. The car identifies the individual user, loads the right user profile, and PIA then adapts the car and its interactive behavior accordingly.

Audi Electronics Venture GmbH (AEV), an Audi subsidiary, has overall responsibility for the PIA predevelopment project. Initial elements could make their way to production before the end of the decade and then gradually expanded thereafter to create a perfect, discrete driver’s assistant.

Car-to-x services and swarm intelligence

Audi will add the first car-to-x services to its connect portfolio in 2016. The first applications are the services traffic sign information and hazard information. With car-to-x, Audi models are interconnected in such a way that they can exchange information virtually in real time via the cellular phone network. This technology enables swarm intelligence – the sharing and use of complex information in a large group. Car-to-x communication can help to improve road safety and to enhance comfort. It is also a fundamental element of future Audi models capable of piloted driving.

The new online services traffic sign information and hazard information are available for the Audi A4/A5 family as well as for the Q7. The cars have been gathering information since the middle of this year, and it will be used to build up a database. After a certain amount of data has been generated, the information will be sent back to the cars for the first time toward the end of the year.

The data transfer for the car-to-x services is handled by the Audi connect SIM, which customers acquire with the Audi connect package. The Audi connect SIM is what is known as an embedded SIM (e-SIM) that is permanently installed in the car.

Traffic sign information
The new service traffic sign information expands on the traffic sign information stored in the MMI navigation module and takes the camera-based recognition of traffic sign to a new dimension. The on-board traffic sign recognition identifies temporary speed limits and reports them to a server in the cloud via the cellular phone network. Once a sufficient number of cars have sent the identical message, it is considered to be verified and can be made available to other Audi drivers.

For added comfort and greater efficiency, this speed information is shared with other systems in the car. The predictive adaptive cruise control (pACC) and the predictive efficiency assistant (PEA) use these current data from the cloud for an anticipatory driving style. In the future, these systems will observe these temporary speed limits even before they enter the camera's field of view.

Hazard information

The second production-ready car-to-x communication application is the new hazard information service. Here cars networked over a server warn one another of hazards on the road – of accidents and breakdowns, skidding hazards due to slippery road surfaces or impaired visibility due to fog. The system evaluates multiple parameters to verify cloud-based hazard information: The electronics in an Audi recognize four different events, for which either one involved car is sufficient (accident or breakdown) or multiple cars have to be affected (skidding hazard or impaired visibility). To detect poor visibility reliably, the connect service evaluates e.g. data from rain and light sensors, as well as the operating mode of the windscreen wipers. An accident or breakdown is reported provided an emergency call has been placed by the eCall system or an airbag has been activated. Only after verified information about a hazard site is available does the system actually report the hazard to the cloud in order to warn following traffic in a timely manner. The warnings appear in the instrument cluster, and the speech output system also informs the driver so that current hazard warnings are received significantly faster.

On Street Parking

Audi is developing additional connect services for the future, such as a parking spot search function under the project name On Street Parking. Cars equipped with car-to-x technology automatically report when they enter and leave a parking spot to the servers in the cloud. The application identifies parking maneuvers based on a variety of parameters, such as drive position changes, steering angles and speed.

In the future, the system will also be able use the information from the ultrasound sensors or the camera to recognize free parking spaces while driving. It will calculate the number of free parking spaces on the side of the road based on statistical models that consider factors such as the time of day. The service shows the driver the probability of finding a free parking spot in real time, making it easier to find a spot, particularly in city centers.

Model car course: car-to-x services and swarm intelligence in 1:8 scale
Audi isn't just researching car-to-x communication, data sharing, swarm intelligence and piloted driving on the road, it is also doing it in 1:8 scale. The company has created the Audi Autonomous Driving Cup for just this purpose. As part of TechDay Connectivity, Audi is using these model cars to demonstrate traffic sign information, hazard information and on street parking.

The plastic body of the blue Audi Q5 miniature conceals a huge amount of technology that makes piloted driving possible. The high-tech model cars are powered by an electric motor that accelerates them to speeds as high as 40 km/h *(24.9 mph)*. The main sensor for monitoring the surroundings is a color camera with depth mapping. As with the production cars, it detects the road surface, traffic signs, obstructions and other road users in front of the model cars. It is supported by ten ultrasound sensors: five at the front, three at the rear and one on each side. Its large coverage range of two to 400 centimeters *(0.8 to 157.5 in)* enables the precise detection of the surroundings, even at high speed. An acceleration sensor registers changes of direction by the model cars and, like all other systems, sends this information in real time to the central on-board computer with a high-speed quad-core processor. The on-board computer is in contact with the laptop at the side of the track via Wi-Fi, very similar to how cars from Audi are connected to the cloud server via the cellular phone network.

The self-driving model car detects important information, such as a traffic obstacle, and enters this in a real-time map. The server then sends this as an early warning to a following car, which can then pass the hazard zone safely and easily. Audi's model car course demonstrates the advantages of car-to-x communication. Audi will continue to refine typical applications, such as traffic sign information and hazard information familiar from its production cars, while also tapping the potential of HERE.

The car-to-x test car fleet: testing of connectivity and data sharing
Before Audi turns a new car or a new technology over to its customers, the function is tested under real-world conditions. To test connectivity and data sharing, 70 cars belonging to Audi managers were on the road throughout Germany from mid-2015 to mid-2016 as part of a pilot project. For the most part, the technology used in this pDw (from the German for personal company car) fleet was production solutions.

After 630,000 test kilometers *(391,463.9 mi)*, more than six billion data sets are awaiting analysis. From the roughly 850 signals from the controllers in the car, the system was able to derive approximately 500 messages per second and send them encrypted and anonymized to the Audi IT data center via the cellular phone network. The back-end software that processes, stores and analyzes the data was developed in-house by Audi. Audi is therefore able to react quickly and flexibly to variations in the data volume.

One objective of the field test was to be able to better evaluate and optimize the characteristics of the Audi models in real-world use. At the same time, Audi gleaned valuable experience with the collection, transfer, storage and analysis of large volumes of data like those that will be needed in the connected traffic world. Appropriately conditioned, the data from the pilot project can be evaluated and used in a variety of ways.

Among the information polled during the field test were the GPS coordinates, speed and fuel consumption, as well as the radio station selected, cellular signal strength, the use of driver assistance functions like adaptive cruise control (ACC) and acceleration profiles. A look at the values for lateral acceleration revealed a conspicuous cluster at approximately -2.6 m/s^2 and + 2.6 m/s^2. This corresponds exactly to what according to studies is lateral acceleration that drivers find to be pleasant. These types of insights will enable Audi to configure its driver assistance systems even better in the future and to give piloted cars a more natural character.

With the insights gleaned from the pDw fleet data, the Audi developers are now able to make even more precise predictions about what is happening on the road and how road users behave. For customers, this will mean greater safety, comfort and efficiency in the future.

Digital HD map from HERE

The piloted cars that Audi is developing must be capable of navigating down to the centimeter. The company HERE, in which Audi holds a stake, generates the digital map required to do this: the HERE HD Live Map.

AUDI AG joined a consortium with the BMW Group and Daimler AG at the end of 2015 to purchase the HERE maps database from the Nokia Corporation – a strategic step. HERE is one of the leading software companies for digital navigation maps and makes location-based services available for nearly 200 countries. 80 percent of all cars with integrated navigation systems currently on the road in Europe and North America use maps from HERE.

The central project of the Berlin-based company is the HERE HD Live Map, which forms the basis for the piloted driving of the future. The new data platform no longer contains any static, purely two-dimensional navigation maps that must be updated periodically via software updates or displays only a few real-time services via select online functions (such as real-time traffic information). The HERE HD Live Map describes the traffic space as a three-dimensional model with unprecedented precision. It is accurate down to the centimeter rather than the meter, and dynamic rather than static. And it is extremely well connected. It uses roughly 80,000 different sources worldwide to continuously update its map material.

The HERE HD Live Map has three layers: The first, the HD Map, contains a static digital image of the environment. Guardrails, traffic lights, street signs, curbs and similar fixed objects are the reference points on which the self-driving cars of the future can orient down to a centimeter. The HD Map also integrates a database with information about hotels, businesses and restaurants.

The most important data for the HD Map are provided by roughly 200 HERE “True Cars” that drive the roads. A rotating LiDar unit (Light Detection and Ranging) is mounted on their roofs. The cloud of points generated by the car is used to create a 360-degree image of the environment extending outward by up to 80 meters *(262.5 ft)* and upward to 30 meters *(98.4 ft)*.

The second layer of the HERE HD Live Map is called Live Roads. This is a dynamic layer that provides updated information in near real-time about such things as construction zones, accidents, rescue operations, black ice or fog. Live Roads content comes from numerous sources, but primarily from the sensors of participating cars. The intelligent swarm generates comprehensive, always-current information about the traffic, such as green waves in city traffic, changing speed limits and free parking spots.

The third layer has to do with humanized driving. Future piloted cars learn from the HERE data pool how the owner behaved in a certain situation resembling the current one. This query enables the car to adjust its behavior to the habits and expectations of the owner.

The HERE HD Live Map is split up into square tiles measuring two kilometers *(1.2 mi)* on each side. This allows the immense volume of data to be broken down into manageable portions. Updates within a tile are in the kilobyte range. The data are hosted in the cloud on a HERE back-end; a vast majority of the transfers to and from the cars are via the cellular phone network. Today's LTE standard already offers a lot of possibilities here, but future solutions promise substantially higher data rates and the faster establishment of connections.

The HERE HD Live Map is still under construction, yet partial functions are already being used by many connected cars in North America and Western Europe. For Audi customers, the map makes demanding driver assistance functions such as the traffic jam assist and the predictive efficiency assistant even more precise and powerful. The new car-to-x services traffic sign information and hazard information will also migrated to the HERE HD Live Map in the future.

Audi, BMW and Daimler regard the HERE, map service, which employs some 6,500 people worldwide, to be an independent, continuously extensible and updatable platform. Whether carmaker or supplier, technology company or service provider: HERE is accessible to all. Cities can also use the new HERE HD Live Map to optimize traffic routing and flow.

Virtual reality

Audi Virtual Training Car

Audi is making increasing use of high-tech simulation tools. One of these is the Audi Virtual Training Car, an Audi A4 equipped with a virtual reality headset for the driver. A driving simulation played back in the VR headset allows the driver to experience in realistic scenarios how the emergency braking assistant Audi pre sense city works – in a car that is actually driving. With this system, Audi dealers worldwide can demonstrate the effectiveness of the Audi assistance systems to their customers convincingly and in rich detail.

The virtual use of Audi pre sense city is part of the international sales training events at the Audi Training Center at Munich Airport. Two Audi A4 sedans* were equipped for this purpose with a VR headset from Oculus. With the headset, the driver can experience the intervention by the emergency braking assistant in a very realistic simulation in a test car that is actually moving.

During the demonstration, the Virtual Training Car drives on a 300 x 600 meter *(984.3 x 1,968.5 ft)* asphalt surface while the driver watches simulated driving scenarios via the VR headset. The moment a pedestrian steps into car's virtual path in the simulation, Audi pre sense city brings the car to an abrupt stop. A Flex-Ray interface provides the connection between the warning system and the brake system.

To fully immerse the driver in the simulation, a head tracker mounted on the rear seat measures the driver's head movements via infrared on the basis of markings on the VR headset. The images on the headset's two high-resolution displays are adjusted according to the head position and direction in which the driver is looking. If the person behind the wheel looks left out the window, for example, he or she sees the left edge of the road.

A high-precision differential GPS locates the Virtual Training Car on the driving surface with an accuracy down to two centimeters *(0.8 in)*. Together with a position sensor in the car, it detects the car's movements and determines the precision position in the simulation.

The virtual world is stored on a hard drive in the trunk of the Audi A4.
A powerful processor and a fast graphics card from Audi's partner NVIDIA send the data to the VR headset and to the touchscreen in front of the passenger seat. Should the driver leave the permissible driving area, a warning is issued so that the trainer on the passenger seat can intervene, if necessary via the parking brake.

The Virtual Training Car is based on a project by Technical Development at Audi. Audi is the first and so far only carmaker to deploy such a system, which it uses to train its international dealers. This simulations allow the salespeople to experience the effectiveness of Audi pre sense city under realistic conditions so they can authentically communicate the systems' advantages to their customers.

After an initial wave of training for roughly 5,000 participants, Audi is now upgrading the simulation. It will soon be able to portray additional assistance functions to impressively demonstrate the effectiveness of the Audi assistance systems in a wide range of driving situations.

Virtual Engineering Terminal

The driver assistance systems of today are the pre-stage to the piloted driving of tomorrow. At TechDay Connectivity, Audi makes it possible to experience this with the help of the Virtual Engineering Terminal.

The Virtual Engineering Terminal is a touchscreen with a diagonal of approximately 1.40 meters *(4.6 ft)* combined with 65-inch monitor and fed with data from four computers. Its virtual environment currently includes five Audi models: the A4, A5, A8, R8 and SQ7 TDI*. For each of these models, the Virtual Engineering Terminal simulates five production assistance systems: the Matrix LED high beam, LED laser high beam, traffic jam assist, park assist and predictive efficiency assistant. It is also used to interactively communicate various predevelopment projects, such as the construction zone lighting assist or the crossing assist. The user can experience these functions in realistic traffic simulations.

If the Matrix LED technology is selected, for example, the stylized image of a parking lot seen from above at night is displayed on the touchscreen. The monitor shows the same environment, with the choice of a bird’s eye view or a cockpit view.

The interaction begins with the user placing a number of Audi models on the virtual parking lot. The red model represents the user’s own car with Matrix LED technology; the blue and the white cars are passive road users.
All models have optical markers on the underbody. These enable the 24 cameras mounted below the touchscreen to detect the position of the cars. So if the user moves the model by hand, the cameras enter the movement in the system. The image on the large monitor changes accordingly. It shows precisely how the red car detects the other cars or objects using its camera sensors and adjusts its Matrix LED lights so that the high beam light pattern excludes the other cars.

Developed in 2012, the Virtual Engineering Terminal is now firmly established at Audi's Technical Development department. The system uses the original control algorithms of the driver assistance systems and simulates the environment, such as routes and other road users. The Virtual Engineering Terminal is continuously being expanded with new functions.

Audi Sales also uses the Virtual Engineering Terminal to explain new assistance systems to dealers and customers. Currently there are three Virtual Engineering Terminals, with more to come.

The Audi VR experience

The brand with the four rings opens up a new virtual world to its customers so that "Vorsprung durch Technik" can be experienced in a very special way. With the help of the Audi VR experience, customers can now virtually explore every last detail of the car of their choice at the dealership – in three-dimensions and from a 360-degree perspective, with all sound effects and all available equipment and trim. The new technology offers an experience that no competitor can match.

When it comes to virtual reality (VR), Audi uses the latest VR headset: the HTC Vive and Oculus Rift. With their large field of view of over 100 degrees, the high refresh rate of 90 images per second and their powerful position tracking, these enable an immersive user experience. Viewers feel as if they have been dropped into the scenery portrayed. The technical performance data of the VR headset is just as impressive. The two OLED displays each have a resolution of 1080 x 1200 pixels and a response time of less than 20 milliseconds throughout the entire application.

In the Audi VR experience, the headset draws its data models from a powerful computer. Audi generates these models on the basis of design data. The brand developed an optimized graphics engine for displaying VR in collaboration with the English specialist Zerolight.

Each vehicle data set is made up of five to seven million polygons, roughly four times more than in a high-end video game. The view can therefore recognize even the tiniest of details, such as the polish of the aluminum inlays or the various gloss levels of the paint finish depending on the position of the virtual light source.

To come up with the desired configuration of the car, the consultant at the Audi dealership can use a tablet to load every current model and equipment feature, from paint colors to wheels, exterior packages and seat upholstery to the infotainment modules.

Two different versions of the Audi VR experience are available. The compact version is designed for locations where space is limited. In this case, customers sit on a couch or an armchair. A camera detects the position of the VR headset, and the system adapts the image displayed accordingly. This enables customers to look around and get closer to interesting details. They start out behind the virtual steering wheel, but the consultant can place customers at different positions outside the car.

The large version of the VR experience, which Audi shows at the Munich airport under the name Audi VR experience advanced, plays on a surface measuring roughly 5 x 5 meters *(16.4 x 16.4 ft)*. Customers can move freely around the virtual car. Audi has already designed a number of diverse VR environments. One setup shows the car in Paris, others in Cannes, on Iceland or even on the moon.

Prototype use of the Audi VR experience began in late 2014. Audi completed the last pilot phase in mid-2016. Series use is now being rolled out successively. The next versions are already in the works and will be presented in the months ahead.

Technologies for portraying virtual cars has been in use at Audi since 2012. Audi stores located downtown in the world’s largest metropolises have less available space than a classic dealership. Powerwalls and tables equipped with touch displays have long since replaced physical cars there. The new VR experience will also be used at these locations in the future.

Fuel consumption of the models named above:

Audi Q7 e-tron quattro
Combined fuel consumption in l/100 km: 1.9 – 1.8** *(123.8 – 130.7 US mpg)*;
Combined electrical consumption in kWh/100 km: 19.0 – 18.1**
(19.0 – 18.1 kWh/62.1 mi);
Combined CO_2 emissions in g/km: 50 – 48** *(80.5 – 77.2 g/mi)*

Audi A3 Sportback e-tron
Combined fuel consumption in l/100 km: 1.8 – 1.6** *(130.7 – 147.0 US mpg)*;
Combined electrical consumption in kWh/100 km: 12 – 11.4**
(12.0 – 11.4 kWh/62.1 mi)
Combined CO_2 emissions in g/km: 40 – 36** *(64.4 – 57.9 g/mi)*

Audi A4 Sedan
Combined fuel consumption in l/100 km: 7.5 – 3.7** *(31.4 – 63.6 US mpg);*
Combined CO_2 emissions in g/km: 170 – 95** *(273.6 – 152.9 g/mi)*

Audi SQ7 TDI
Combined fuel consumption in l/100 km: 7.6 – 7.2** *(30.9 – 32.7 US mpg);*
Combined CO_2 emissions in g/km: 199 – 189** *(320.3 – 304.2 g/mi)*

**Fuel consumption and CO_2 emission figures given in ranges depend on the tires/wheels used as well as the engine/transmission version.

Appendix:

Data protection/privacy
Audi treats data protection as a high priority. Audi fully complies with the respective national laws governing personal data, data protection and privacy rights. The brand follows clear principles when handling the personal data of its customers:

Autonomy
Audi collects, saves, transfers and uses personal data exclusively in accordance with the statutory regulations. If the use of personal data will extend beyond a specific contractual arrangement or other statutory permission, the consent of the customer for the purpose in question is obtained. Personal data is fundamentally only used for the specific purposes for which it was originally collected and within the scope of the use or usage requirement specified by the customer. Services are not contingent upon consent by the customer to use data for purposes such as advertising, for example.

All data used with the consent of the customer are anonymized prior to transfer to the Audi IT server and analysis. The customer can delete infotainment data at any time.

Data minimization
Audi uses anonymized or pseudonymized data whenever possible unless the collection, processing and use of personal data is required in the pursuit of a legitimate objective. *[Example?]*

Transparency
Audi informs customers in a suitable manner of how their personal data is used. This includes in particular which data are collected and processed, for what purpose the data is used and whether data is sent to third parties. Transparency also includes informing the customer what personal data about them is held by Audi. The German Data Secrecy Act covers personal data.

Data security
Audi uses state-of-the-art technical and administrative protective measures, and today makes targeted use of recognized and tested embedded security mechanisms and standards to protect data against, in particular, unauthorized access, processing or transmission, loss, modification or destruction. Security mechanisms undergo continuous development as part of the development of new functions in order to both comply with the latest data protection requirements and to ensure the associated security of data in the vehicle by means of state-of-the-art technical and administrative measures.

Transmission of data with Audi connect safety & service
Vehicles equipped with Audi connect safety & service send the following vehicle data to the Audi Emergency Call Center in the event of an accident or a manually initiated emergency call: GPS coordinates, the direction of travel and the number of occupants. In the case of an online roadside assistance call or when making an online appointment for service, the car sends service-relevant technical condition data to the service partner chosen by the customer. Should the customer no longer wish to use the emergency call service, he or she can have the function deactivated by the service partner.

The transmission of a car's GPS-based position data by Audi to the online traffic data service provider is performed anonymously if the driver of the vehicle has activated online traffic information in his or her navigation system and is receiving this information. If the driver turns off the service, however, the car no longer sends any position data to the service provider. The position data are encrypted and absolutely cannot be associated with a specific car or user.

Encryption between vehicle and cloud
The protection of the vehicle- and back-end infrastructure as well as secure transmission are essential to Audi. Audi uses encryption methods such as those used in online banking for the connection between both the car and the smartphone to the Audi back-end. The data are also encrypted for storage on the Audi servers. Accessing of the data for administrative purposes is traceably documented. For the customer account on the myAudi platform, password guidelines that meet the current security standard are used. The online connection to the myAudi platform is always encrypted.

For remote control via the Audi connect services, Audi attaches maximum importance to data security. Communication never passes directly between the smartphone and the car; there is always the firewall of a secure Audi server in between. For the vehicle status report, the car sends the latest data to the Audi server, where the customer can access it at any time by encrypted transfer to their smartphone. An extra PIN must be input via the smartphone to enable the remote actions to be carried out.