International Battery SEMINAR & EXHIBIT VIRTUAL March 9-11, 2021

Cambridge EnerTech's
Grid-Scale Energy Storage
Engineering Battery Utility into the Grid
MARCH 10-11, 2021 | ALL TIMES EASTERN STANDARD (UTC-05:00)

Battery Durability and Reliability Under Electric Utility Grid Operations:
20-Year Forecast under Different Grid Applications

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Battery Durability and Reliability under Grid Operations

Integrate **field data** with **lab testing** to predict lifetime BESS

Objective/Significance

Evaluate degradation & lifetime of BESS in support of grid scale deployment

Improve economic understanding of future commercial & base deployments

Approach

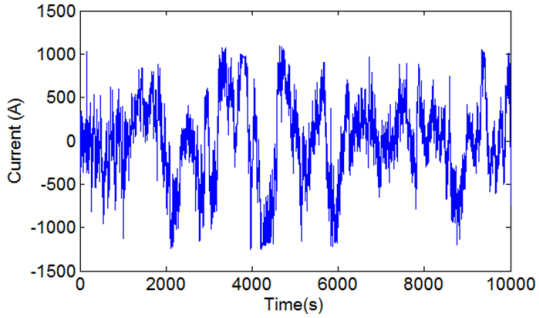
Assess battery performance in BESS and under controlled conditions

Analyze degradation using non-destructive methods

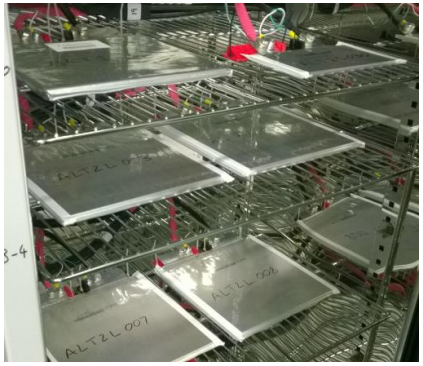
Link controlled and deployed degradation to forecast remaining useful life

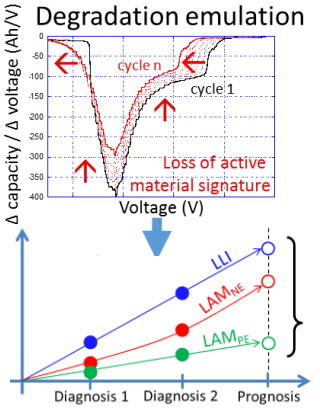
Field data → **Usage analysis** → **Laboratory testing** → **HNEI custom analysis**

Understand how the cells were utilized in the field



Custom design of experiment: Cover representative and aggressive usage





Prognosis

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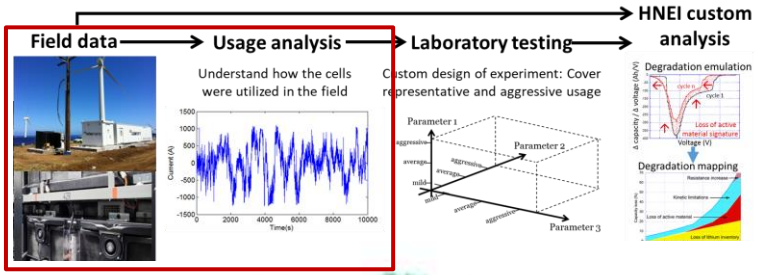
Field data

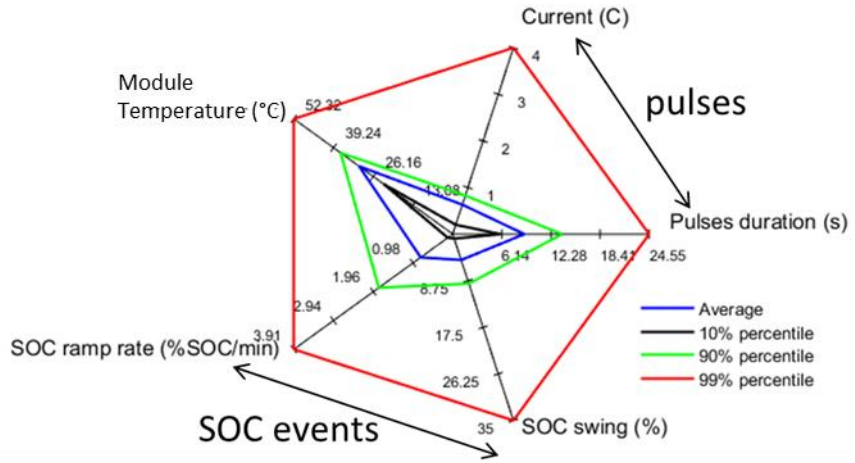


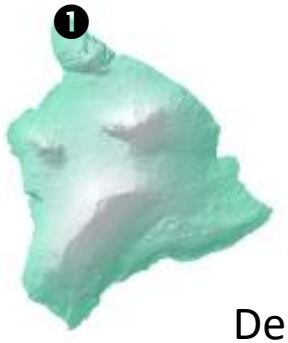
Hawaiian Electric

GridSTART
Hawai'i Natural Energy Institute | University of Hawai'i

Moloka'i, HI (grid: 5.5MW)
2MW/330kWh, Commissioned in February 2016
Altairnano GEN2 60Ah cells, 416(7P)S1P
Reserve, Fault response

O'ahu, HI (grid: 1.1TW)
1MW/250kWh,
Commissioned in February 2016
Altairnano GEN2 60Ah cells, 384(7P)S1P
Volt-VAR, Power quality





Big Island, HI (grid: 190MW)
1MW/250kWh, Commissioned in December 2012
Altairnano GEN1 50Ah cells, 384(7P)S1P
Frequency regulation, Wind Smoothing

Demonstrated over 8000 full cycles equivalent operation

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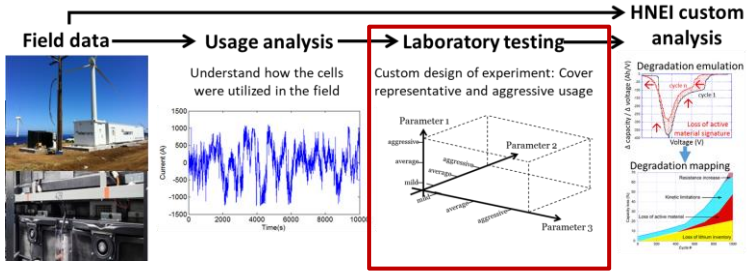
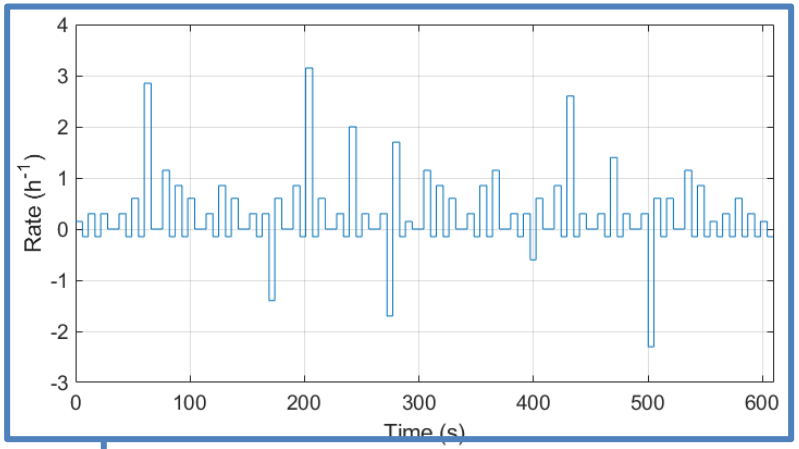
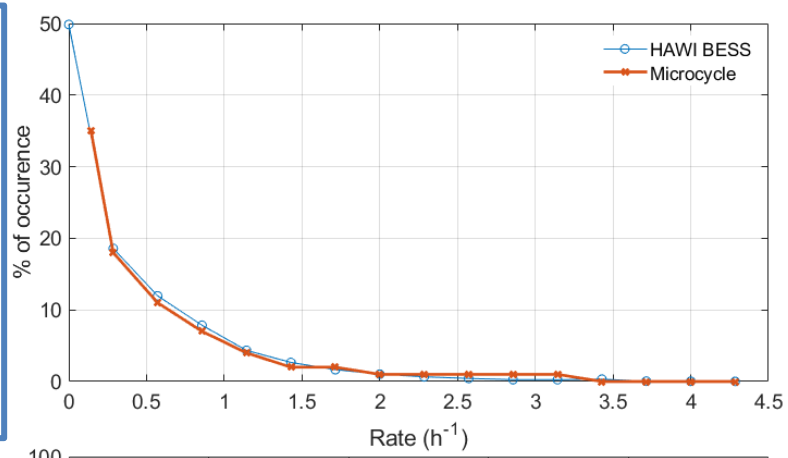
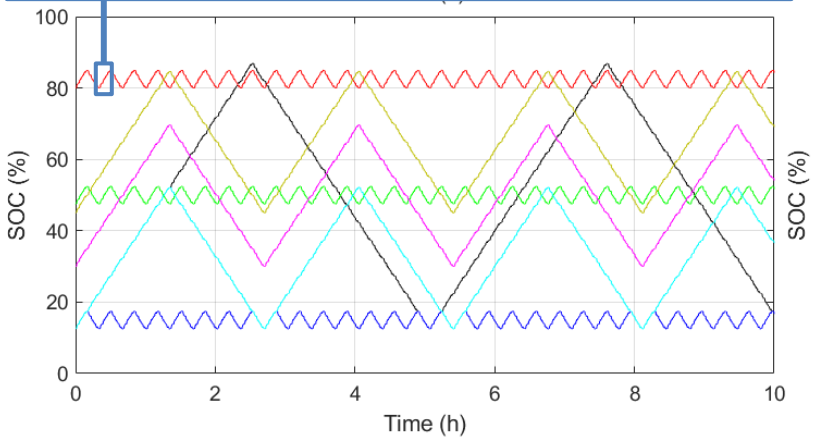
Laboratory testing – Cycle aging

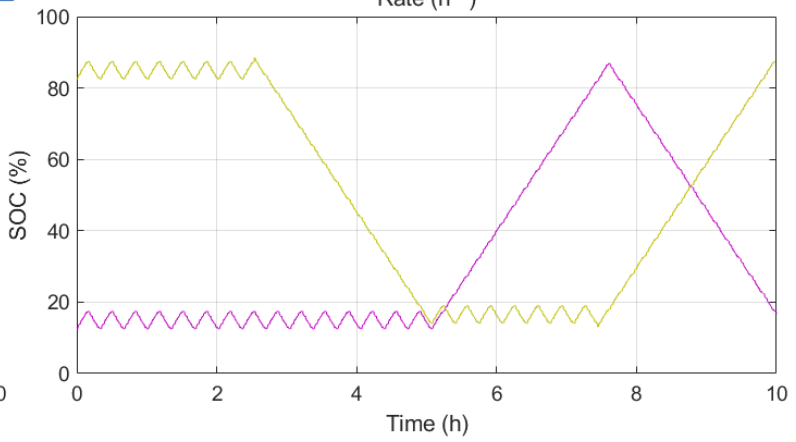


Laboratory testing encompassing a wide range of grid applications including frequency regulation, reserve and peak shaving.









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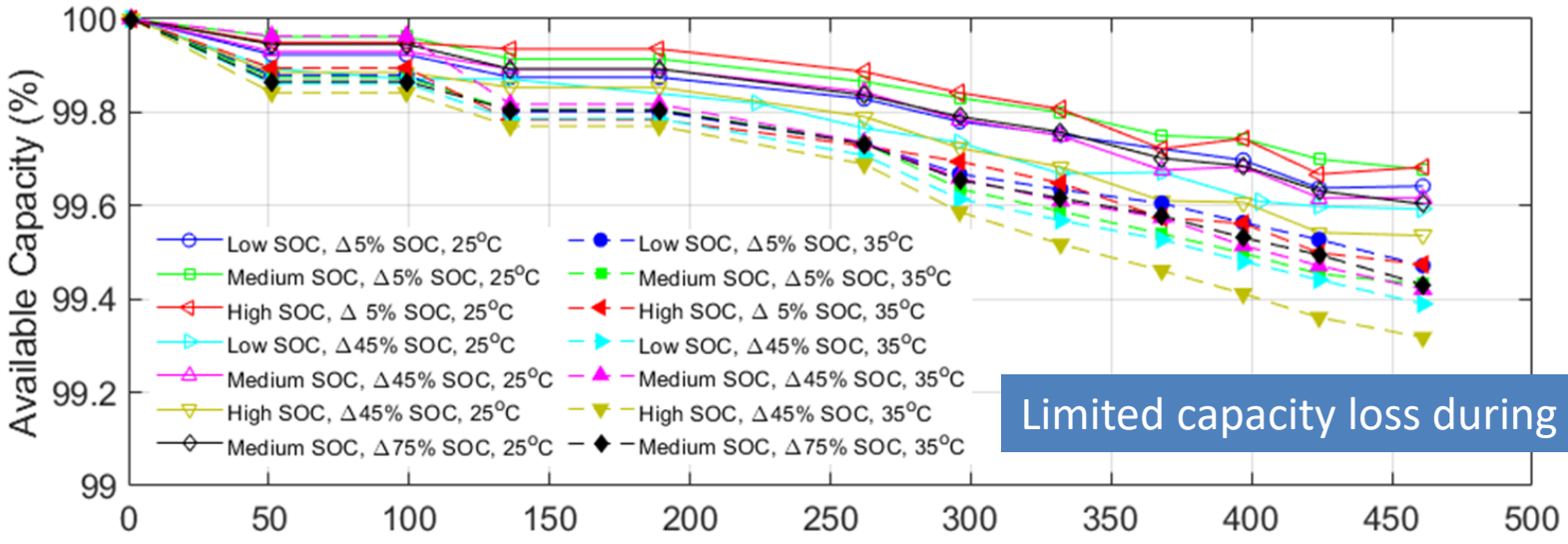
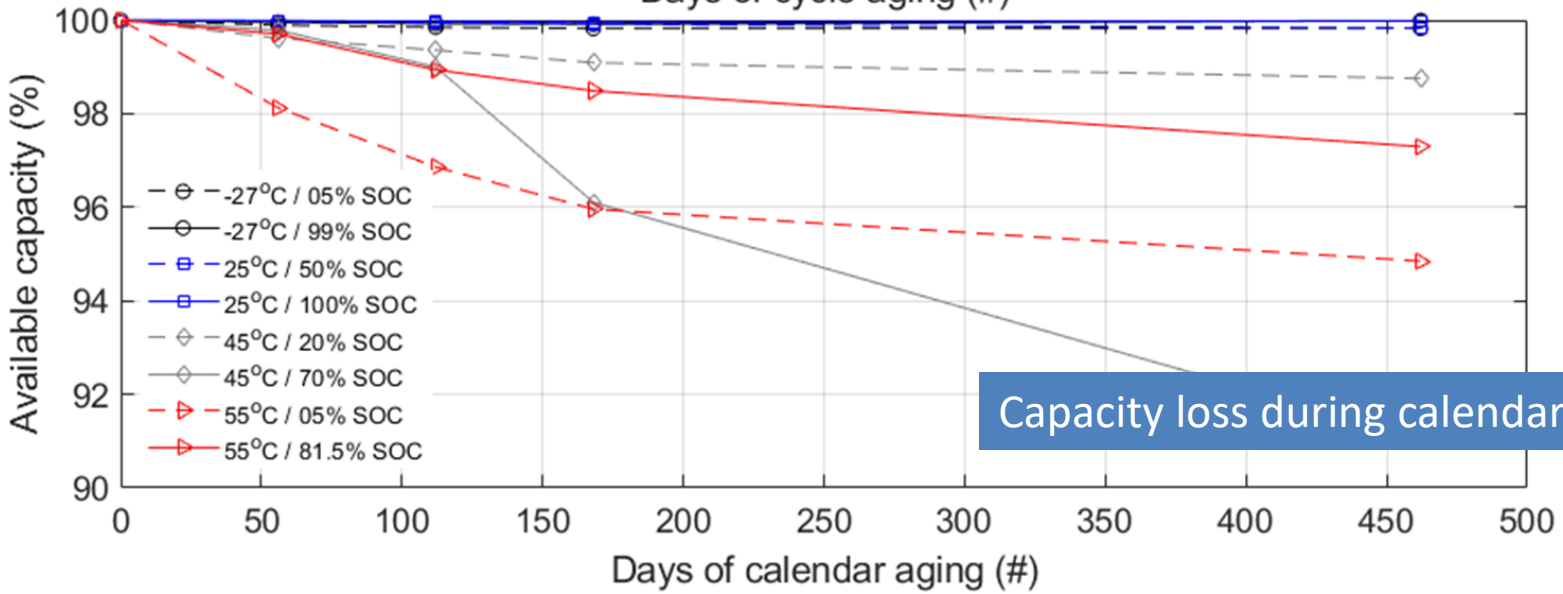
Laboratory testing – Cycle aging



Limited capacity loss during aging



Capacity loss during calendar aging

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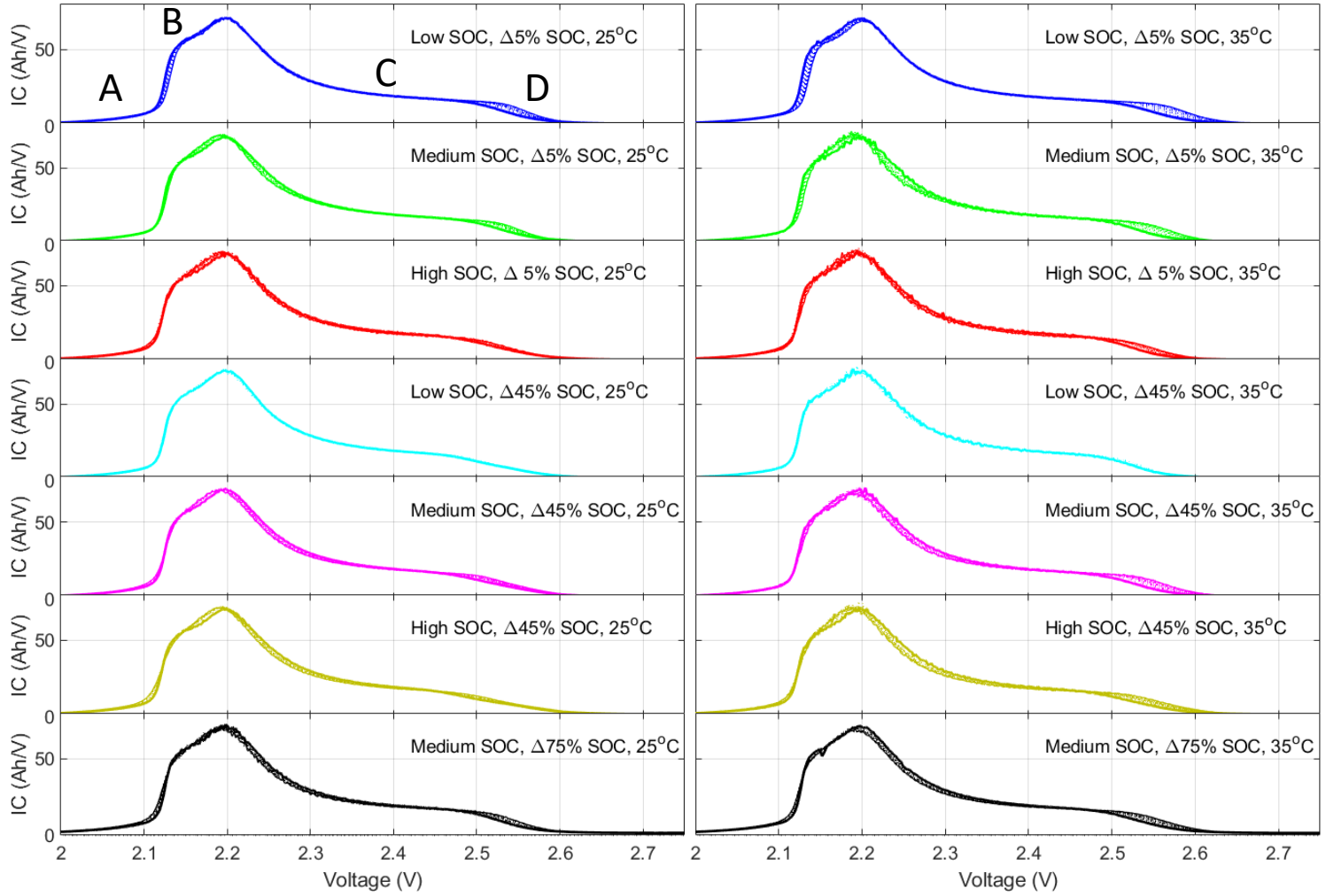
Laboratory testing – Cycle aging

No capacity loss do not mean no degradation…



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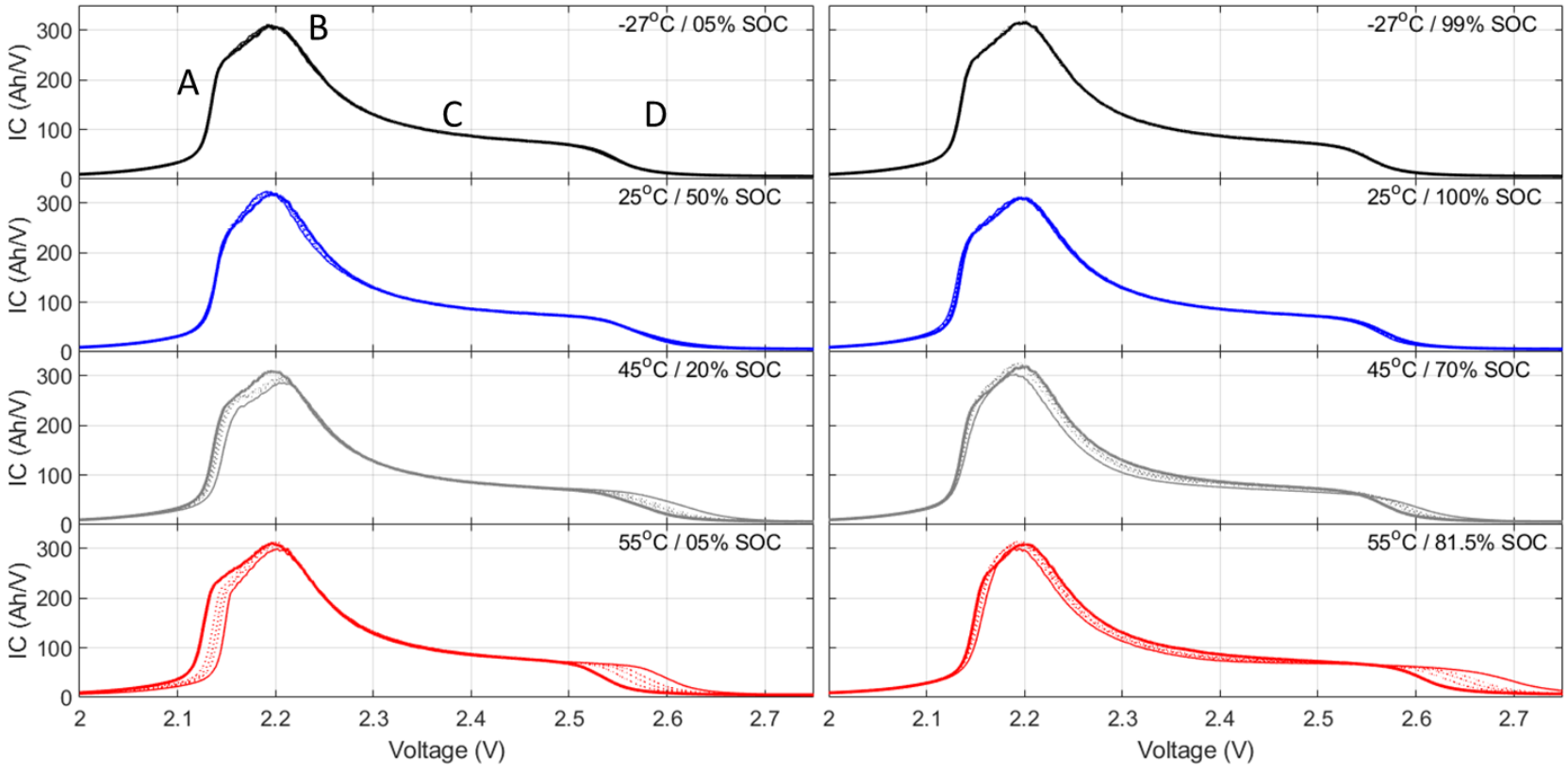

Voltage variations differ in between cells: different degradations
Effect on remaining useful life?

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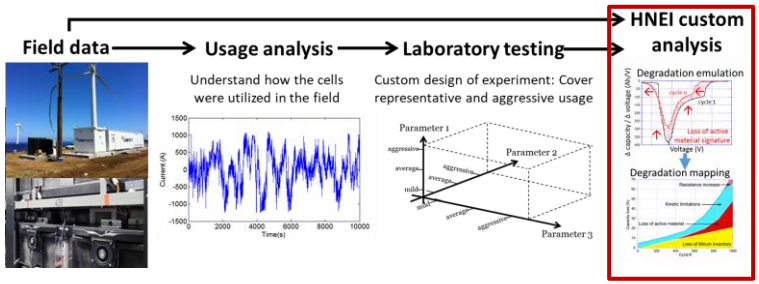
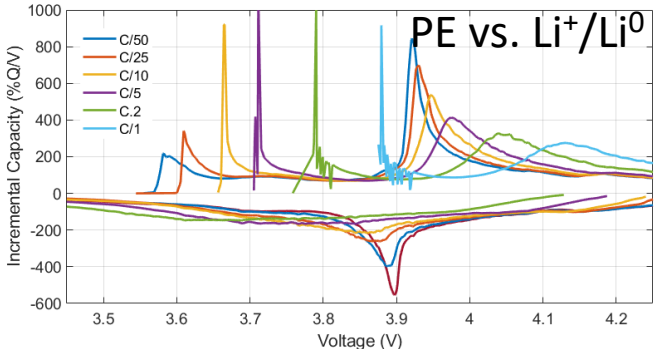
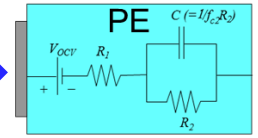
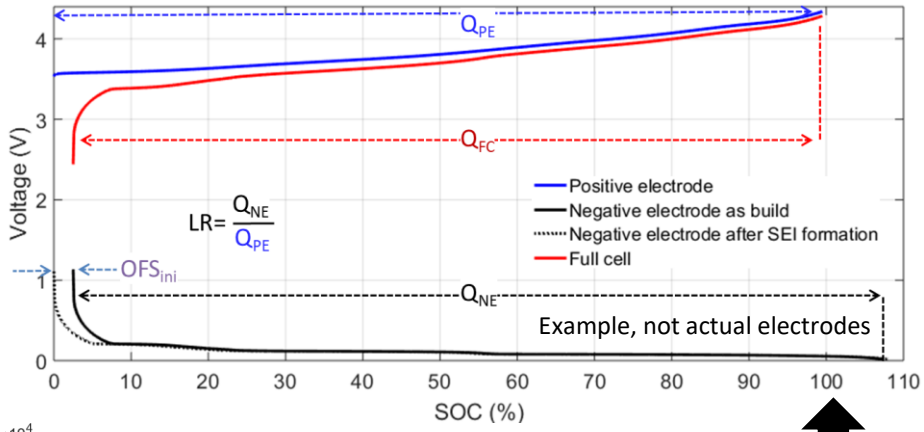
HNEI custom analysis: Incremental capacity analysis

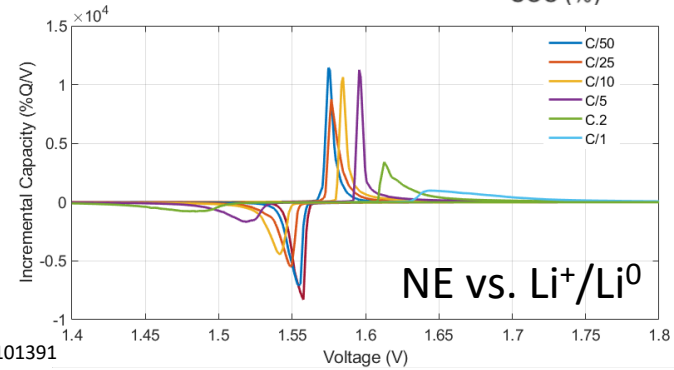


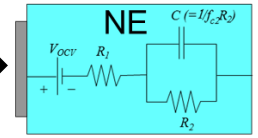
Mechanistic modeling











‘alawa

https://www.soest.hawaii.edu/HNEI/alawa/

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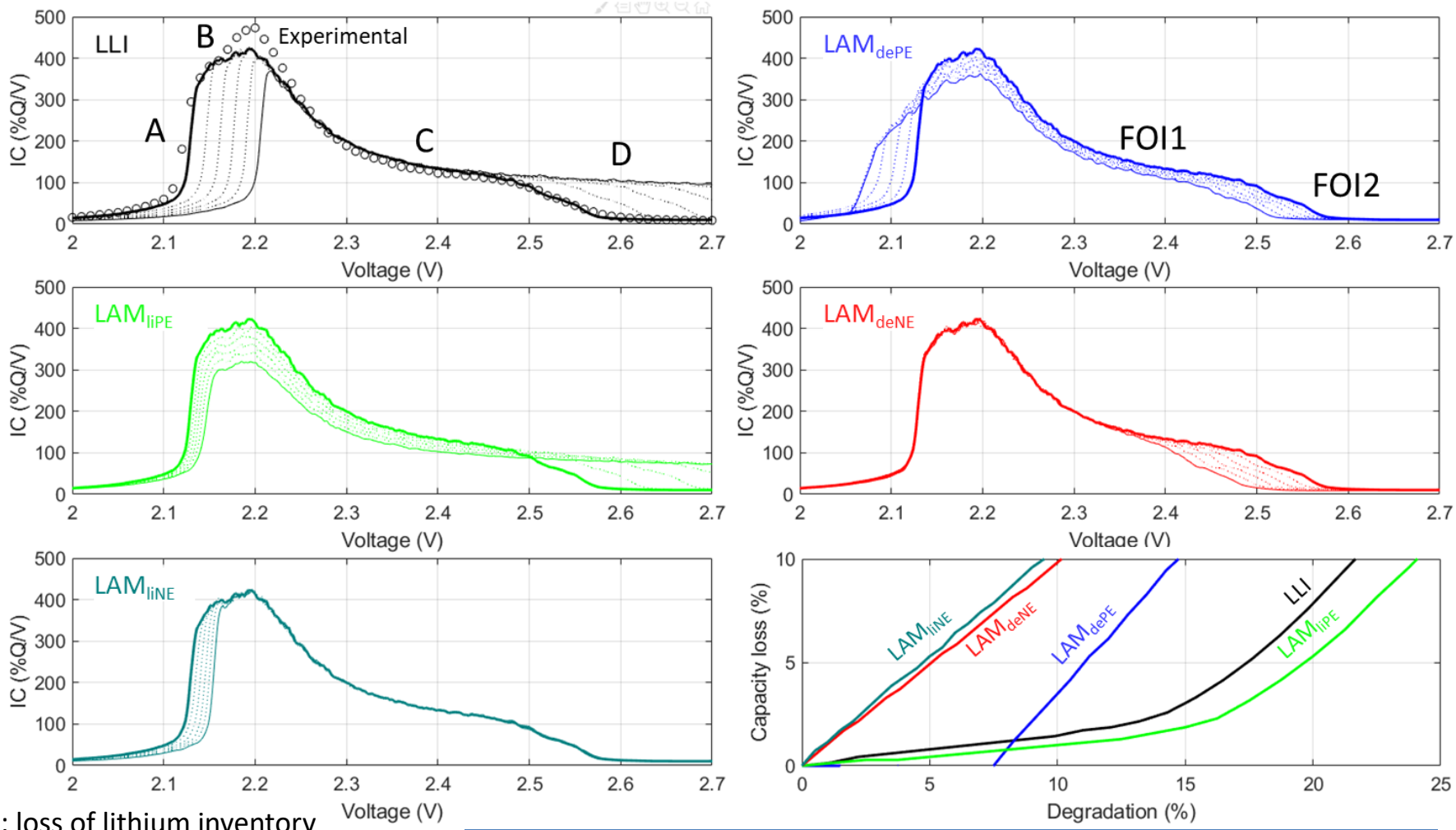
HNEI custom analysis: Incremental capacity analysis

Mechanistic modeling: Predict voltage response under different degradations



LLI: loss of lithium inventory
LAM: loss of active material

Assessed the impact of each active component of the cell

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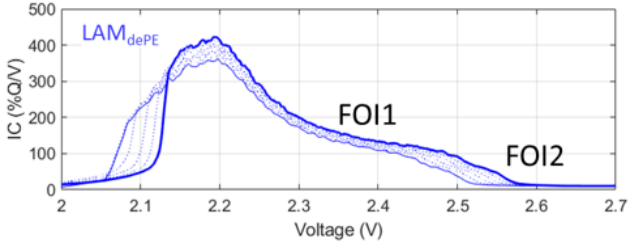
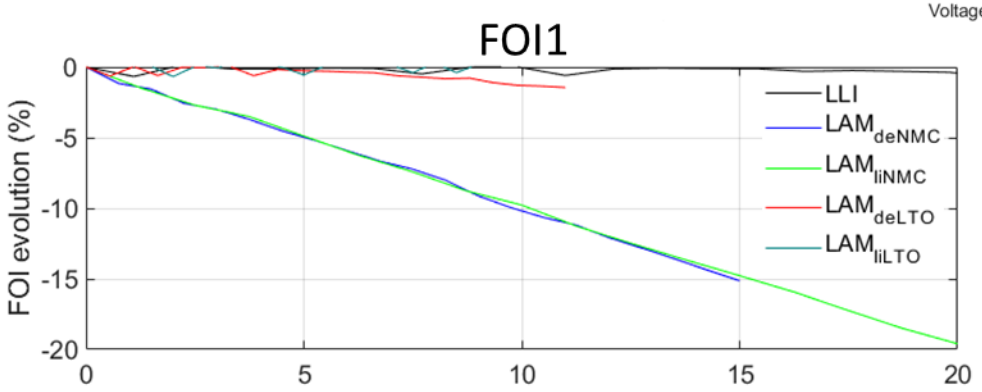
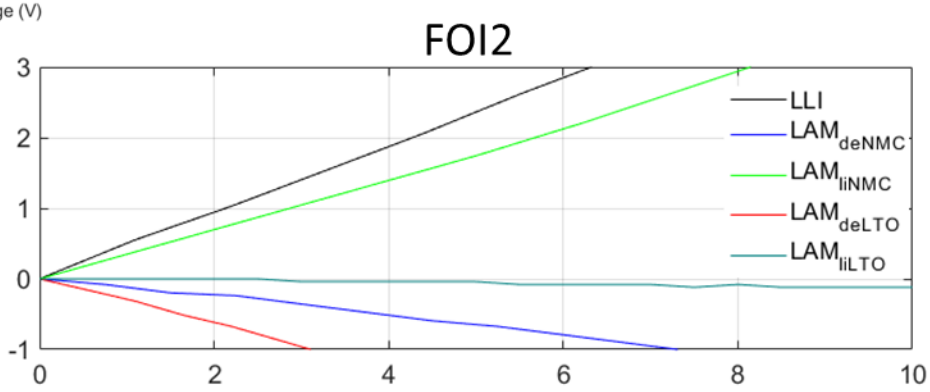
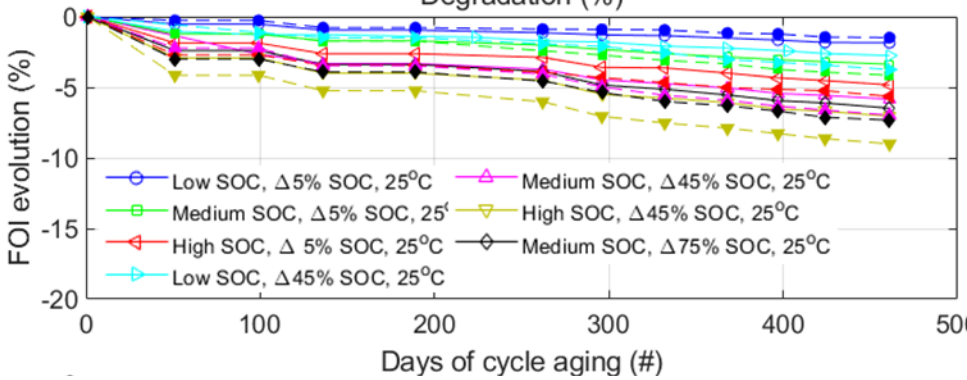
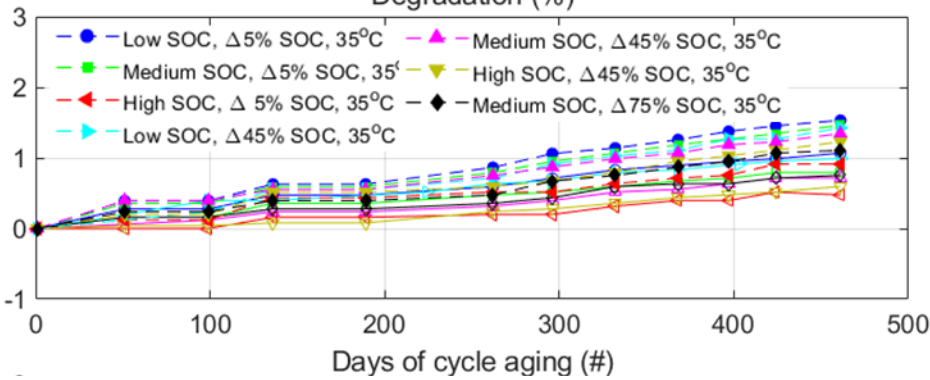
HNEI custom analysis: Incremental capacity analysis











Both LAMs and LLI can be automatically quantified

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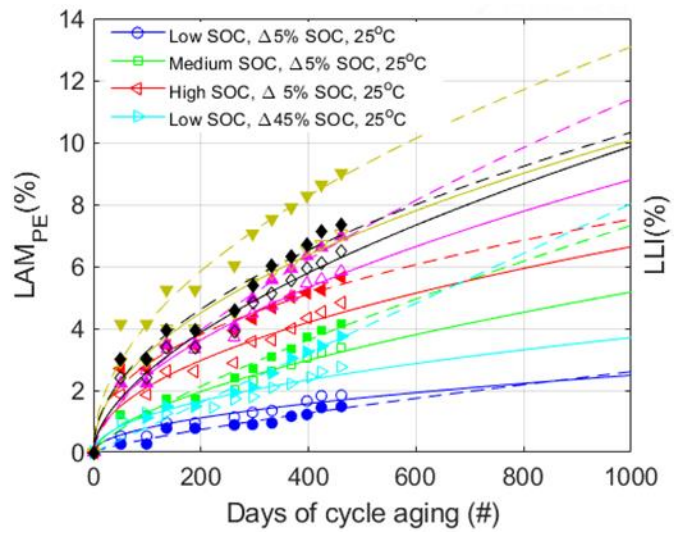

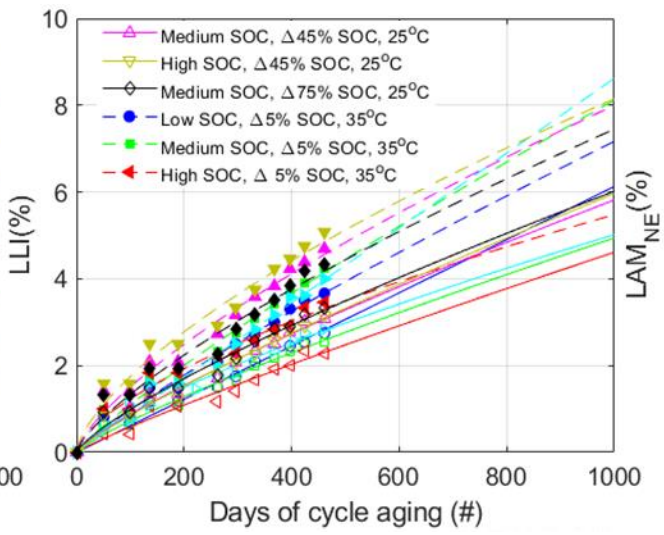

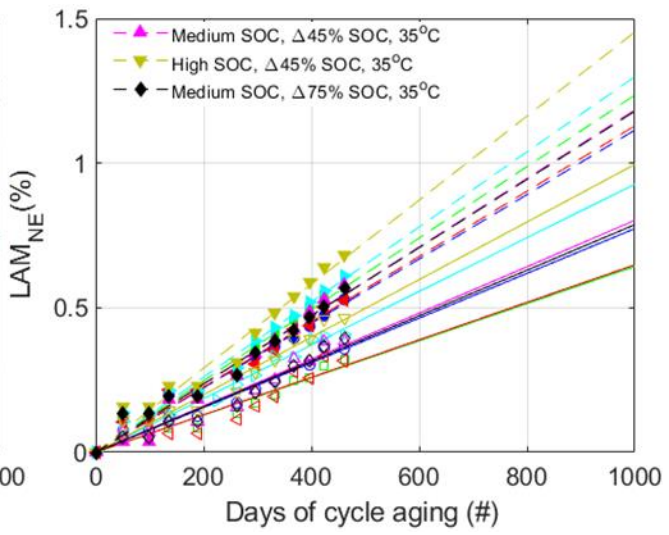

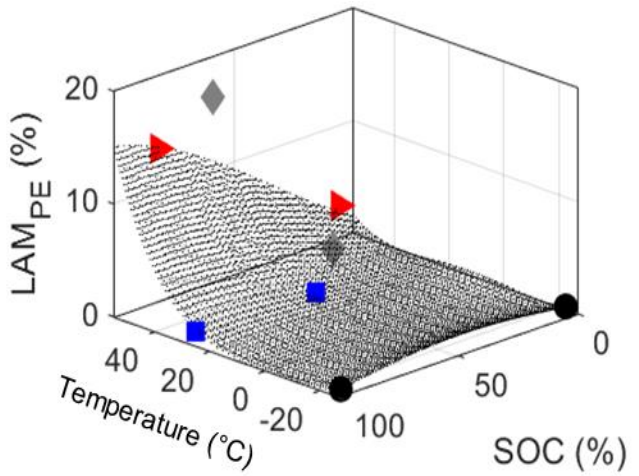

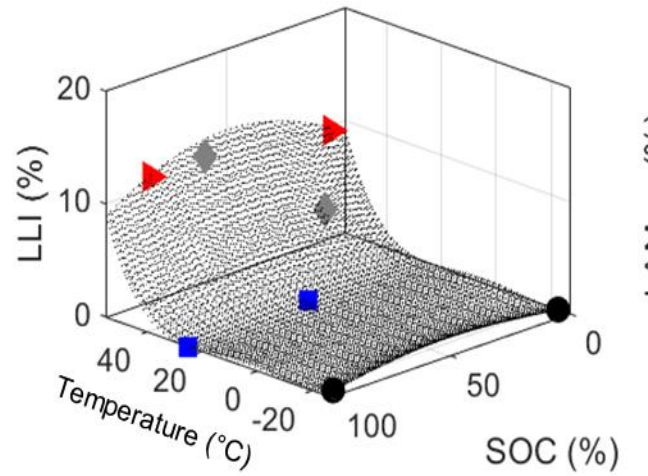

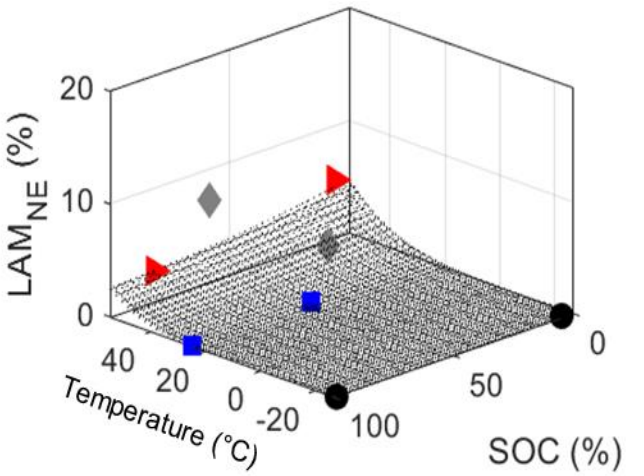

Impact of duty cycle on LAMs and LLI deciphered

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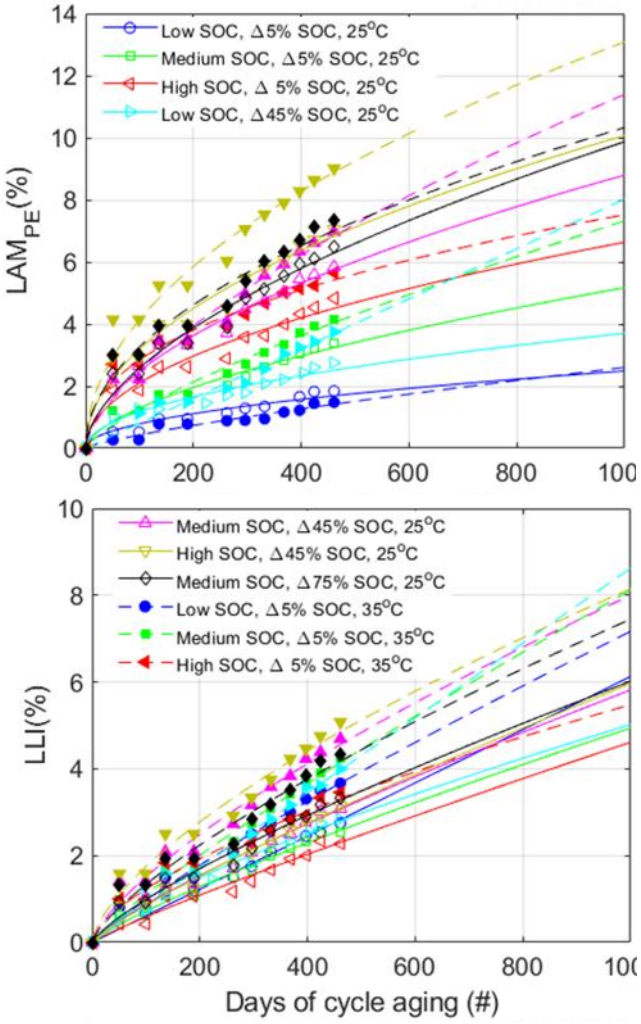
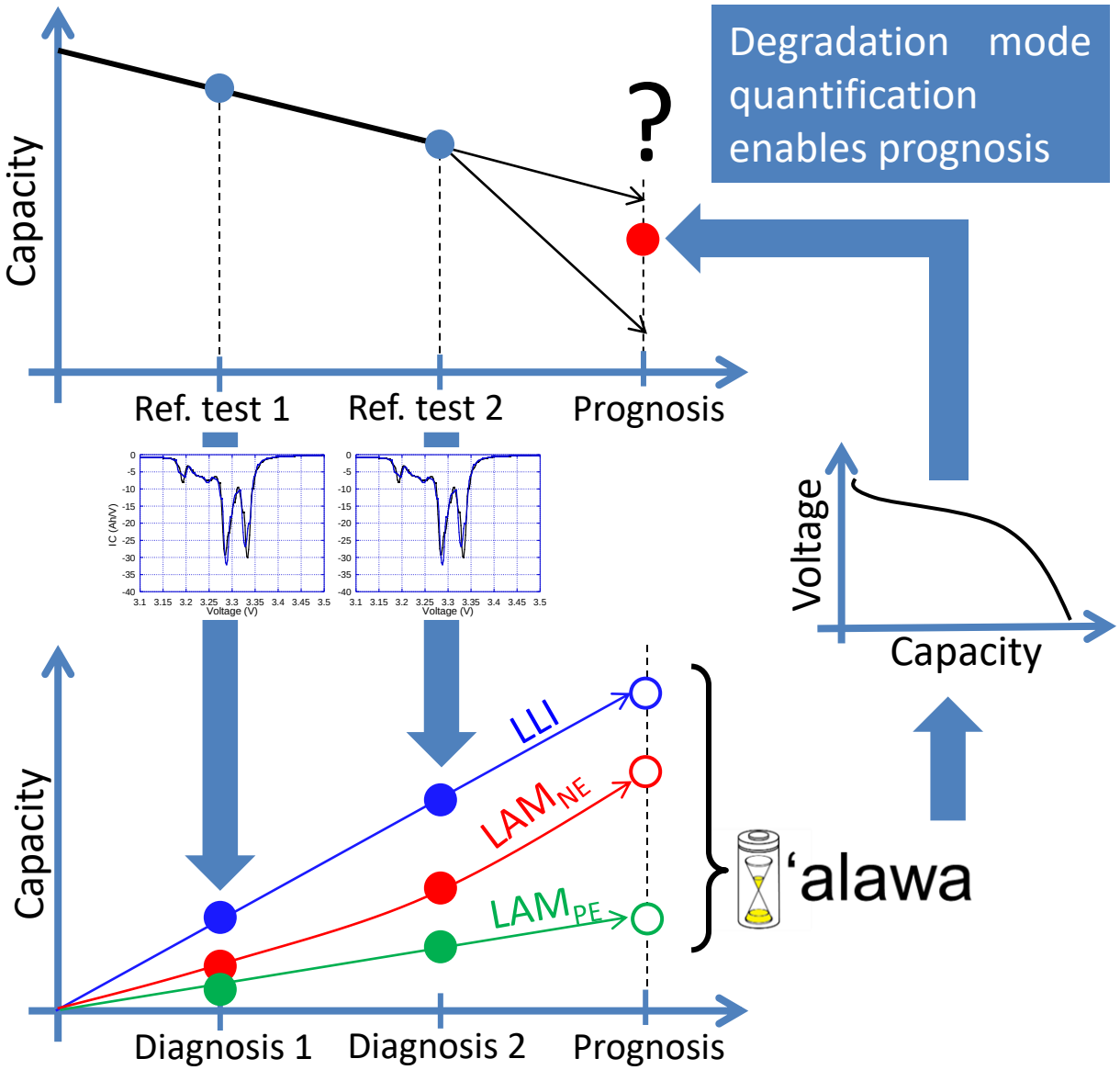
HNEI custom analysis: Prognosis





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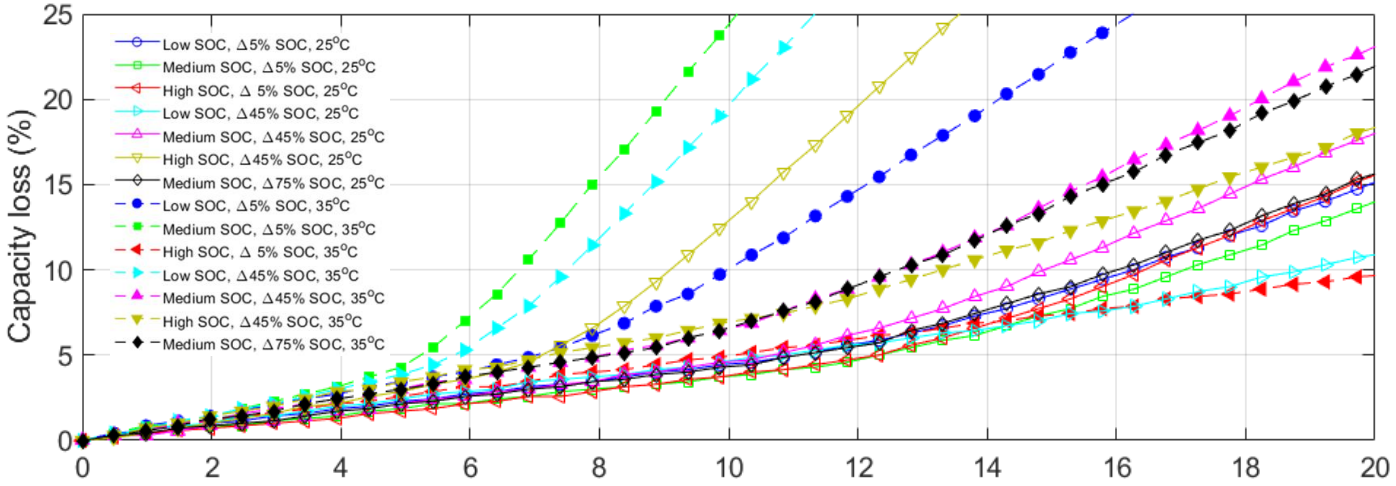

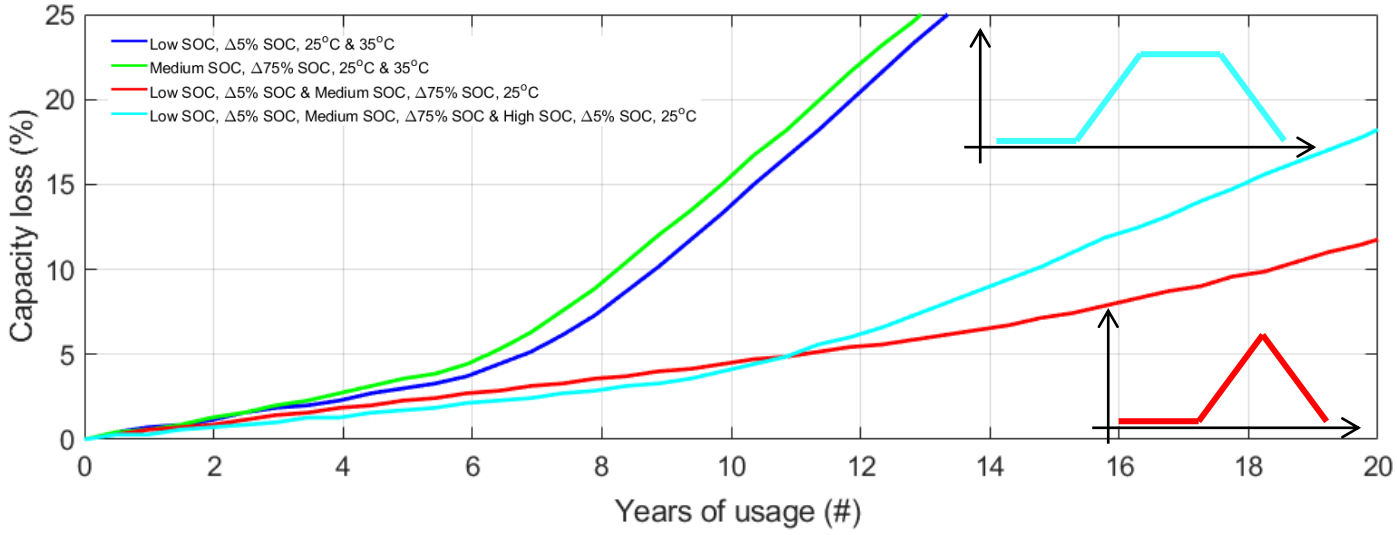

Degradation mode quantification enables prognosis

Varied duty cycles showed degradation close to the ones of the main experiment

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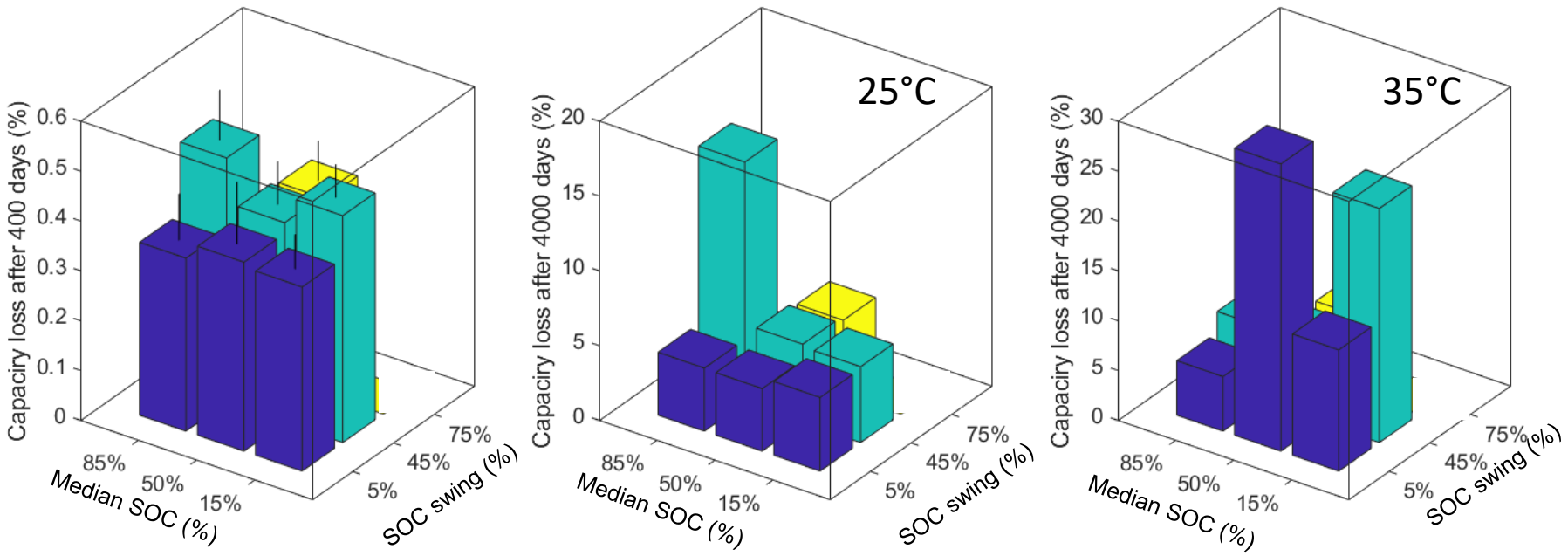

Worst conditions could not have been deciphered from testing alone

Frequency regulation: OK at 25°C except for 45% swings around high SOC
At 35°C , high SOC seems to be a better alternative.

Load Shifting / Curtailment: OK at 25°C and 35°C

Reserve: OK at 25°C and 35°C

Knowledge can be used to forecast impact under different applications

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Conclusions & Perspective

Conclusions

- Cell tested under conditions representative of the various grid usages
- Remarkably low capacity loss after more than 450 days of cycle-aging testing
- 20- year prognosis showed possibility of accelerated aging for some cells
- Cells adapted for most grid usages

Perspective

- Model performance based on laboratory testing
- Compare lifetime performance model to field data to determine BESS SOH
- Optimize BESS control strategies to limit degradation

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Acknowledgments

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Thank you for tuning in!

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