NREL battery lifespan

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The researchers use lab evaluations, electrochemical and thermal data analysis, and multiphysics battery modeling to assess the performance and lifetime of lithium-ion battery systems to determine:

Battery health is readily diagnosed in lab settings but can be difficult to measure during energy storage system operation, as common lab diagnostic tests require long times or expensive test equipment to perform. NREL researchers use physics-based models and machine learning to enable rapid, scalable diagnostic tests to analyze electrochemical data and monitor battery health metrics.

State-observer algorithms, such as Kalman filters, can also help estimate battery state-of-charge and state-of-health during real-world use. Using accelerated aging data, NREL developed dual-Kalman filters that update state-of-charge and state-of-health from battery voltage responses while also estimating predictive life model parameters to calculate the remaining useful life or simulate the battery degradation trajectory.

Given that batteries degrade with use and storage, predictive models of battery lifetime must consider the variety of electrochemical, thermal, and mechanical degradation modes, such as temperature, operating windows, charge/discharge rates, storage environment, and cycling patterns. NREL uses expert insight and machine learning to identify accurate and robust models for battery life prediction with the AI-Batt tool. AI-Batt empowers rapid fitting of complex battery degradation trends with a comprehensive set of data visualization, model identification, and model simulation tools.

This suite of tools pairs NREL"s high-fidelity battery degradation model with electrical and thermal performance models for modeling battery cells, packs, and systems. Open-source models for battery lifetime are provided for users to explore battery life research questions.

NREL battery life modeling capabilities include the state-of-the-art BLAST suite, extending expensive laboratory battery-aging datasets to real-world scenarios and pack architectures. The model captures degradation effects due to both calendar time and cycle aging, including constant discharge/charge cycling, as well as more complex cycling profiles, such as those found in vehicles and grid storage applications.

Multiphysics models are also used to provide feedback during the cell design process. Compared to experimentation, physical models of stress and degradation allow engineers to better understand the impacts of design concepts on battery lifetime to optimize the design process. For example, multiphysics models can inform designers to reduce stresses in an electrode stack to avert a shortened lifespan, such as those caused by fast charging.

With validated models of battery performance and lifetime, battery controls or energy storage system designs can be optimized for revenue, lifetime, or reliability. Researchers use health-aware dispatch to meet key battery performance requirements while minimizing degradation. Optimization of energy storage system design can be performed by techno-economic modeling tools, such as the Renewable Energy Integration and Optimization platform and System Advisor Model, which incorporate NREL"s predictive battery life models.

Research at NREL is optimizing lithium-ion (Li-ion) batteries used in electric vehicles (EVs) and stationary energy storage applications to extend the lifetime and performance of battery systems. Battery lifetime predictive modeling considers numerous variables that factor into battery degradation during use and storage, including:

BLAST-Lite is a simplified version of NREL"s battery lifetime models for a variety of Li-ion battery designs, parameterized from lab data available in Python or MATLAB. BLAST-Lite can be easily implemented into larger techno-economic analysis tools and is currently used by the System Advisor Model and Renewable Energy Integration and Optimization platform. BLAST-Lite incorporates example load profiles for stationary energy storage or vehicle applications and temperature profiles for U.S. cities.

NREL"s BLAST suite provides insight into research or engineering problems related to the design, economics, controls, or thermal management for common use-cases of battery energy storage systems.

Researchers can use BLAST tools to simulate the lifetime performance of stationary energy storage applications, such as behind-the-meter residential systems, corner charging stations for EVs, and utility-scale energy storage.