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The bigger, the better? How car battery size affects energy consumption, costs, and emissions

Range anxiety, or the drivers' fear of not reaching their destination or the next charging station on a single battery charge, is often cited as a primary concern for potential buyers and users of battery electric cars. In Europe, the median driving range of battery-powered passenger cars was 419 km in 2022, reflecting a 10% increase over two years. Nearly 60% of Europeans have expressed that a driving range of 500 km is the minimum they would consider for purchasing a battery electric vehicle (BEV).

As longer ranges require larger capacity batteries, concerns are growing over the environmental and economic tradeoff between larger batteries and the actual benefits for drivers. While longer ranges promise autonomy and convenience to the driver, the associated larger battery increases energy consumption and greenhouse gas emissions over a vehicle's lifetime. Furthermore, it increases the vehicle's overall costs due to higher purchase price and operational expenses.

An alternative to a larger battery is opting for a smaller one and using fast charging during longer-distance trips. However, fast charging also comes with some disadvantages. Fast charging is more expensive than slow charging and requires more energy for battery temperature control.

How does battery size impact energy consumption, costs, and greenhouse gas emissions for different vehicle user types? How much do different driver types benefit from a larger battery?

- » Near **60% of Europeans** consider a range of 500 km for their battery electric car as a minimum requirement
- » Car battery sizes are increasing in Europe: a **10% rise** in the median driving range from 2020 to 2022.

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SIMULATION: URBAN, RURAL, LONG-DISTANCE DRIVERS

An ICCT study simulates annual driving profiles for three generic user types over the course of one year: an urban commuter, a rural commuter, and a frequent long-distance driver. The users have access to charging when needed or when convenient. A compact battery electric vehicle is modeled, resembling the Volkswagen ID.3. The effect of battery size is analyzed by simulating four battery capacities: 28, 58, 87, and 116 kWh.

The analysis takes into account the effect of the battery capacity on vehicle mass, the type of charging, and the energy consumption of the thermal management system for the cabin and battery. It also considers the annual ambient temperature variability in Berlin, Germany.

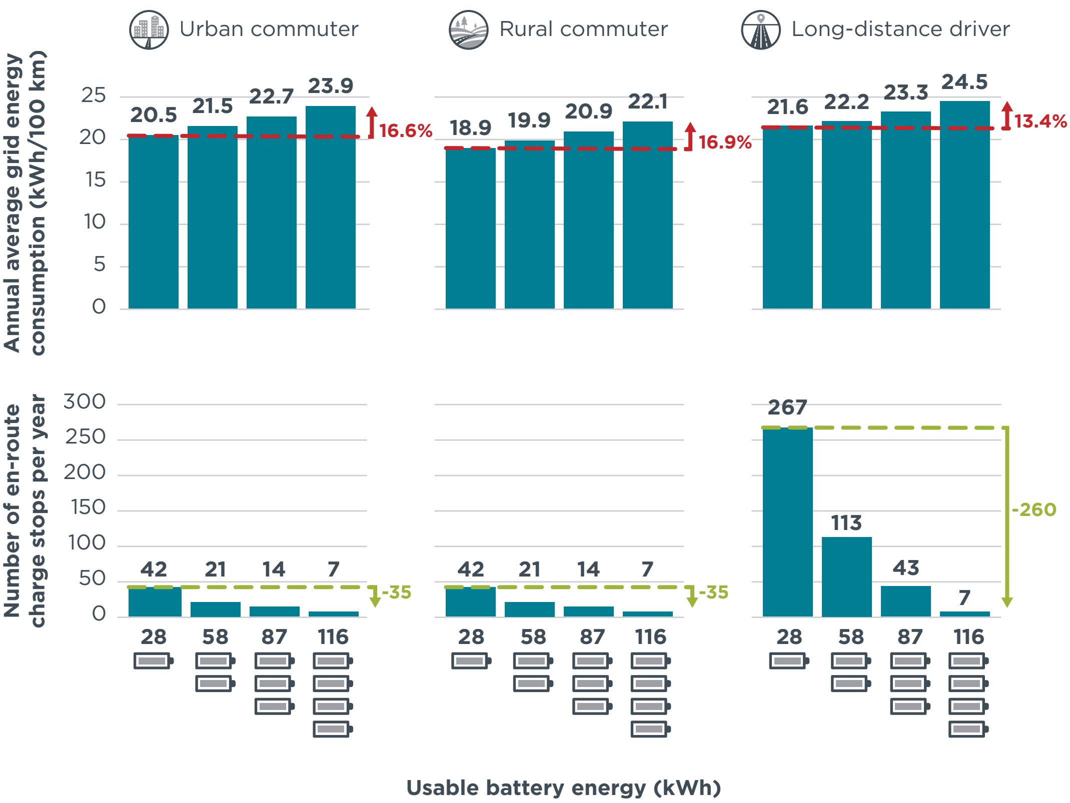
KEY FINDINGS

The simulation results provide insights for consumers and regulators, with the key findings described below and summarized in Figures 1 and 2.

Energy consumption: A larger battery size increases the energy consumption for all users, but only the long-distance driver benefits from a substantial decrease in en-route charging stops. Using a 116-kWh battery instead of a 28-kWh battery increases energy consumption between 13.4% and 16.9% for the three driver types. For long-distance drivers, en-route charging stops per year decrease by 260, or an average of 0.7 charging stops per day. However, urban and rural commuters only save 35 additional stops per year, or an average of 0.14 stops per day, by more than quadrupling the battery size.

Figure 1

Energy consumption and number of charging stops by battery size



Annual average energy consumption and number of en-route fast charging events per year for the simulated compact segment battery-electric vehicle for three user types as a function of usable battery energy

Costs: Doubling the battery electric vehicle range from 250 to 500 km will raise the total cost of ownership by 15% to 23%. The increase in total cost of ownership is more pronounced for the rural and urban driver types, with 20% and 23% higher costs, respectively. The lower energy consumption and purchase price of a vehicle with a smaller battery results in substantially lower expenses despite the higher electricity cost associated with more frequent fast charging.

Emissions: Using a small battery and reducing electric energy consumption contributes to lower vehicle life-cycle greenhouse gas emissions for all users. In relative terms, the urban commuter experiences the biggest increase in emissions when doubling the battery size (20%). This is due in large part to the more frequent and shorter trips of this user type, which requires more frequent cooling or heating of the cabin and battery and thereby increases the energy consumption of the thermal management system.

» Urban and rural commuters will require no charging stop in **98%** of their trips over the year.

» In the case of long-distance trips, doubling the battery range reduces the number of charging stops per day by 2-3.

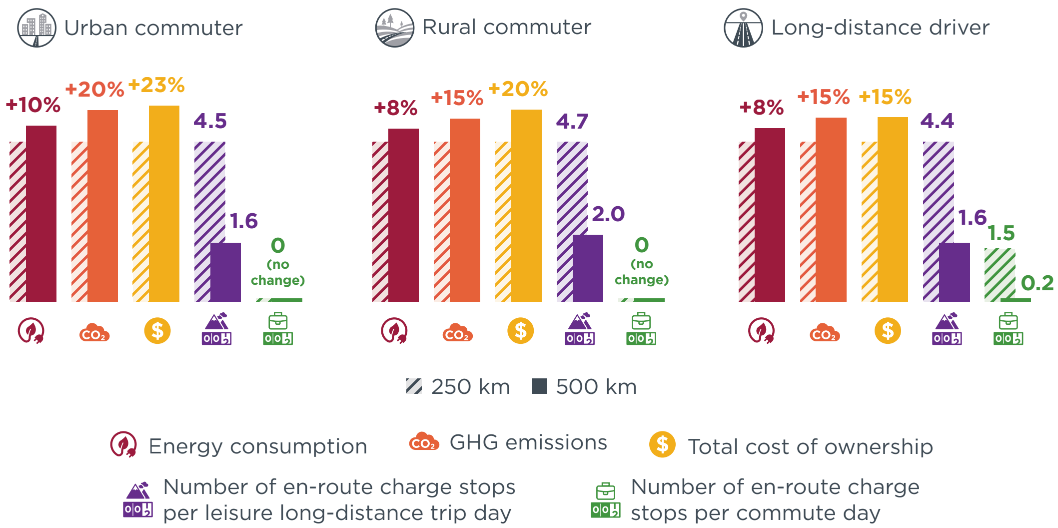
HOW MUCH DO DRIVERS BENEFIT FROM A LARGER BATTERY?

Most of the year, a larger battery does not affect the number of en-route charging stops for the urban and rural driver types. Fast charging stops are only required during long-distance trips. In the case of urban and rural commuters, days with long-distance trips represent less than 2% of those taken in a year. Doubling the range from 250 to 500 km will not decrease the number of days where en-route charging is required but will reduce the number of charging stops per long-distance trip to two.

The long-distance driver will benefit from a longer range with one charging stop less per commute day but at the expense of 15% more in costs. Due to the frequent long-distance trips, the long-distance driver benefits most from a vehicle with a 500-km range compared to a vehicle with a 250-km range. However, for the urban and rural commuter user types, the larger battery comes at a considerably higher cost than a smaller battery combined with fast charging.

Figure 2

Effect of doubling the average real-world range of a compact battery electric vehicle



ABOUT THE METHODOLOGY

In order to simulate a wide range of battery sizes for the same vehicle model, the study uses the Siemens Simcenter Amesim simulation software. The vehicle model data is obtained from a recent test project conducted by the Technical University of Munich (TUM) and from the German car club ADAC database. The thermal management system model is calibrated using findings of a study real-world electric vehicle energy consumption published by the German Federal Environment Agency. The vehicle model is calibrated to match the official Worldwide harmonized Light vehicles Test Procedure (WLTP) energy consumptions values of the reference Volkswagen ID.3 vehicle with a 58-kWh battery and to the consumer-reported values in spritmonitor.de.

PUBLICATION DETAILS

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Authors: Carolina Poupinha, Jan Dornoff

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Contact: Carolina Poupinha, c.poupinha@theicct.org

www.theicct.org

communications@theicct.org

@theicct

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