

Optimizing Battery Lifespan:

How Vehicle-to-Grid and Smart Charging
Influence EV Battery Aging





Introduction

There is currently much discussion surrounding the durability and performance of electric vehicle (EV) batteries, as they are among the most critical and costly components of the vehicle. A common concern is that frequent charging cycles could negatively impact the battery's lifespan.

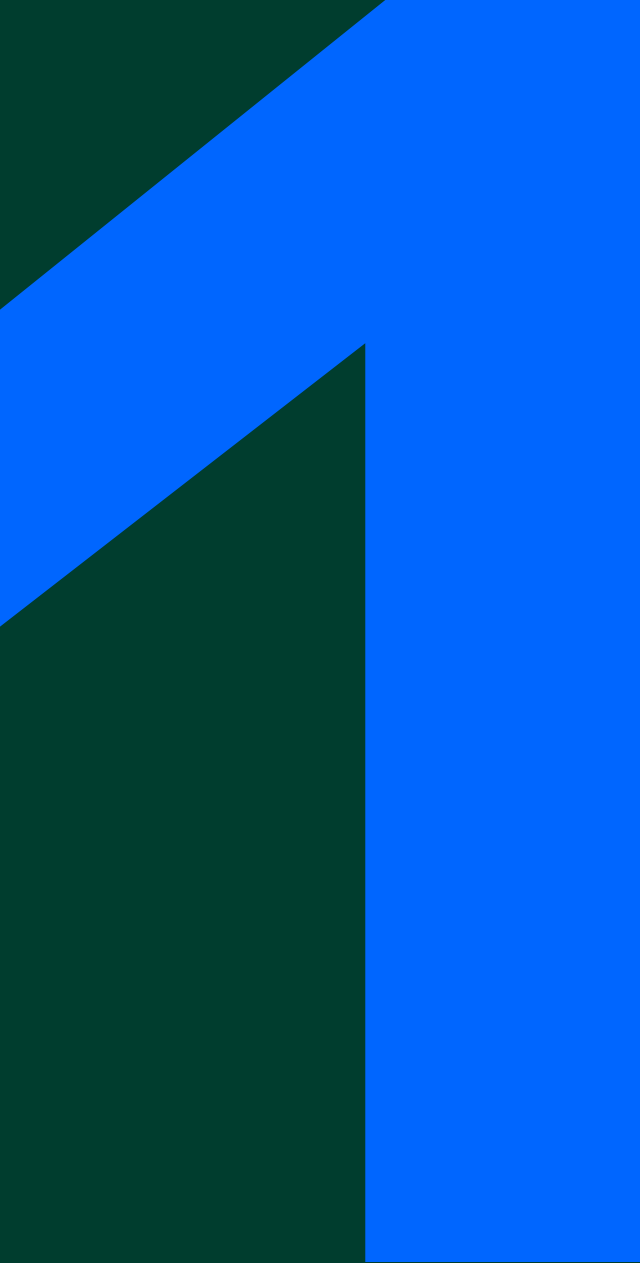
To address these concerns, The Mobility House Energy - the leading expert in smart and grid-integrated charging - and RWTH Aachen University conducted a joint study to examine the long-term effects of charging processes, with a particular focus on Vehicle-to-Grid (V2G) applications and their impact on EV batteries.



Raphael Hollinger
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Overview and Objective

The main objective of the study was to analyze the longterm effects of smart charging (V1G), **bidirectional charging (V2G)**, and immediate charging (IC) on various battery cell types available on the market.





Methodology



Simulation of Battery Usage

over a period of ten years based on empirical aging models for the following scenarios:

- **Smart Charging (V1G)**

Smart charging optimizes the **charging process over time** – taking into account grid load, electricity prices, and individual departure times. The goal is to shift charging into periods with more favorable energy availability while keeping the battery in its optimal charge range with minimal aging.

In the simulation, charging takes place at a **constant power of 11 kW** within defined time windows. The state of charge is managed to avoid prolonged periods at high State of Charge (=amount of energy stored in a battery in %, SoC).

- **Bidirectional Charging (V2G)**

With bidirectional charging, the vehicle battery is not only charged but can also be **discharged into the power grid or household grid when needed**. The vehicle serves as a mobile energy storage system that can flexibly respond to grid requirements or market signals.

In the simulation, charging and discharging occur at **11 kW based on a realistic driving profile**. The charge cycles (Depth of Discharge, DoD = discharge depth in percent) are predominantly small (<30%) and remain in the mid-charge range (20–80% SoC) to minimize aging.

- **Immediate Charging (IC)**

With immediate charging, the **charging process starts immediately after connecting the vehicle** – at full charging power until the maximum state of charge (90%–100% SoC) is reached, regardless of price or grid signals.

In the simulation, this behavior was assumed as the baseline and worst-case scenario, since it leads to long periods at high SoC, accelerating aging. Cyclical effects from full charging cycles are also considered, with no optimizing measures such as charge target limits or scheduled charging being applied.



Taking into account:

- Calendar aging (i.e., aging over time)
- Cyclical aging (i.e., aging caused by charging and discharging cycles)



Selection of Representative Automotive Cells:

- Cylindrical cell (e.g. Tesla, Lucid, BMW, etc.)
- Pouch cell (e.g. GM, Ford, Nissan, VW, etc.)
- Prismatic cell (e.g. Nio, BYD, etc.)

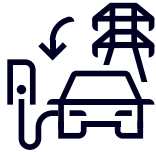


Calculation of State of Energy (SOE)

profiles, based, among other factors, on trading activities generated by the “multimarket” algorithm - i.e., the marketing of energy across multiple markets simultaneously.



Results



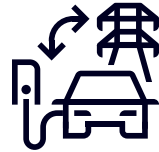
Smart Charging (V1G) significantly reduces aging by minimizing calendar aging and avoiding long periods at high state of charge.

After 10 years, V1G leads to a **reduction in battery aging** of between **3.3 and 6.8 percentage points**.*

This corresponds to a **capacity gain** of **1.8 – 3.6 kWh**, or an additional **10.9 – 22.5 km of range** according to WLTP standards.

Taking current energy market conditions into account, smart charging provides customers with a monetary **benefit of €2,000 – €4,000** over a ten-year period.

*percentage points



Bidirectional Charging (V2G) only has a minimal impact on overall battery aging, as the additional charge cycles occur predominantly in the mid-charge range (20%-80% SoC) and with small charge depths (<30% DoD).

After 10 years, the **additional aging** caused by V2G ranges between **1.7 and 5.8 percentage points**.

This corresponds to a capacity loss of **0.9 – 3.1 kWh**, or **5.8 – 19.2 km of range** according to WLTP standards.

Replacing this lost capacity would cost approximately €100–€300 today, while V2G delivers a **monetary benefit of €6,000 – €10,000** to the customer over a ten-year period.



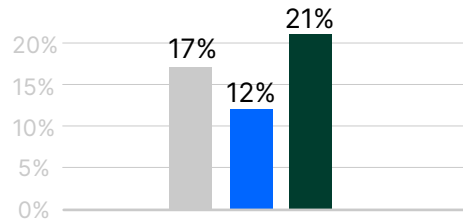
Immediate Charging (IC) is the least favorable option, as it does **not** allow for **battery monetization** and simultaneously leads to **higher battery aging** (and increased stress on the power grid).

The increased aging in this scenario arises not primarily from many charging and discharging cycles, **but mainly from long periods at high state of charge**. A consistently high SoC significantly accelerates the calendar aging of battery cells.”

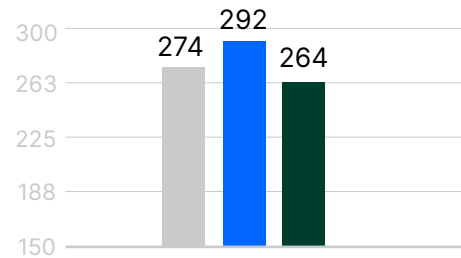
Results



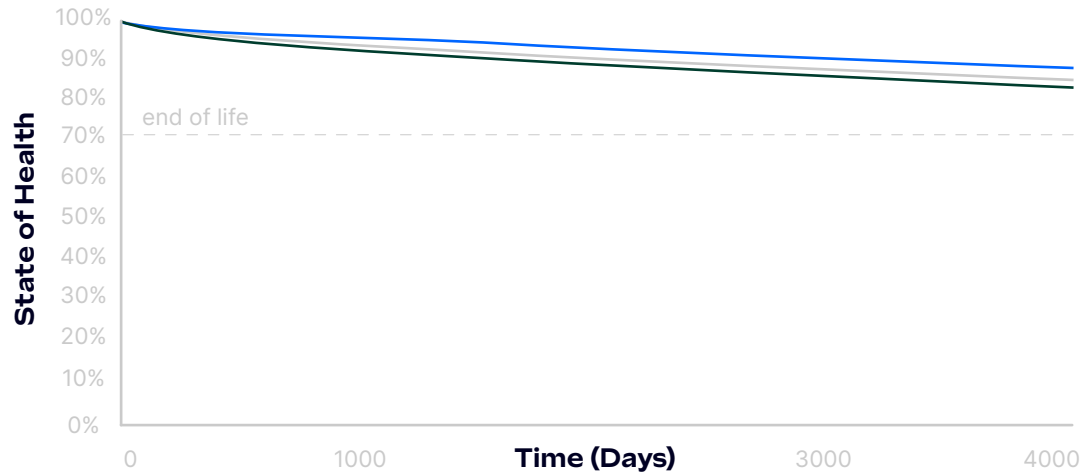
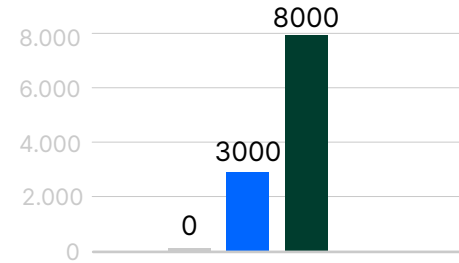
**Battery degradation
after 10 years in %**



Reach after 10 years in km



**Financial benefit
after 10 years in €**



- Instant Charging (IC)
- Smart Charging (V1G)
- Bidirectional Charging (V2G)



Involved Organizations & Experts

The [Mobility House Energy](#), [ISEA Institute](#) of RWTH Aachen at CARL (Center for Ageing, Reliability and Lifetime Prediction of Electrochemical Power Electronic Systems)

THE MOBILITY HOUSE
Energy

CARL
Center for Ageing, Reliability
and Lifetime Prediction of
Electrochemical and Power
Electronic Systems

RWTH AACHEN
UNIVERSITY





Background

The investigation of battery aging in the V2G context helps to better leverage the advantages of electric vehicles and renewable energy, develop economically viable and sustainable solutions, and fully unlock the potential of V2G technologies.

- **Battery lifespan and reliability:**
Batteries in electric vehicles have a limited lifespan, which is influenced by charging and discharging cycles as well as other factors such as average state of charge and temperature.
- **Optimizing V2G-usage:**
A solid understanding of aging processes enables the design of V2G services in a way that minimizes battery degradation
- **Grid stability and energy storage:**
V2G systems have the potential to enhance grid stability and better integrate renewable energy by serving as flexible storage solutions.
- **Development of Improved Battery Management Systems (BMS)**
When BMS and energy market operators work in alignment, V2G operation becomes especially gentle on the battery. Battery limits can be better communicated and considered in energy trading.
- **Sustainability and environmental protection:**
Longer battery lifespans reduce the environmental impact of battery production and disposal. This is clearly reflected in the emission-reducing effects of V1G and V2G:
 - V1G = -0.2 tCO₂/EV/a
 - V2G = -1.2 tCO₂/EV/a

*tCO₂ / EV / a = tons of CO₂ per electric vehicle per year





Additional Information:

Vehicle-to-Grid [Factsheet](#)

[Projects](#) realized by The Mobility House Energy



About The Mobility House

The Mobility House is shaping the future of energy and mobility. Founded in 2009, the technology company operates worldwide from Munich, Zurich, London, Paris, Singapore, and Belmont (CA).

About The Mobility House Energy

The business unit The Mobility House Energy integrates EV and stationary batteries into the energy system – increasing flexibility, maximizing value, and reducing CO₂ emissions. With its proprietary technologies FlexibilityAggregator and FlexibilityTrader, the company controls, optimizes, and trades storage assets across multiple markets. In 2024, The Mobility House Energy, together with Mobilize (Renault Group) and Renault, launched the world's first commercial Vehicle-to-Grid product in France.

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