Electromobility in winter: Intelligent thermal management in Audi models preserves range and performance

- **Audi embeds mechanisms to preserve batteries and charging capacity**
- **Preconditioning heats the high-voltage battery and interior before departure**
- **Heat pump generates soothing warmth and protects against loss of range**

Ingolstadt, December 15, 2021 – In the winter, electrically powered cars have to bring the interior and the battery system to the right temperature. This double task already requires a lot of energy from them. Low exterior temperatures exacerbate the problem – and affect high-voltage batteries' performance. Nonetheless, concern over excessive loss of range in electric Audi models is unfounded: with intelligent thermal management, the brand provides outstanding performance and range in its cars; special protective mechanisms ensure long battery life. In an interview, Pierre Woltmann, head of thermal management for high-voltage batteries at Audi, and Thomas Anzenberger from thermal management virtual functional development explain how the company with the four rings is effectively meeting the challenges of winter operation.

Do drivers of electric Audi models need to be concerned about limitations in the winter?
Thomas Anzenberger: I can answer that question with an unequivocal no. The size of our high-voltage batteries alone makes doubt about performance and range in the winter unwarranted. Our intelligent thermal management always selects the most efficient methods to heat the battery and the interior appropriately in the winter. As a result, high-voltage batteries have long lifespans, when our customers precondition for each season via what are known as AC charging stations or a home Wallbox. That function is particularly useful in the winter. It goes easy on the cells and simultaneously minimizes range loss because the battery is already in the optimal temperature range and therefore does not need to be heated as much.

How does the cold affect a high-voltage battery?
Pierre Woltmann: The performance of a high-voltage battery is fundamentally dependent on the charge level and the temperature. The colder it is, the less power the battery can provide. Electrochemical processes are a factor in this. At cold battery temperatures, the battery's electric internal resistance increases and the usable capacity decreases. We protect the battery by releasing less amperage at a lower temperature. Additionally, the battery can absorb the waste heat from liquid-cooled high-voltage components like the power electronics, the drive system, and the charger and be heated directly by a cooling agent heater.

What are the effects of cold on charging?
Woltmann: Charging can take longer at low battery temperatures. For that reason, the battery has to be heated during charging, ideally even on the way to charging. Upon connecting with the charging point, the vehicle automatically communicates with the power source.

That's how the charging point knows how much electricity the battery can absorb at any time. So we ensure that the battery isn't overloaded. When it's charging, the battery draws the electricity it needs for heating power from the charging point.

What is the job of thermal management?
Thomas Anzenberger: Basically, thermal management is responsible for distributing the heat flows between the drive system, the high-voltage battery, and the interior. Our heat pump system has acquitted itself well in this context above all. It converts energy from the powertrain or the surrounding air. That is heat that is available for the battery or, in the winter, for the interior as well. Using the surrounding air as an energy source is relatively new: we use it to balance the declining waste heat from the powertrain, which operates increasingly efficiently. That way, we have access to two mutually independent systems via the powertrain and the surrounding air, which we use to heat the interior and the high-voltage battery.

How is the temperature of the battery and the interior regulated while driving?
Anzenberger: In order to ensure a reliable supply of heat even in very cold temperatures, our heat pump system, which is built into most of our electric models, integrates additional high-voltage heaters into the operating strategy. This ensures a comfortable interior even in extreme situations and quickly produces the ideal battery temperature of about 25 to 30 degrees Celsius (*77 to 86 degrees Fahrenheit*) for maximum performance. A second electric heater is available in our winter package for the particularly cold northern countries. An additional heater for electric bicycles is also available as an option in some models.

Woltmann: When our customers want to ride with maximum efficiency in cold exterior temperatures, the thermal management algorithm heats the battery to lower temperatures and, while it releases less driving power as a result, it also increases the vehicle's range.

What additional technical solutions has Audi developed to make the high-voltage battery independent of the effects of temperature?
Woltmann: As a point of intersection with thermal management, we offer what is known as preconditioning, which has a positive effect on both the battery and the interior. It is possible to set the precise time of departure with the charging and departure timer – directly in the vehicle or with the myAudi app. As a result, the automatic charging process charges the battery to the preset level and a favorable temperature as close to the departure time as possible. This way, the loss of range is significantly reduced by heating the battery. In addition, preconditioning adjusts the temperature of the vehicle interior to the desired level prior to departure.

Anzenberger: In the e-tron GT quattro* and RS e-tron GT*, conditioning for the charging process even functions automatically while driving in order to achieve consistently high charging capacity at fast-charging stations, namely when the e-tron route planner is used in these models. Depending on the outside air temperature, the intelligent thermal management system then additionally brings the battery to a temperature range that is optimal for charging while the car is driving and before charging starts, in addition to preconditioning.

*The collective fuel/electric power consumption values of all models named and available on the German market can be found in the list provided at the end of this MediaInfo.

This additional mobile preconditioning of the battery in the e-tron GT quattro* and RS e-tron GT* ensures the best and fastest possible charging results.

How does Audi reduce range loss by heating the interior?
Woltmann: Compared with a combustion engine, an electric car has much less waste heat and energy available for heating. The heat that the battery, electric motor, and power electronics generate can be conducted into the interior with a heat pump. Basically, the heat pump works like a refrigerator – but in reverse. The more waste heat is available, the more efficiently the pump works. In the best case scenario, it can generate up to three kilowatts of heat output from one kilowatt of electrical energy. That technology is very useful particularly in the winter because it replaces a thermoelectric heating element. Depending on the external temperature, the heat pump can reach a higher range in comparison with conventional heating.

What can customers who don't have a garage available do?
Woltmann: Anyone who needs more range as soon as they get into the car should precondition. Ideally, it should be done by AC charging, which is generally more efficient than DC charging because there is less power loss due to the lower currents. AC charging is also gentler because it doesn't put as much strain on the battery. There is less amperage flowing with AC charging. The battery can absorb that even at very low battery temperatures, which means that the battery doesn't have to be heated as much. Charging should happen – regardless of whether it is AC or DC – immediately before starting a trip via the departure timer in order to use the higher battery temperature to gain range or immediately after driving in order to utilize the higher battery temperature to charge faster and more efficiently.

What happens to a cold battery at a fast-charging station?
Woltmann: Regardless of the model, the algorithm in the vehicle recognizes when the car is being charged at a DC fast-charging station. The currents are released regardless of the charge level and temperature. With the active heating that we have implemented, we are significantly reducing the charging time in cold temperatures.

When do high-voltage batteries reach their limit?
Woltmann: To protect the battery, we don't release any more electricity starting when the core temperature reaches minus 30 degrees (*-22 Fahrenheit*). But for that to happen, the car would have to be exposed to such an extreme temperature over a long period of time. Obviously it is also possible to drive an e-tron model with a sufficient charge level and a preheated high-voltage battery in external temperatures of minus 30 degrees.

From a technical perspective, what additional advice can you give for the winter?
Anzenberger: By using the car's computer and the range monitor in the Audi MMI with range prediction while driving, customers can directly read how much range they are gaining when, for example, the interior temperature is reduced. The range can be increased with Range Mode. This slightly restricts comfort functions, drive power, and the maximum speed.

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Fuel/electric power consumption of the models named above
Information on fuel/electric power consumption and CO_2 emissions in ranges depend on the tires/wheels used as well as the selected equipment.

Audi e-tron GT quattro
Combined electric power consumption in kWh/100 km (62.1 mi): 21.8–19.9 (WLTP); 19.6–18.8 (NEDC); combined CO_2 emissions in g/km (g/mi): 0 (0)

Audi RS e-tron GT
Combined electric power consumption in kWh/100 km (62.1 mi): 22.5–20.6 (WLTP); 20.2–19.3 (NEDC); combined CO_2 emissions in g/km (g/mi): 0 (0)

Audi e-tron
Combined electric power consumption in kWh/100 km (62.1 mi): 26.1–21.0 (WLTP); 24.3–20.9 (NEDC); combined CO_2 emissions in g/km (g/mi): 0 (0)

The indicated consumption and emissions values were determined according to the legally specified measuring methods. Since September 1, 2017, type approval for certain new vehicles has been performed in accordance with the Worldwide Harmonized Light Vehicles Test Procedure (WLTP), a more realistic test procedure for measuring fuel consumption and CO2 emissions. Since September 1, 2018, the WLTP has gradually replaced the New European Driving Cycle (NEDC). Due to the more realistic test conditions, the consumption and CO2 emission values measured are in many cases higher than the values measured according to the NEDC. Additional information about the differences between WLTP and NEDC is available at www.audi.de/wltp.

At the moment, it is still mandatory to communicate the NEDC values. In the case of new vehicles for which type approval was performed using WLTP, the NEDC values are derived from the WLTP values. WLTP values can be provided voluntarily until their use becomes mandatory. If NEDC values are indicated as a range, they do not refer to one, specific vehicle and are not an integral element of the offer. They are provided only for the purpose of comparison between the various vehicle types. Additional equipment and accessories (attachment parts, tire size, etc.) can change relevant vehicle parameters, such as weight, rolling resistance and aerodynamics and, like weather and traffic conditions as well as individual driving style, influence a vehicle's electric power consumption, CO2 emissions and performance figures.

Further information on official fuel consumption figures and the official specific CO2 emissions of new passenger cars can be found in the "Guide on the fuel economy, CO2 emissions and power consumption of all new passenger car models," which is available free of charge at all sales dealerships and from DAT Deutsche Automobil Treuhand GmbH, Hellmuth-Hirth-Str. 1, 73760 Ostfildern-Scharnhausen, Germany (www.dat.de).