

Energy Storage System Performance and Reliability Analytics From Shared Data

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PROJECT OVERVIEW

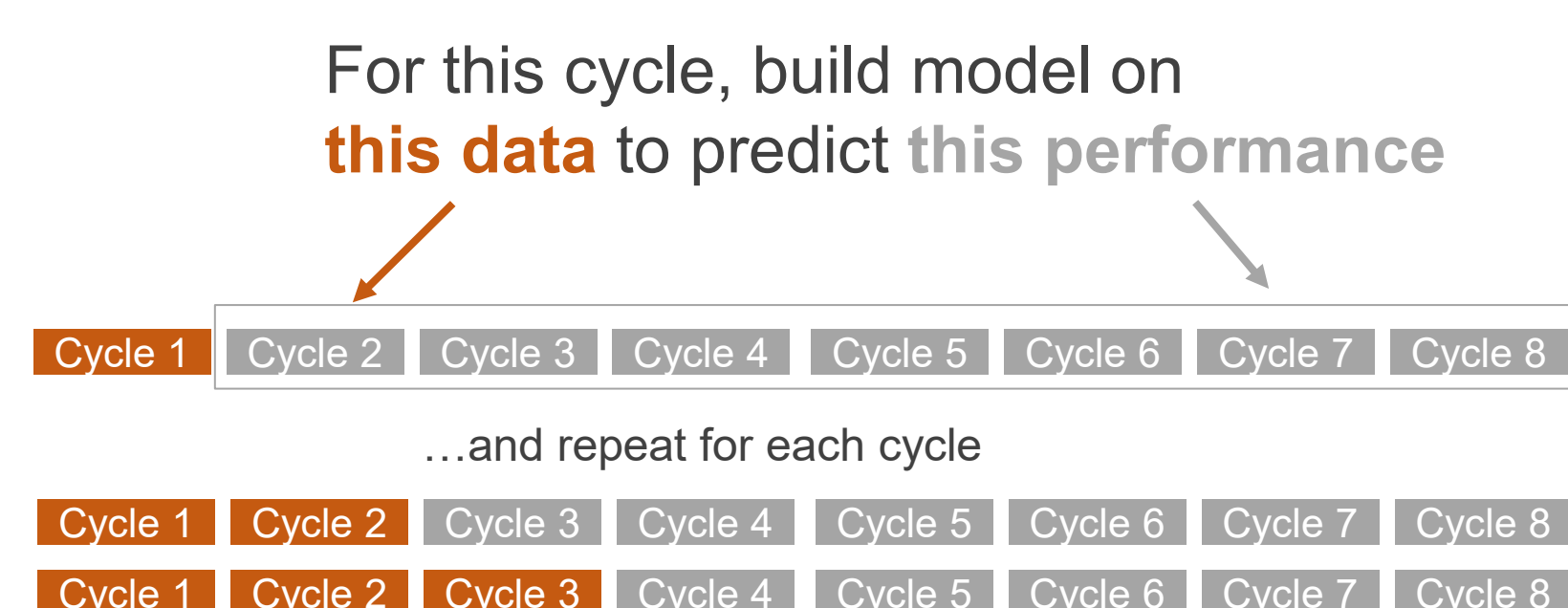
- Energy Storage System (ESS) time series datasets obtained from various utilities as part of the Washington Department of Commerce (WADOC) Grid Modernization project
- Additional ESS time series datasets obtained via collaboration with EPRI
- A performance model that also includes degradation mechanisms is essential to forecast battery economic benefits over battery's lifespan
- A robust method of testing predictive capability of BESS models is developed
- Multiple BESS datasets allow for robust testing of BESS methodologies
- With multiple BESS datasets of each chemistry, insights from single cell data can be used to model degradation, with coefficients constrained across BESSs of similar chemistry

Datasets Collected

Alias	Chemistry	Rated Power (kW)	Rated Energy (kWh)	Energy/Power Ratio (kWh/kW)
EPRI Flow 1	Vanadium Flow (VRF)	90	270	3.0
EPRI Li-Ion 1	NMC	1000	2000	2.0
EPRI Li-Ion 2	NMC	1000	1000	1.0
EPRI Li-Ion 3	LFP	Anonymous	Anonymous	4.0
EPRI Li-Ion 4	LFP	10000	30000	4.0
EPRI Li-Ion 5	LFP	Anonymous	Anonymous	3.0
WADOC Flow 1	Vanadium Flow (VRF)	1000	3200	3.2
WADOC Flow 2	Vanadium Flow (VRF)	2200	8000	3.6
WADOC Li-Ion 1	LMO/NMC	2000	1000	0.5
WADOC Li-Ion 2	LFP	2000	4400	2.2
WADOC Li-Ion 3	LFP	1000	2000	2.0
WADOC Li-Ion 4	LFP	1000	5500	5.5
WADOC Li-Ion 5	LFP	668	1840	2.8

Modeling Methodology

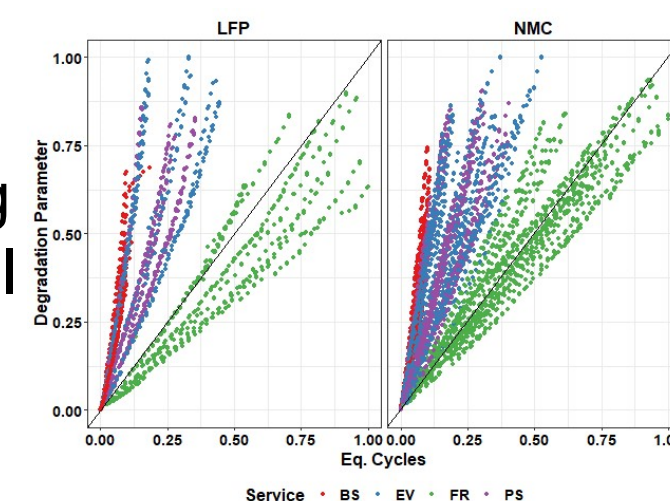
- High level regression-based model required for ESS level modeling
- Take all ESS datasets from WADOC and EPRI, and use ElasticNet machine learning algorithm to predict how SOC changes with time based on power applied to the battery and SOH of the battery. SOH also estimated from history of power and SOC.



$$\frac{dSOC}{dt} = f(\text{Power}, \text{SOC}, \text{SOH})$$

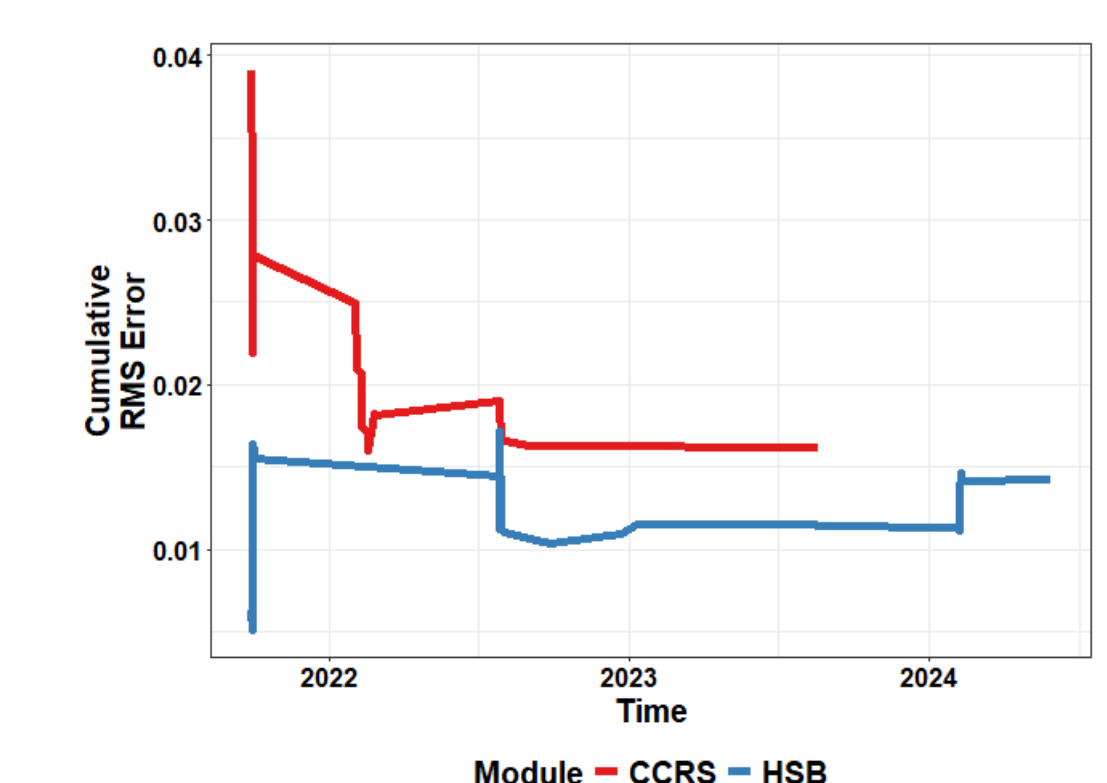
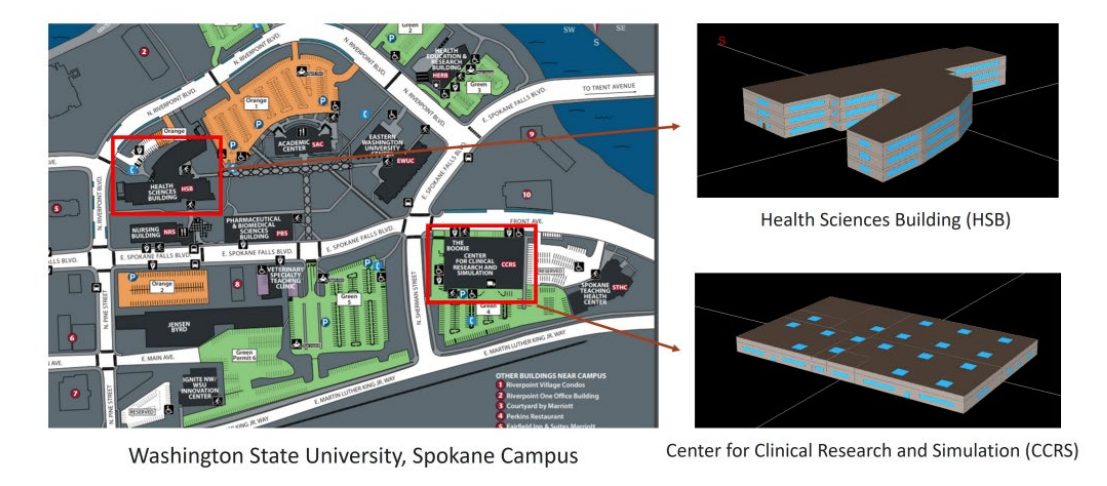
$$\frac{dSOH}{dt} = f(\text{Power}, \text{SOC})$$

- Degradation rate is predicted as a function of power and SOC from physics-based modeling – simplifying assumptions are made and major mechanisms identified to translate physics-based model to system level inputs. We focus on loss of lithium due to SEI layer formation while ignoring SEI diffusion limitations and SEI layer cracking. Future work will include SEI diffusion limitation, SEI layer cracking, and cathode dissolution.
- For physics-based estimation of SOH Model is also applied to single cell data from lab to better identify SOH dependence on applied power and SOC, due to a larger variety of lab conditions available



New Dataset: Avista

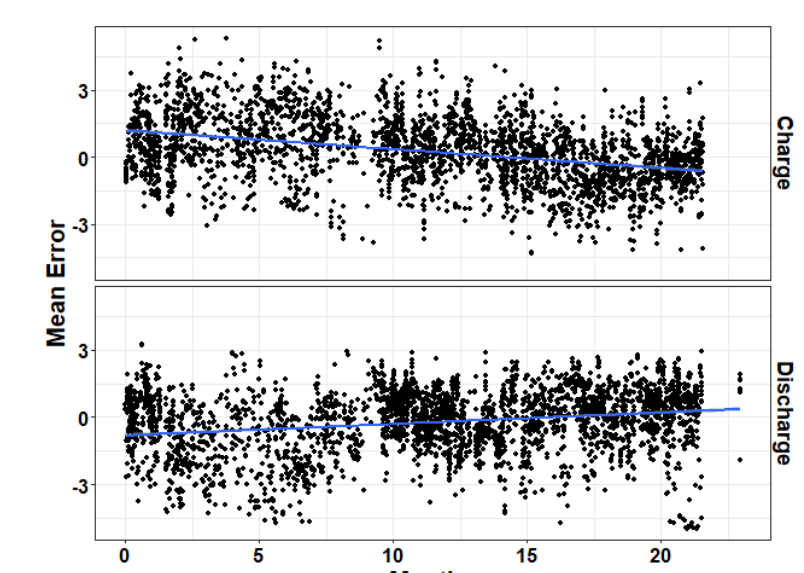
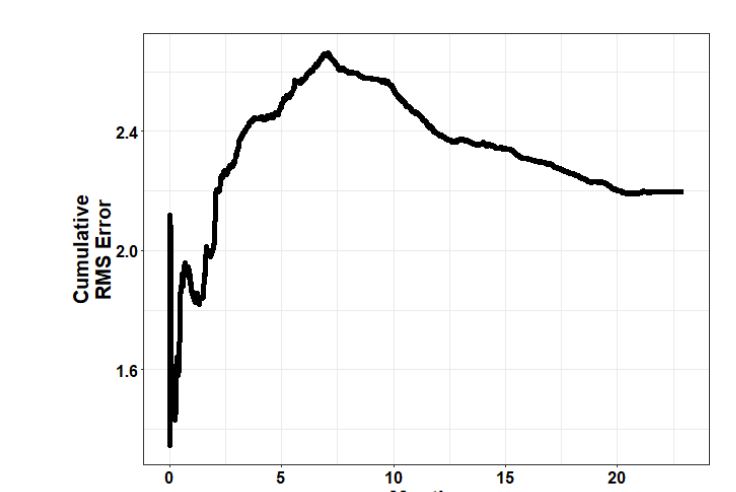
- Shared Energy Economy Microgrid (Spokane, WA)
- Operated by Avista
- Lithium Iron Phosphate (LFP)
- 668 kW/1840 kWh
- BESS consists of two modules, data is acquired separately for each
- API developed by Avista to enable automatic data transfer to PNNL
- BESS tested sporadically over course of three years – lack of cycling gives insight into calendar aging
- Two years of data available at 5 min resolution, including power, SOC, voltage, and current



New Dataset: EPRI Anonymous 2

- LFP Chemistry, 3h duration (rated power and energy anonymous)
- BESS consists of eight modules, data for each is acquired separately
- Two years of data available at 5 min resolution
- After data cleaning this gives 10,000 charges/discharges to analyze and model
- Detailed information available for each module – includes power, SOC, max/min/avg voltage, max/min/avg current, max/min/avg temperature
- Some limited information given at rack level – max/min/avg voltage, max/min/avg current

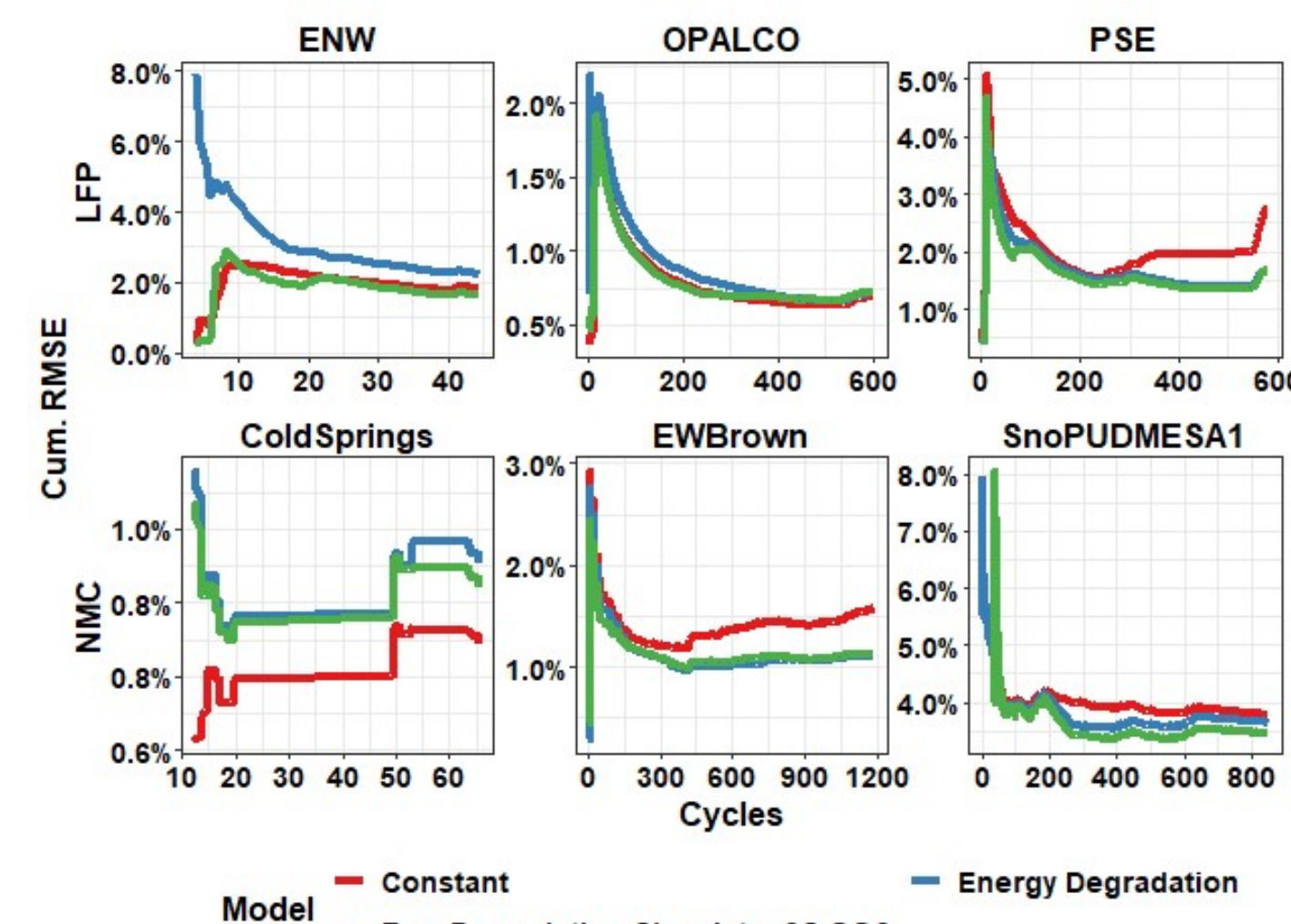
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Modeling Results

- We compare a more complex model to simpler models to test if the complex model improves predictive capability
- Out of sample error compared for **base model with no degradation**, a **simple energy-based degradation model**, and the **physics based degradation models**

Same physical parameters and tuning parameters used for all LFP ESS models, and physical parameters tested vs LFP single cells



Same physical parameters and tuning parameters used for all NMC ESS models, and physical parameters tested vs NMC single cells