

# Out-of-Balance Batteries Have Shorter Lives

At the most fundamental level, batteries lose capacity due to two factors:

1. Cell degradation – Degradation of the electrochemical and/or mechanical properties of the cells.
  - Cells degrade whenever a battery is used. Cell degradation inevitably leads to end of life of the battery. This is why batteries don't last forever.
2. Out of balance cells – Cells with mismatched capacity and/or mismatched SOC.
  - Out-of-balance is a separate phenomenon from cell degradation. Out of balance cells prevent the battery from being fully charged or fully discharged. Once cells get out of balance, the condition worsens with each charge/discharge cycle, steadily eroding battery capacity and accelerating the journey to the battery's end of life.

A battery reaches end of life when its state of health (SOH) drops below a threshold, typically 80%. When the battery gets out of balance its SOH declines steadily, which means that the battery reaches end of life prematurely.

If you can eliminate out of balance conditions, you can end premature battery death and maximize battery life.

# How True Balancing Extends Battery Life

## **The Impact of True Balancing on Battery Life**

To estimate the impact of True Balancing on battery life, we analyzed samples of lithium-ion batteries from six different battery manufacturers. All six of the batteries were made by tier-2 manufacturers in Asia. All six are large manufacturers. Each is among the top 20 battery manufacturers in the world by production volume.

All of the batteries that we analyzed use passive balancing. We analyzed the rate at which these batteries lose capacity. We then analyzed how these batteries would perform if they switched to True Balancing. The charts on the following pages show the results of that analysis.

# Loss of Capacity With Passive Balancing

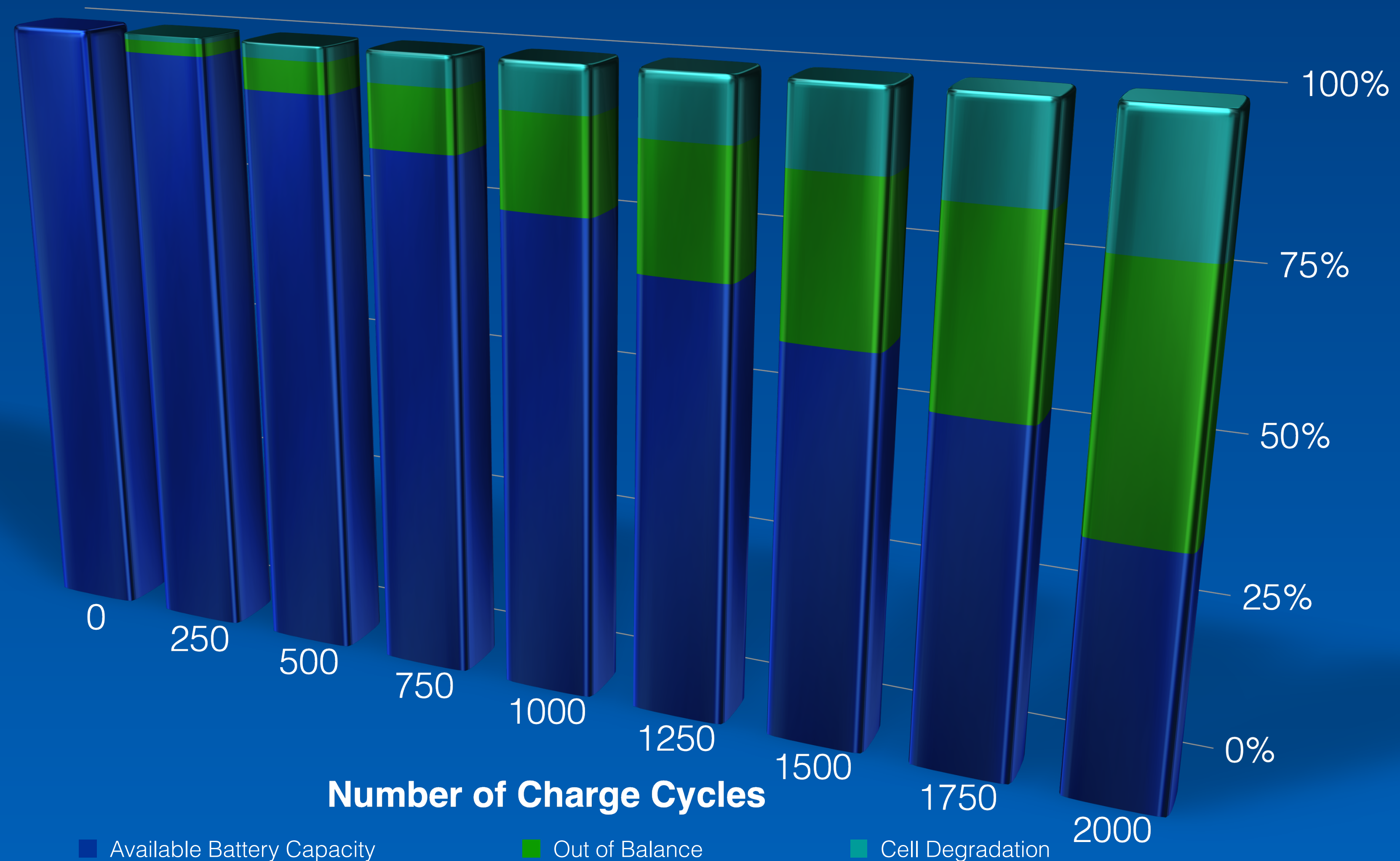
Our analysis indicated that the batteries reached 80% SOH (end of life) at about 1000 charge/discharge cycles.

This performance would not be accepted by any major EV manufacturer.

Note that most of the loss of capacity is due to out of balance cells. A fraction of the loss of capacity is due to cell degradation.

*Note: We didn't put all of the batteries through 2000 charge/discharge cycles. We relied on circuit analysis and modeling to get these results. Two of the manufacturers provided data on rate of degradation of their cells, which was used in this analysis.*

*We showed our results to three of the battery manufacturers. They confirmed that our analysis accurately reflects the performance of their batteries.*





# Loss of Capacity With True Balancing

True Balancing can double the lives of the batteries that we analyzed — from 1000 to 2000 charge/discharge cycles. This is achieved by eliminating loss of capacity due to out of balance cells.

This analysis was performed on batteries made by tier-2 manufacturers. Batteries made by tier-1 manufacturers will perform better than tier-2 batteries.

True Balancing probably can't double the life of tier-1 batteries. However True Balancing will significantly extend the life of any battery by completely eliminating loss of capacity due to out of balance cells.

