AVILOO

BATTERY DIAGNOSTICS

WHITE PAPER



BATTERY HEALTH AND BATTERY DEFECTS

Understanding SoH correctly, spotting risks early

The state of health (SoH) determines an EV battery's range, safety, and resale value — but every manufacturer calculates it differently.



This white paper explains:

- HOW SOH IS DETERMINED
- WHY VALUES CAN DIFFER SO WIDELY
- WHICH BATTERY DEFECTS YOU SHOULD KNOW

THE **ONLY** INDEPENDENT EV BATTERY QUICK TEST.

WHAT DOES SoH MEAN?

THE TERM

SoH stands for **State of Health**, the health status of an electric or plug-in hybrid vehicle's battery. E-mobility is a young industry, and to this day there are no uniform standards for calculating SoH – every manufacturer takes a different approach.

AVILOO's starting point is therefore what every EV driver really cares about: range. Because range depends directly on the battery's state of health.



Plug-and-Play: results in 3 minutes.

WHY THIS MATTERS

Unlike a combustion engine, the heart of an electric car – the battery – needs regular checks. Knowing your car's SoH lets you realistically judge the range you can actually achieve and catch usage errors early. That boosts both comfort and driving safety.

THE DATA BEHIND IT

AVILOO holds the market's most extensive database on EV battery degradation behavior. It currently covers more than 96% of all available electric and plug-in hybrid models, built on years of test series, monitoring, and data analysis.

Knowing your battery's state of health can save you an unnecessary investment of up to €22,000 / £18,500 for a new battery.

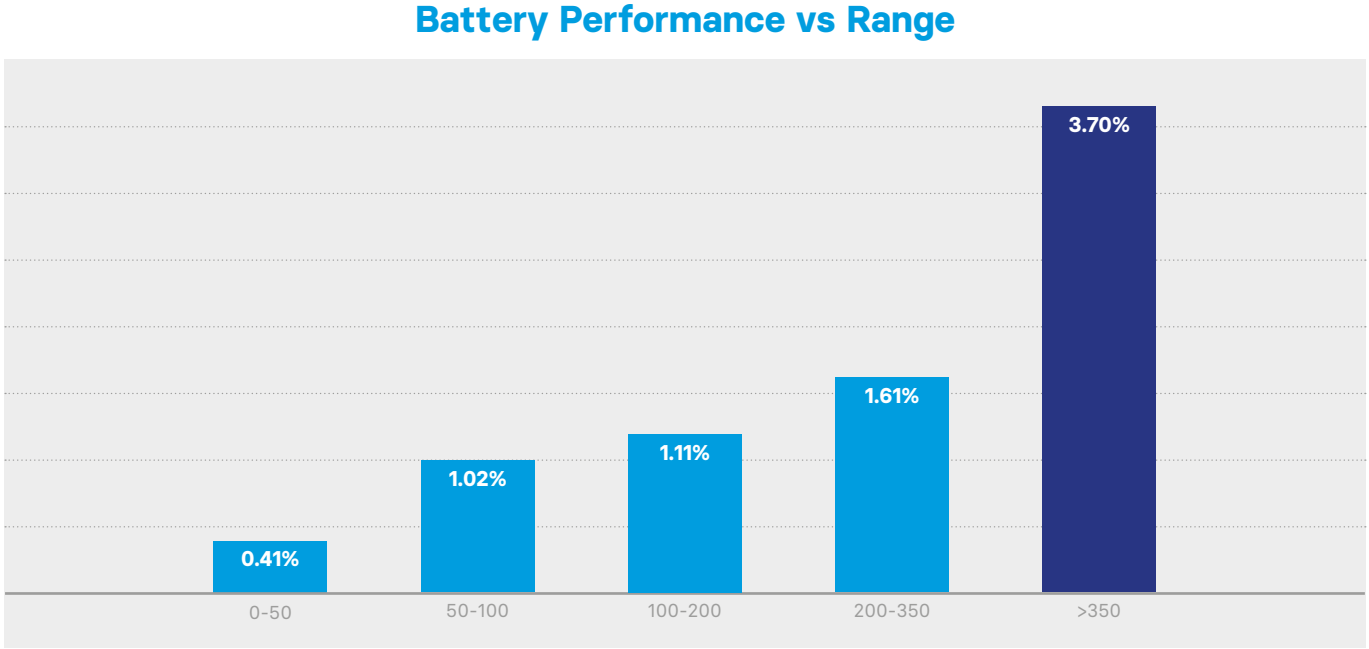


Fig. 1

HOW IS SoH CALCULATED?

SoH cannot be measured directly. It always describes a battery's condition relative to its original condition, and there are different reference values and calculation methods for this.

An overview of the two most important reference values:

→ CAPACITY-BASED SoH

One possible reference value is the battery's capacity, given in ampere-hours. The advantage: in theory, it's independent of temperature and driving style. In practice, however, temperature and the measurement cycle have a considerable influence, and internal resistance is not taken into account.

→ ENERGY-BASED SoH

The extractable energy in kilowatt-hours determines the actual range and is therefore the most meaningful reference value: 90% SoH then really means 90% of the original range. The drawback lies in its complexity, since extractable energy depends heavily on temperature and load profile.

For vehicles, a fixed load profile is therefore used as the basis: the WLTP cycle at 23°C.

THE WLTP APPROACH

WLTP stands for Worldwide Harmonised Light Vehicles Test Procedure, a globally standardized test procedure for vehicle consumption. WLTP data is meant to reflect a driving profile as realistic as possible, taking various influencing factors into account.

The formula behind it is simple: current WLTP divided by WLTP when new. The problem: to correctly determine "WLTP current," the car would actually have to be driven according to the WLTP standard, which is time-consuming, expensive, and barely practical for everyday use. The reference value for new condition can at least be taken directly from the manufacturer's data sheet.

The energy-based SoH is the only reference value where the percentage directly corresponds to real-world range. That's why AVILOO relies on this approach for all its tests.

> ***Increased internal resistance reduces the vehicle's range. Especially in older vehicles, this causes the capacity based SoH to become inaccurate and tend to read too high.***
>
> Patrick Schabus, Chief Product Officer AVILOO



FROM PACK TO INDIVIDUAL CELL

CALCULATION AT PACK LEVEL

The simplest method determines battery health directly from the entire pack. It's fast but imprecise: energy can only be drawn as long as every single cell operates within its specified range. This method says nothing about the health of individual cells.

CALCULATION AT CELL LEVEL

When SoH is determined at the cell level, you also know the state of charge and balancing status of every cell. Three methods are used to calculate the pack's overall SoH:

AVERAGE	The pack SoH is the average of all cell SoHs. Not recommended – the deviation from real-world range can be large.
WEAKEST CELL	The weakest cell determines the overall SoH – like the weakest link in a chain. Significantly more accurate than the average.
SoCE	State of Certified Energy from the GTR22 standard. AVILOO combines this by pairing cell level energy-based SoH with the weakest cell and the balancing status.

HOW THE PREMIUM TEST CALCULATES

The PREMIUM Test relies on energy-based SoH, measured at the cell level. The formula:

$$\frac{\text{Current energy content}}{\text{Energy content when new}} \times 100$$

Current energy content: measured usable energy of the test vehicle.

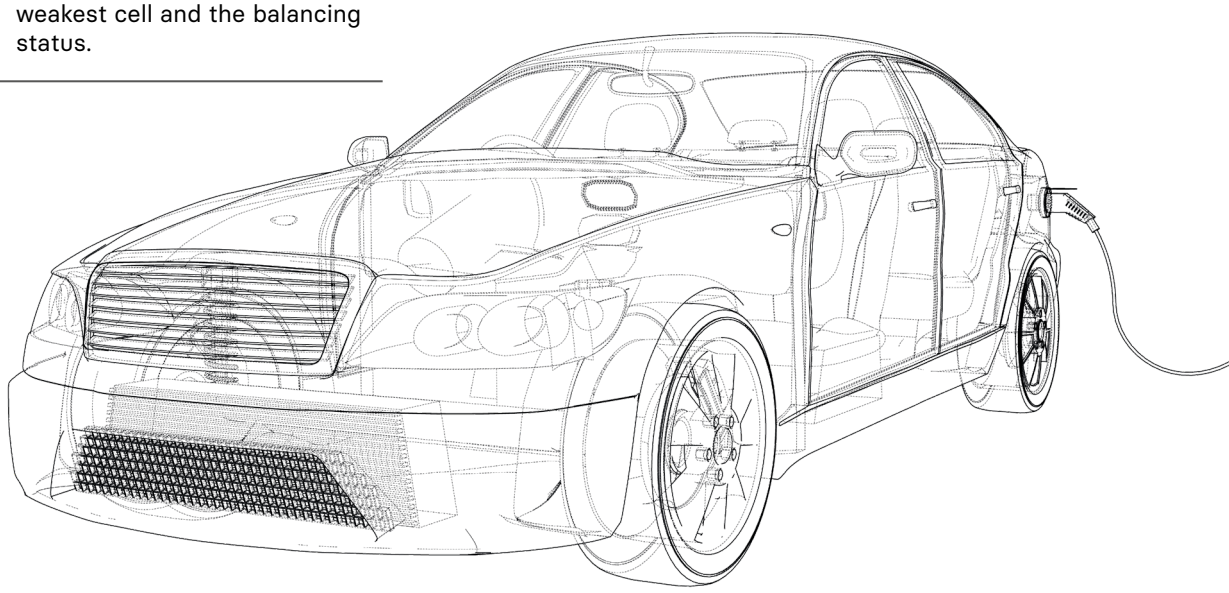
Energy content when new: measured usable energy in new condition.

AVERAGE

A vehicle model has a battery capacity of 60 kWh when new. The AVILOO PREMIUM Test determines an extractable capacity of 54 kWh.

54 kWh ÷ 60 kWh = 0,9 → **SoH von 90%**

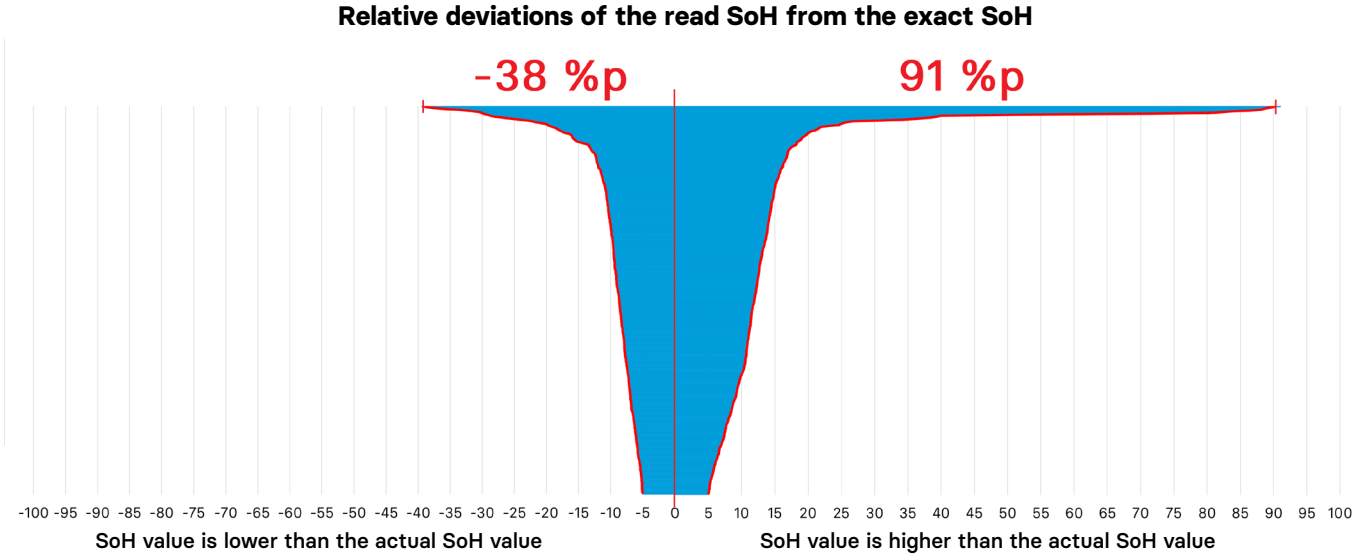
So that temperature and driving style don't distort the result, every measurement is additionally compensated to a battery temperature of 25°C and to a discharge rate corresponding to the WLTP cycle.



WHY SoH VALUES DIFFER SO WIDELY

SoH values from different sources are fundamentally not comparable. In an analysis of 1,000 vehicles, AVILOO compared the SoH value read out from the vehicle with the actual value calculated from real data. The results show some substantial deviations.

DIFFERENCE BETWEEN THE READ SOH AND THE ACTUAL SOH



THREE REASONS FOR THE DISCREPANCIES

1. Technical limits in the BMS.
The battery management system calculates SoH using small, power-limited processors. Many of them reach their limits in the process. The AVILOO Battery Data Cloud, by contrast, works with far greater computing power and continuously learns.

2. Real data instead of extrapolation.
An exact SoH value requires data from an actual charging or discharging process. The BMS instead works with statistically extrapolated lab data.

3. Different methods.
Every manufacturer uses its own rules and reference values – one calculates via discharging, another via charging. This alone causes a spread of roughly +15 to -10 percent; the rest comes down to inaccuracies in the algorithms.

A real-world example: A customer had their SoH read out – result: 80%. After a software update at the workshop, the same vehicle suddenly showed 100%, even though nothing about the battery had changed.

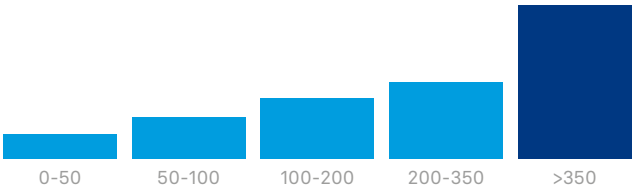
CONCLUSION: Only an independent test based on real measured data rather than extrapolations delivers an SoH value that's genuinely comparable across different vehicles and brands.

DETECTING BATTERY DEFECTS EARLY

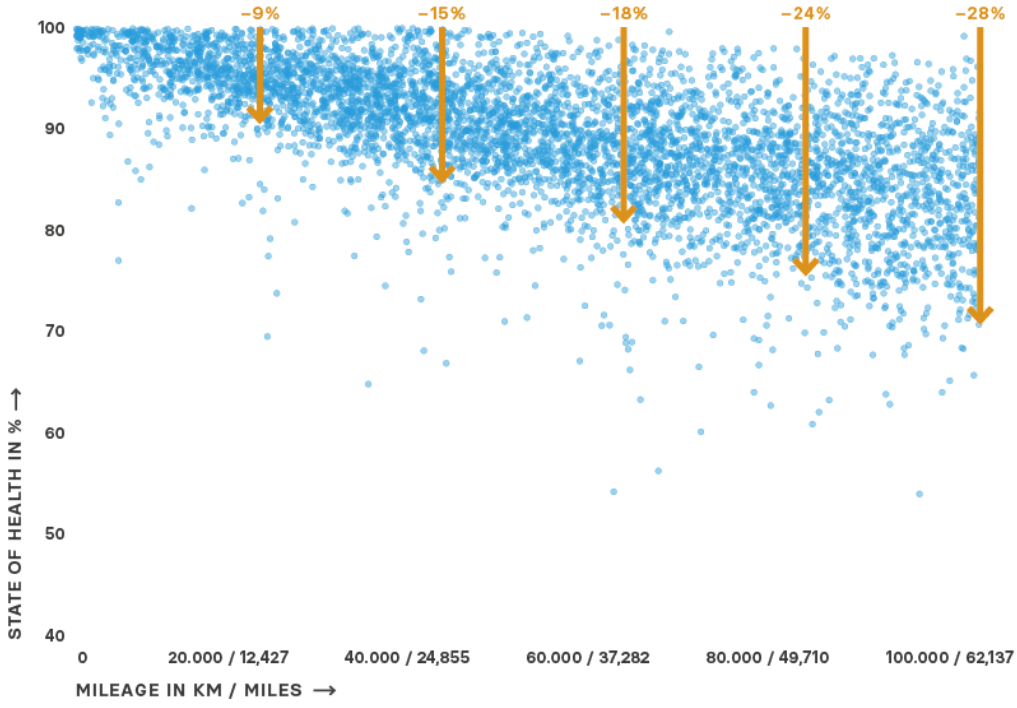
Across tens of thousands of tests, AVILOO registers one to two battery defects per 100 tests. Detecting them early is crucial for two reasons: safety and warranty. A defective battery can lead to sudden power loss, overheating, or, in extreme cases, complete failure. Many manufacturers offer warranties for repair or battery replacement, but the terms are often opaque for customers. Anyone who reports and documents defects early can more easily enforce warranty claims.

BATTERY DEFECTS BY MILEAGE

As mileage increases, the number of cell abnormalities rises significantly. This underscores how important regular testing is, especially for older and used vehicles.



Share of battery defects per 1,000 km / 621 miles of mileage: from 0.41% (0 to 50,000 km / 31,069 miles) to 3.70% (over 350,000 km / 217,480 miles).



SoH progression of real vehicles by mileage: the more kilometers driven, the greater the spread between individual vehicles.

FOUR TYPES OF BATTERY DEFECTS

BMS issues. Monitors voltage, temperature, and charge level of every cell. Measurement errors can, in rare cases, lead to incorrect balancing, often fixable through recalibration.

Increased internal resistance. Usually increases with age, extends charging and discharging times, and can cause voltage drops under intensive driving.

Aging. A certain amount of capacity loss is unavoidable. Since the weakest cell determines the overall condition, replacing a single module can significantly improve the battery.

Mechanical deformation. With every charge and discharge cycle, particles migrate between the electrodes. Usually reversible, though permanent damage is possible after an accident.

REDUCING RISK, INCREASING SAFETY

PHEV OR BEV: AN IMPORTANT DIFFERENCE

In plug-in hybrids, the battery is significantly smaller relative to vehicle size and weight than in fully electric cars. In addition, how often the purely electric driving mode is used at all affects battery condition. This makes PHEVs and BEVs not directly comparable when it comes to battery diagnostics.

FIRES ARE RARE, BUT SHOULD BE TAKEN SERIOUSLY

The probability of a battery fire is very low. It's usually preceded by what's known as thermal runaway – overheating that spirals out of control, triggered by short circuits, overcharging, or thermal overload. Modern battery management systems and stable cell designs reliably protect against this. Still, the rule applies: the older the battery and control unit, the more important regular checks become.

FIVE TIPS FOR A LONG-LASTING BATTERY

- **Moderate driving style:** hard acceleration puts unnecessary strain on the cells.
- **Correct charging:** smaller, more frequent charges are better than a few full charges.
- **Preconditioning:** eases strain on the battery and speeds up charging, especially in winter.
- **Use fast charging sparingly:** only use it when truly necessary.
- **Test regularly:** this way anomalies are caught before they become a problem.

HOW AVILOO HELPS

Both AVILOO tests, FLASH and PREMIUM, analyze the battery down to the cell level and uncover anomalies that often don't trigger an error code in the BMS.

The **PREMIUM Test** measures the battery over a longer period and determines internal resistance down to the cell level. It also holds TÜV certification.

The **FLASH Test** delivers a result in just three minutes, making it ideal for vehicle dealers and quick everyday decisions.

The **AVILOO Battery Warranty** is the world's first warranty for EV batteries. It builds on the AVILOO FLASH Test: every qualifying vehicle receives it automatically and free of charge, with a one-year term, 20,000-kilometer coverage, and €3,000 compensation if the SoH limit is not met.





Vehicles with no abnormalities in the FLASH Test receive the AVILOO Certified seal – a clear signal of trust for buyers.



Every qualifying vehicle automatically receives the free Battery Warranty – clear protection for buyers.

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5 Years ISO 9001

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