



Hawai'i Natural Energy Institute Research Highlights

Electrochemical Power Systems

Battery Intelligence: Diagnosis and Prognosis

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to develop approaches, tools, and protocols to improve batteries diagnosis and prognosis via non-invasive in-operando techniques.

BACKGROUND: Battery diagnosis and prognosis is a difficult task. Lithium- and sodium-ion batteries are much more complex than traditional batteries and their degradation is path dependent as different usages (current, temperature, state of charge range/window, etc.) will lead to different type of degradation. In addition, since large battery packs are composed of thousands of cells, the use of complex models or multitude of sensors is precluded.

Traditionally, battery diagnosis is handled via two opposite approaches. The academic route aims for maximum accuracy and achieves it by inputting a lot of resources. The second route, the one usually used on deployed systems, uses as little resources as possible and must not be destructive. As a result, it is ineffective in predicting the true state of health.

PROJECT STATUS/RESULTS: This assessment led HNEI to define and develop a third industry-compatible intermediate route to reach an accurate diagnosis with cost-effective and non-destructive methods, using only sensors already available in battery packs while requiring limiting computing power. HNEI developed a mechanistic modeling framework where a battery digital twin is built from individual electrode data and where the battery degradation is emulated by the scaling or the translation of one electrode versus the other. Using this framework, the voltage variations associated with

the degradation mechanisms can be predicted.

Machine learning and artificial intelligence are also starting to play a crucial role in diagnosing and prognosing batteries. However, their accuracy is limited by the little to no training data available to validate algorithms. To solve this issue, HNEI applied the mechanistic modeling approach to develop the first synthetic training datasets. Recent work highlighted the possible opportunistic diagnosis of battery usage for photovoltaic-connected batteries using models trained and validated on synthetic datasets.

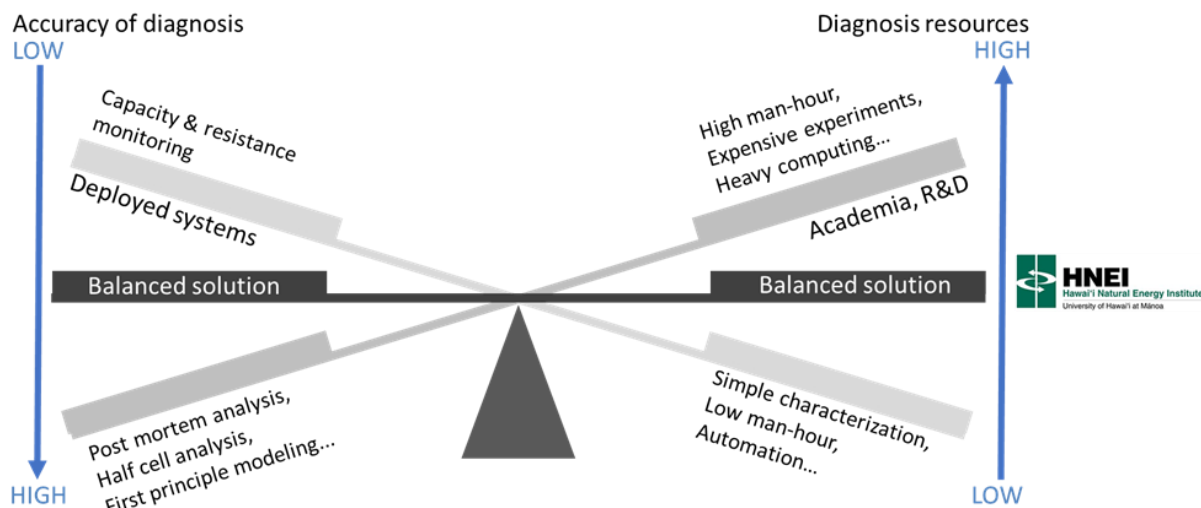
This project is currently ongoing with four industrial collaborations on different aspects of the problem including blends, silicon content, relaxation, and metal plating. Research conducted for this project is completed in the [PakaLi Battery Laboratory](#).

A full suite of software and models were developed. The main model has been licensed by more than 150 organizations worldwide. This work has also led to a patent and over 55 publications, all available on the [project page](#) with the most recent linked on the following pages.

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ADDITIONAL PROJECT LINKS

PAPERS AND PROCEEDINGS:

Battery Testing

1. 2025, T. Rüther, et al., [Battery pack states, properties, and characterization techniques beyond cell level](#), Cell Reports Physical Science, Vol. 6, Paper 102919. (Open Access: [PDF](#))
2. 2025, A. Fernando, et al., [Model-Free Emulation of the Impact of Kinetics and Temperature on Commercial Li-ion Batteries](#), Journal of Power Sources, Vol. 654, Paper 237796.
3. 2024, D. Beck, A. Greszta, A. Roberts, M. Dubarry, [Improved Mechanistic Degradation Modes Modeling of Lithium and Sodium Plating](#), Batteries, Vol. 10, Issue 12, Paper 408. (Open Access: [PDF](#))
4. 2024, M. Dubarry, et al., [Communication—Forecast of the Impact of Degradation Modes on a Commercial Hard Carbon/Na₃V₂\(PO₄\)₂F₃-based Na-ion Battery](#), Journal of the Electrochemical Society, Vol. 171, Issue 8, Paper 080541. (Open Access: [PDF](#))
5. 2024, A. Fernando, et al., [Voltage relaxation characterization methods in lithium-ion batteries](#), Measurement: Energy, Vol. 3, Paper 100013. (Open Access: [PDF](#))
6. 2024, A. Fernando, et al., [Benchmark dataset for the study of the relaxation of commercial NMC-811 and LFP cells](#), Cell Reports Physical Science, Vol. 5, Issue 1, Paper 101754. (Open Access: [PDF](#))

Battery Modeling

1. 2025, P.O. Mmeka, M. Dubarry, W.G. Bessler, [Physics-Informed Aging-Sensitive Equivalent Circuit Model for Predicting the Knee in Lithium-Ion Batteries](#), Journal of the Electrochemical Society, Vol. 172, Issue 8, Paper 080538. (Open Access: [PDF](#))
2. 2025, G. Darikas, M. Dubarry, A. Barai, M. Amor-Segan, D. Greenwood, [Assessment of the Impact of Silicon on Loss of Active Material Quantification in Blended Silicon/Graphite Negative Electrodes](#), Journal of the Electrochemical Society, Vol. 172, Issue 8, Paper 080536. (Open Access: [PDF](#))
3. 2025, F. Yasir, S. Sepasi, M. Dubarry, [Big Data Study of the Impact of Residential Usage and Inhomogeneities on the Diagnosability of PV-Connected Batteries](#), Batteries, Vol. 11, Issue 4, Paper 154. (Open Access: [PDF](#))
4. 2024, M. Dubarry, et al., [Investigation of the impact of different electrode inhomogeneities on the voltage response of Li-ion batteries](#), Cell Reports Physical Science, Vol. 5, Paper 102138. (Open Access: [PDF](#))
5. 2024, D. Beck, et al., [Electrode Blending Simulations Using the Mechanistic Degradation Modes Modeling Approach](#), Batteries, Vol. 10, Issue 5, Paper 159. (Open Access: [PDF](#))
6. 2024, N. Costa, et al., [ICFormer: A Deep Learning model for informed lithium-ion battery diagnosis and early knee detection](#), Journal of Power Sources, Vol. 592, Paper 233910. (Open Access: [PDF](#))

PRESENTATIONS:

1. 2025, P.O. Mmeka, et al., [A Physically-Informed and Aging-Sensitive Equivalent Circuit Model for Predicting the Knee in Lithium-Ion Batteries](#), Presented at the 248th ECS Meeting, Chicago, IL, Oct. 12-16.
2. 2025, M. Dubarry, [Recent Advances on Degradation Modes Modeling for Li-Ion and Na-Ion Batteries](#), Presented at the 247th ECS Meeting, Montréal, Canada, May 18-22.
3. 2024, T. Hofmann, et al., [Transfer Learning from Synthetic Data for SOH Estimation](#), Presented at the 246th ECS Meeting, Honolulu, HI, Oct. 6-11.
4. 2024, M. Dubarry, et al., [Investigation of the Impact of Different Electrode Inhomogeneities on the Voltage Response of Li-Ion Batteries](#), Presented at the 246th ECS Meeting, Honolulu, HI, Oct. 6-11.
5. 2024, D. Beck, et al., [Electrode Blending Simulations Using the Mechanistic Degradation Modes Modeling Approach](#), Presented at the 246th ECS Meeting, Honolulu, HI, Oct. 6-11.