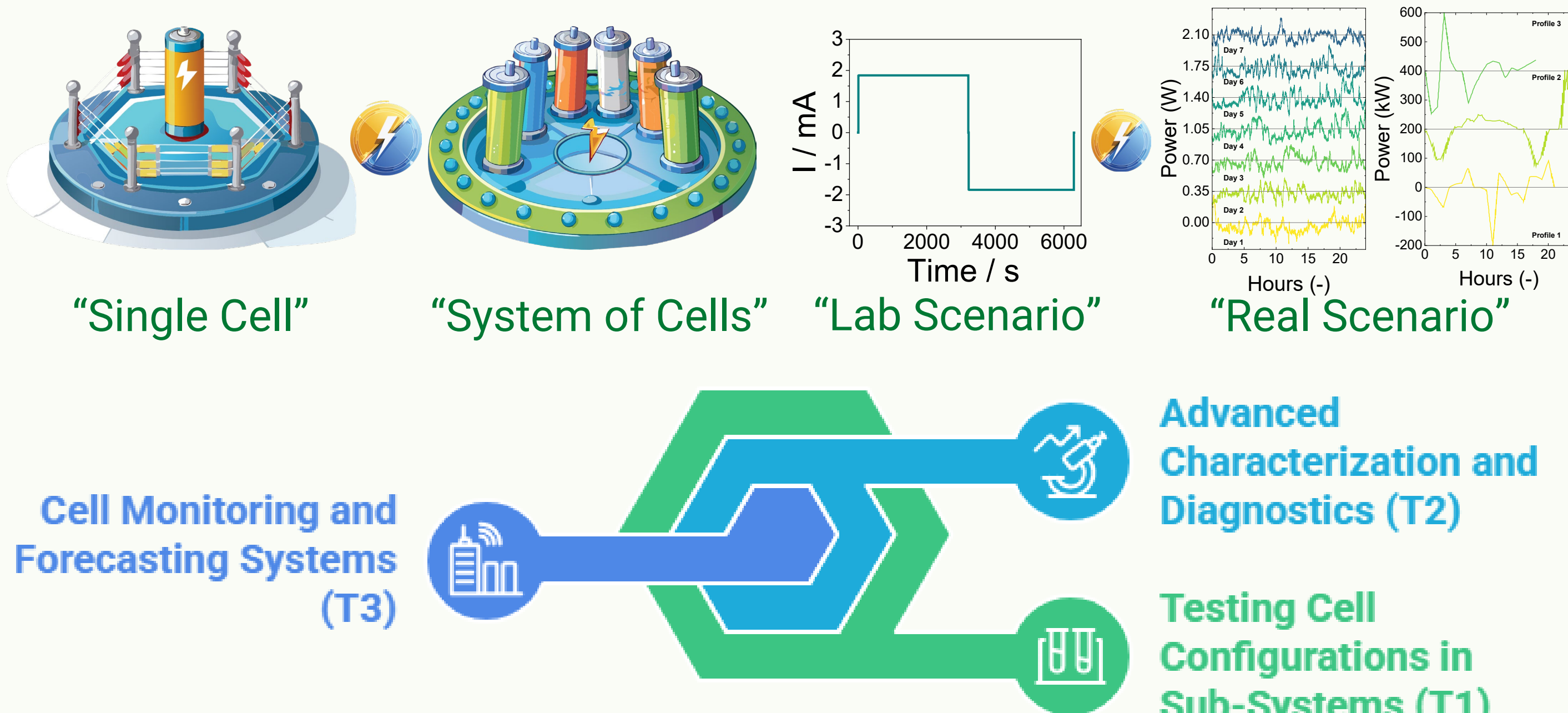


## Project Overview

**Project Goal:** Assess safety and degradation in commercial battery cells under real grid duty cycles to identify failure modes and early onset conditions for catastrophic failure

Most testing uses simplified profiles, missing key degradation and safety issues specific to grid use. The team combines large-format cell testing, advanced diagnostics, and strong ties to utility to enable realistic evaluation under grid-relevant conditions. We apply actual grid cycling data and advanced electrochemical and materials diagnostics to uncover failure mechanisms not captured by standard protocols. This work will improve lifetime predictions, safety, and reliability for grid-scale and second-life battery systems—critical for utilities, OEMs, and regulators and directly supporting DOE OE's goals in grid modernization, safety, reliability and cost



## Industry Collaborator

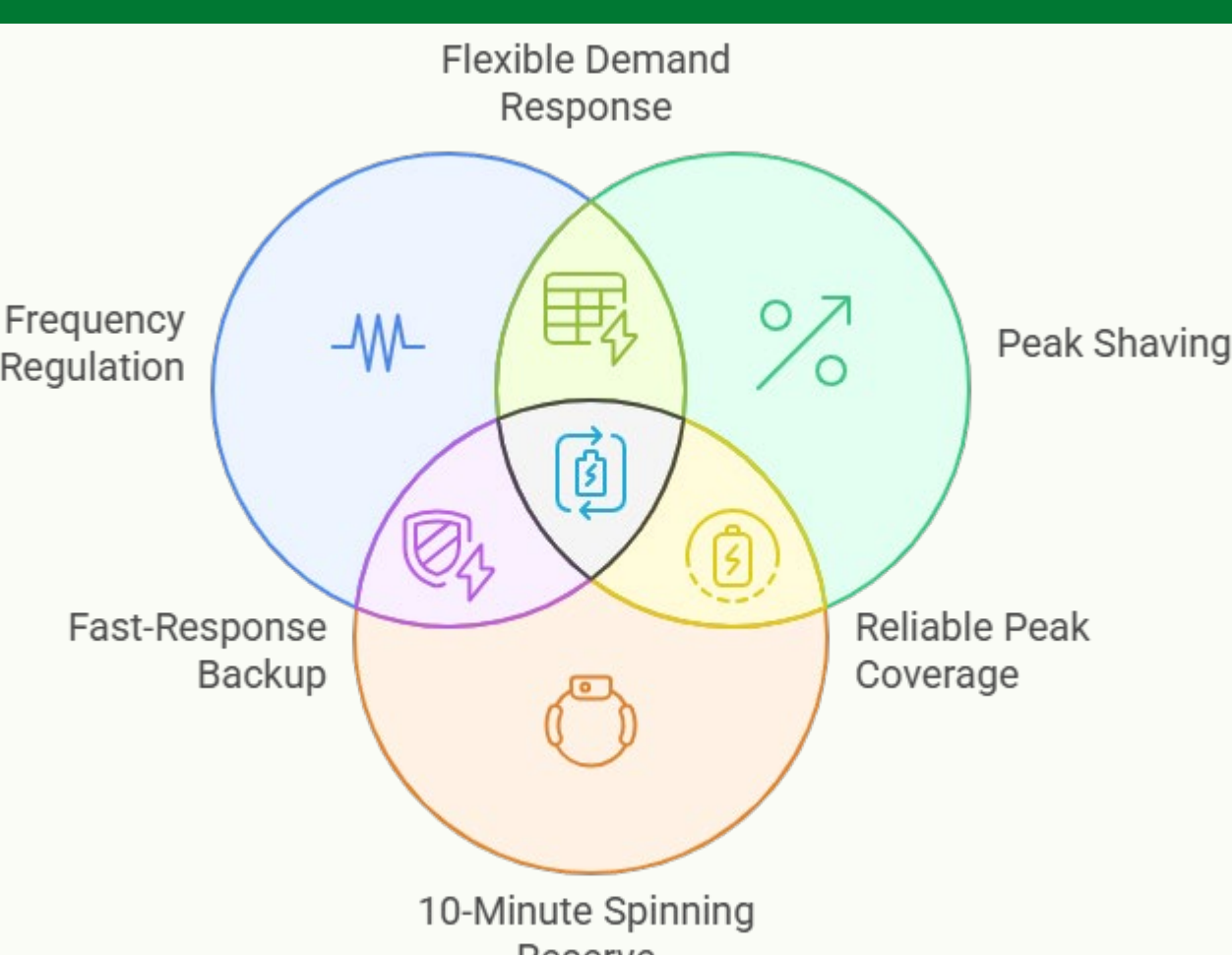


Formal NDA in place. Critical input on

- Cell chemistry
- Form factors
- Operational protocols and profiles
- Research needs

Key challenges—such as assessing the impact of thermal gradients within cells—are directly informed by real-world grid deployment needs. This ensures that outcomes are immediately relevant and translatable to field applications.

## Background and Motivation



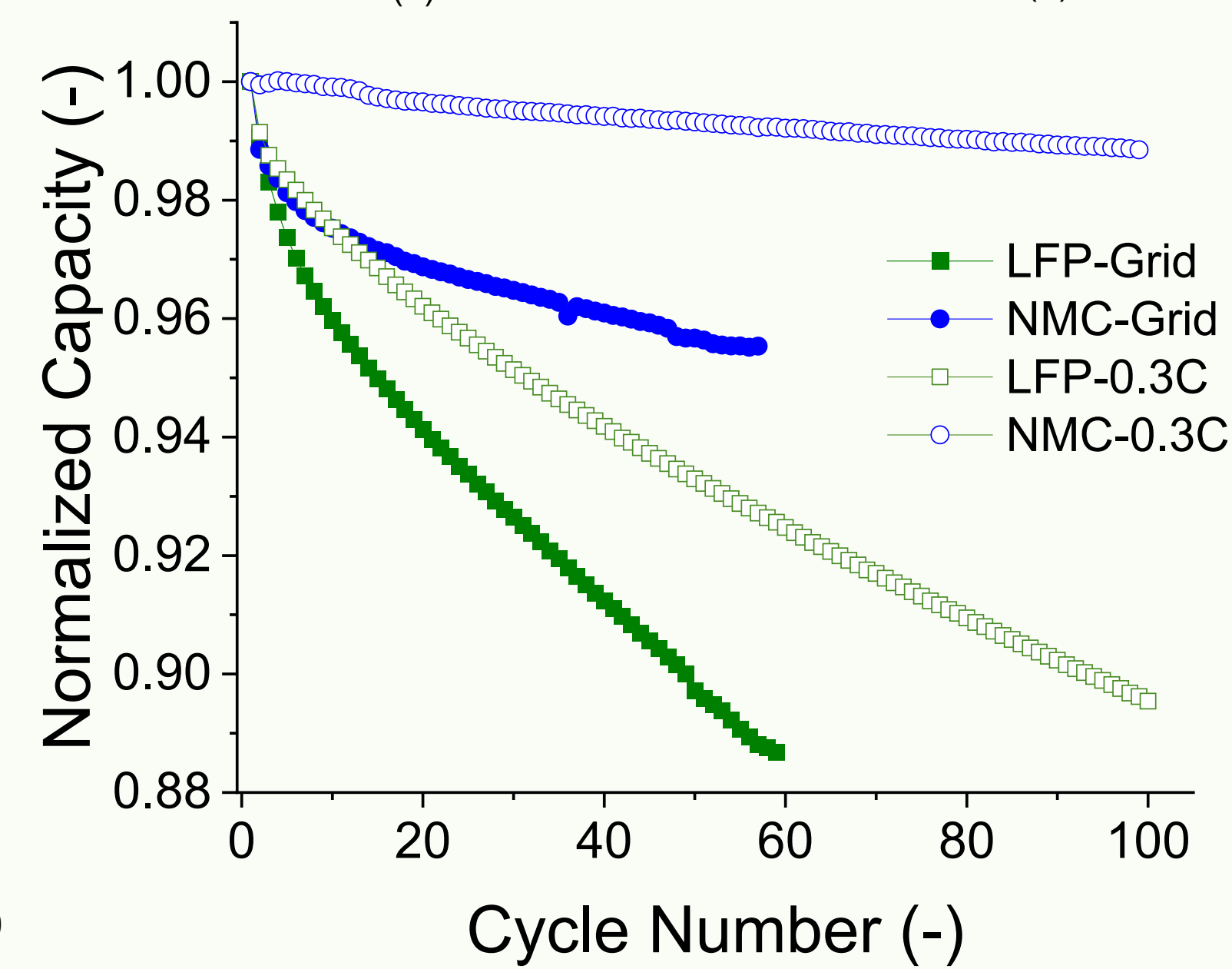
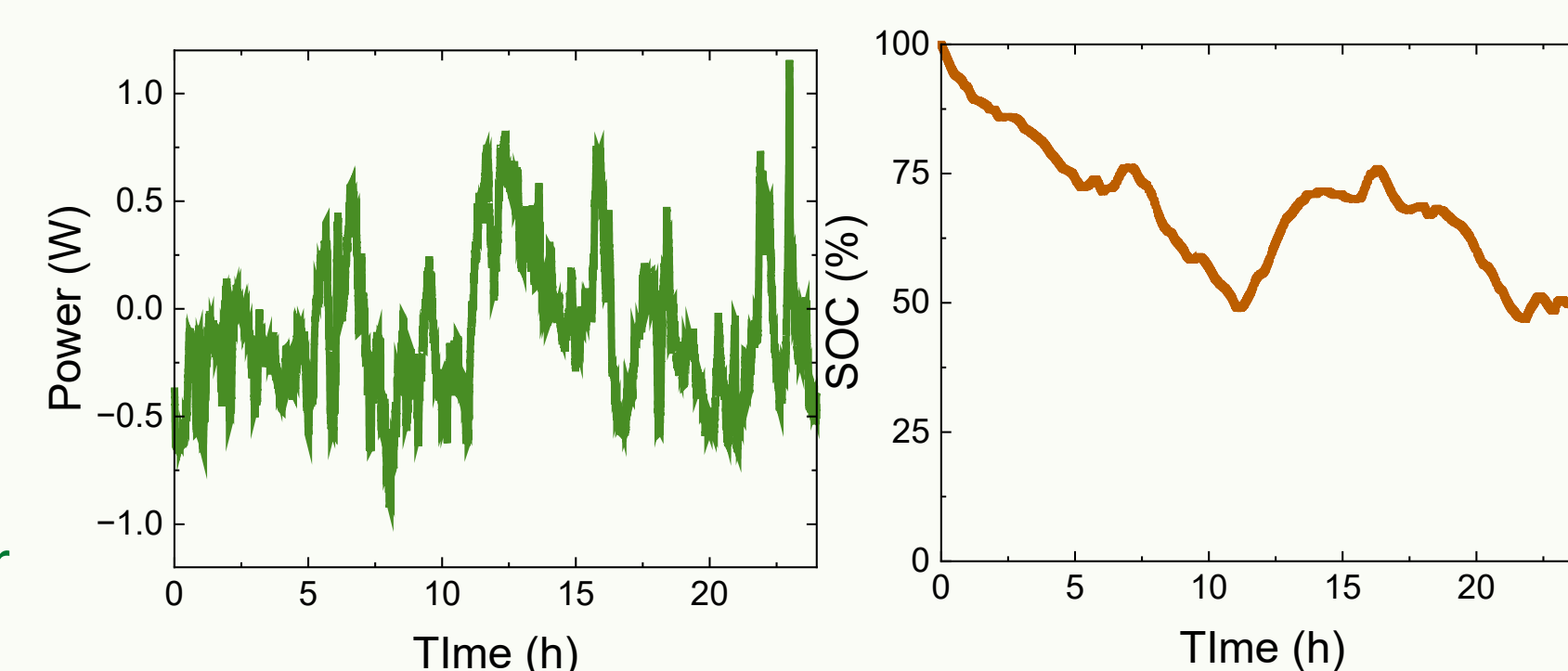
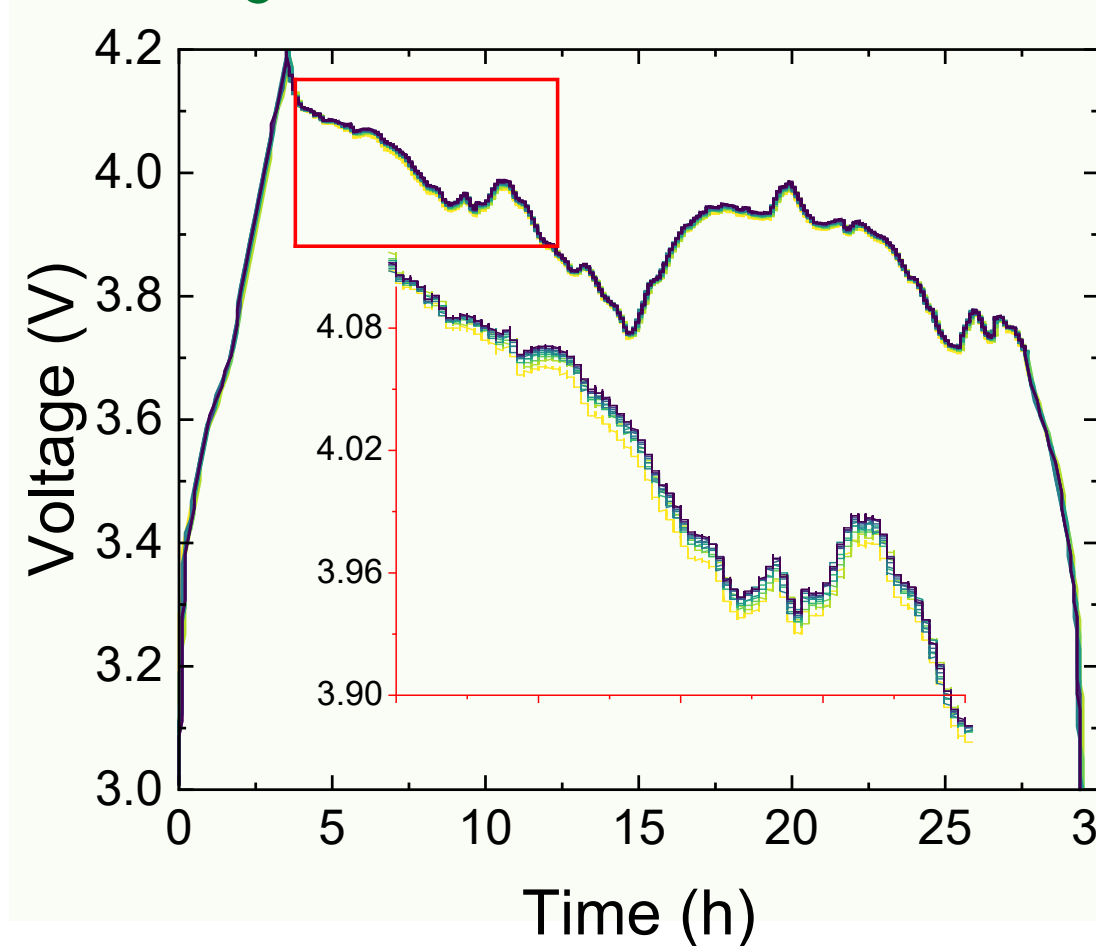
Grid-tied energy storage systems are tasked with delivering a mix of services—including **frequency regulation, peak shaving, and 10-minute spinning reserves**—often in dynamic combinations to maximize return on investment. These complex duty cycles impose non-trivial mechanical, thermal, and electrochemical stresses on batteries.

As energy storage systems increasingly integrate **both new and used cells**, understanding how these cells interact under real-world operating conditions is critical. This project seeks to identify safety risks, performance degradation patterns, and compatibility issues arising from such mixed deployments—enabling more reliable, cost-effective grid storage solutions.

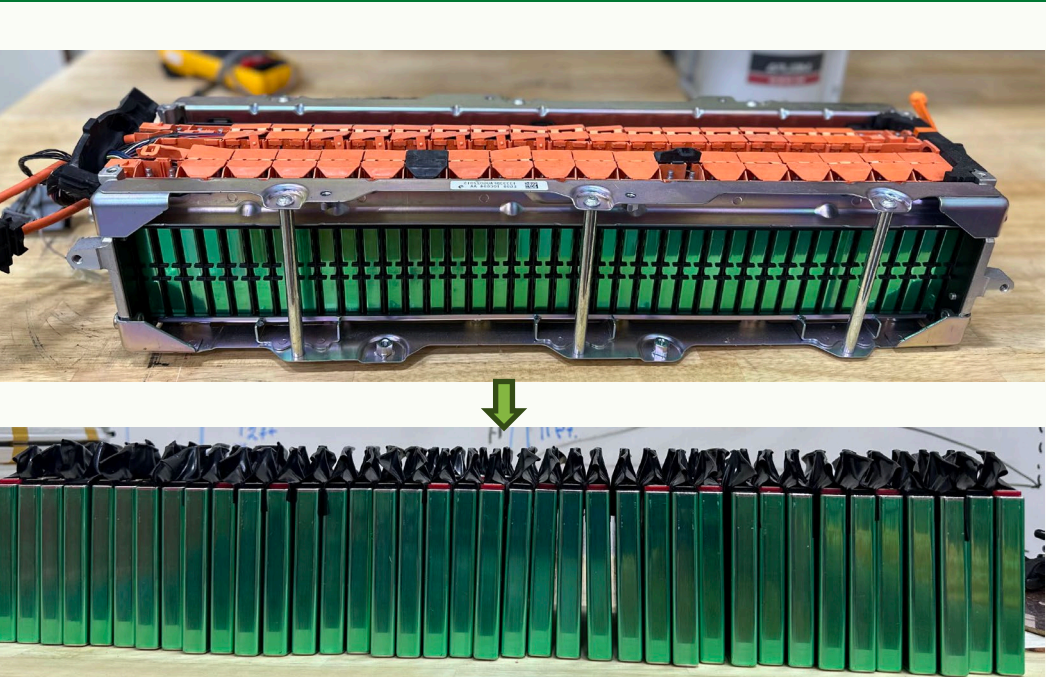


## Evaluation of Fresh Cells under Grid Protocols

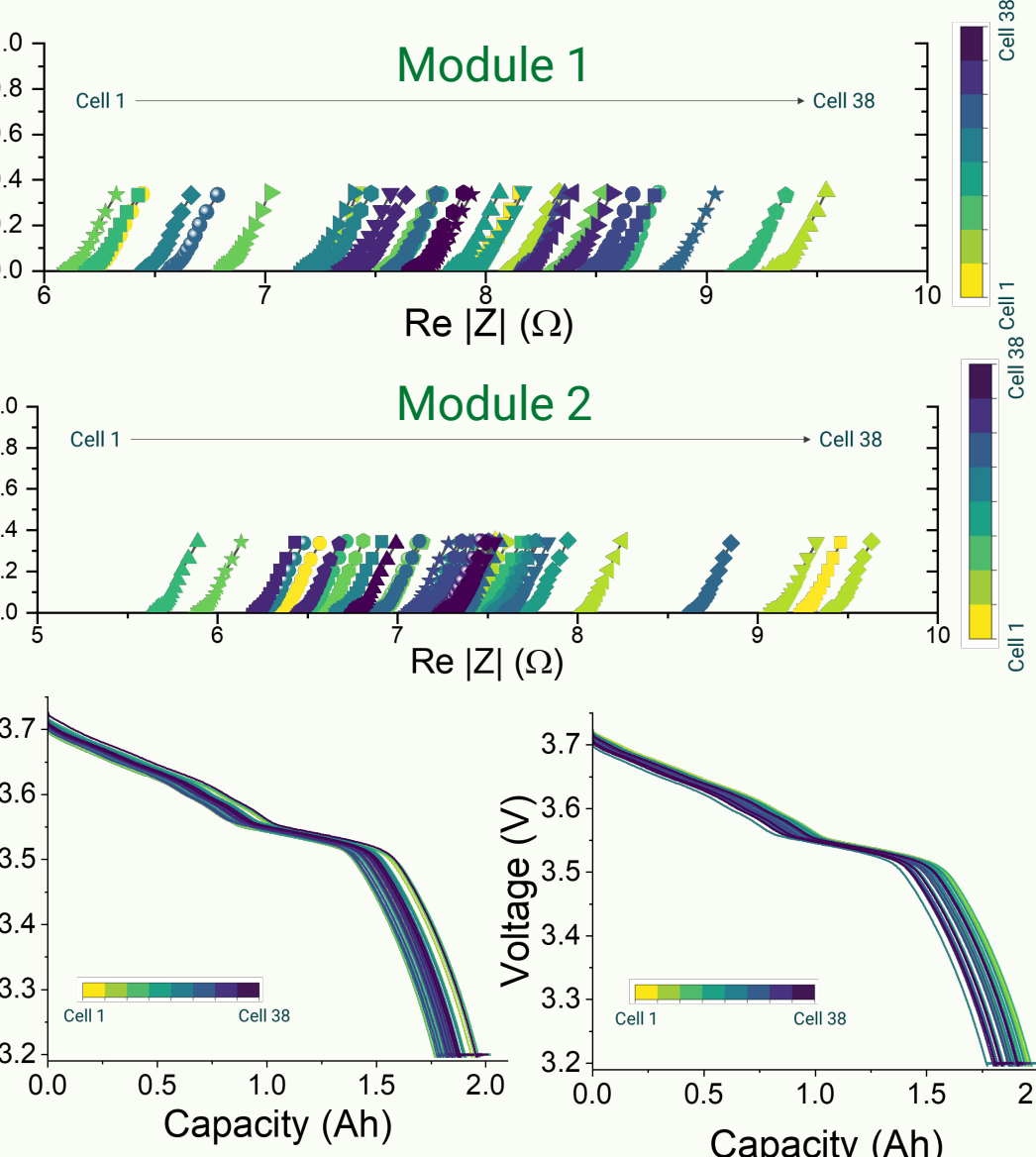
We employ a **24-hour frequency regulation-based grid profile** derived from California utility data, as reported in *Nature Energy* 4, 42–50 (2019). This real-world profile captures high-resolution charge-discharge fluctuations representative of grid operation. For this study, the profile is **scaled and adapted** to our 1.5 Ah pouch cells, and we identify strong degradation of the multi-layer cells under the grid profile warranting further investigation



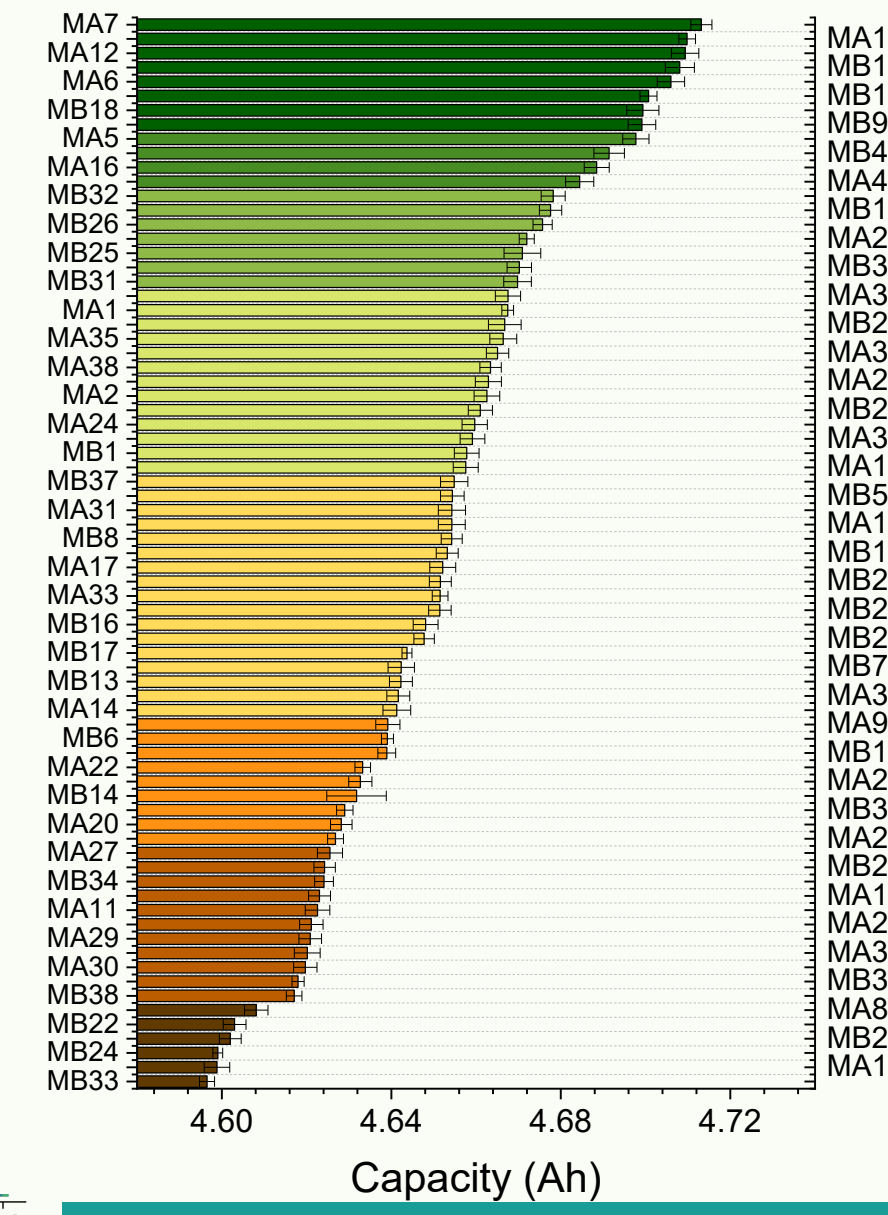
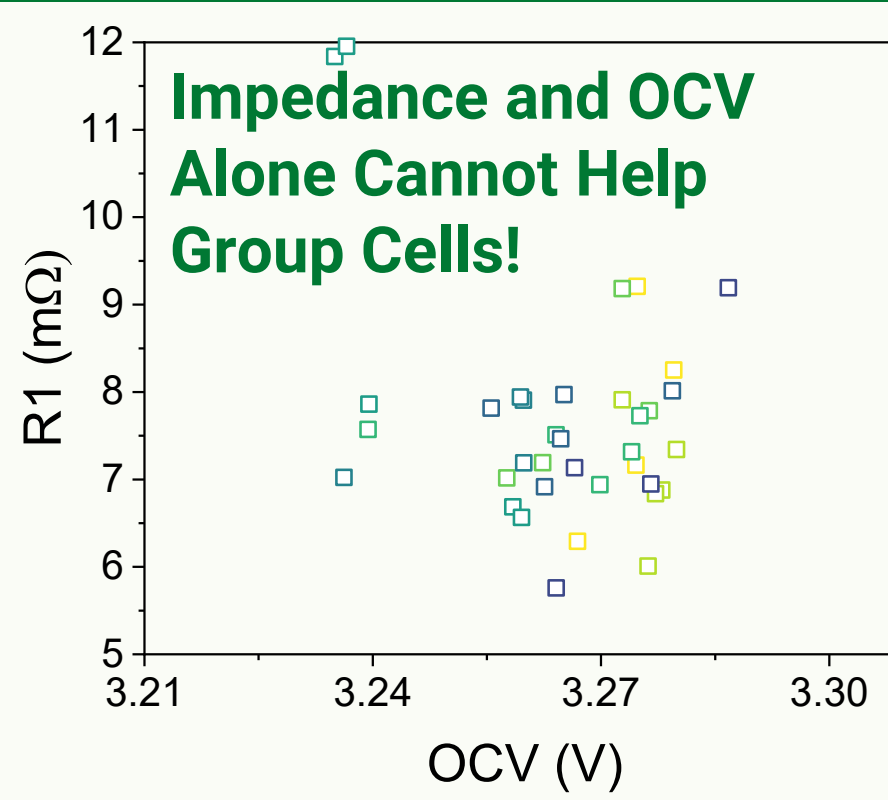
## Identifying Pathways for Efficient Integration of End-of-Life EV Batteries to Grid Storage



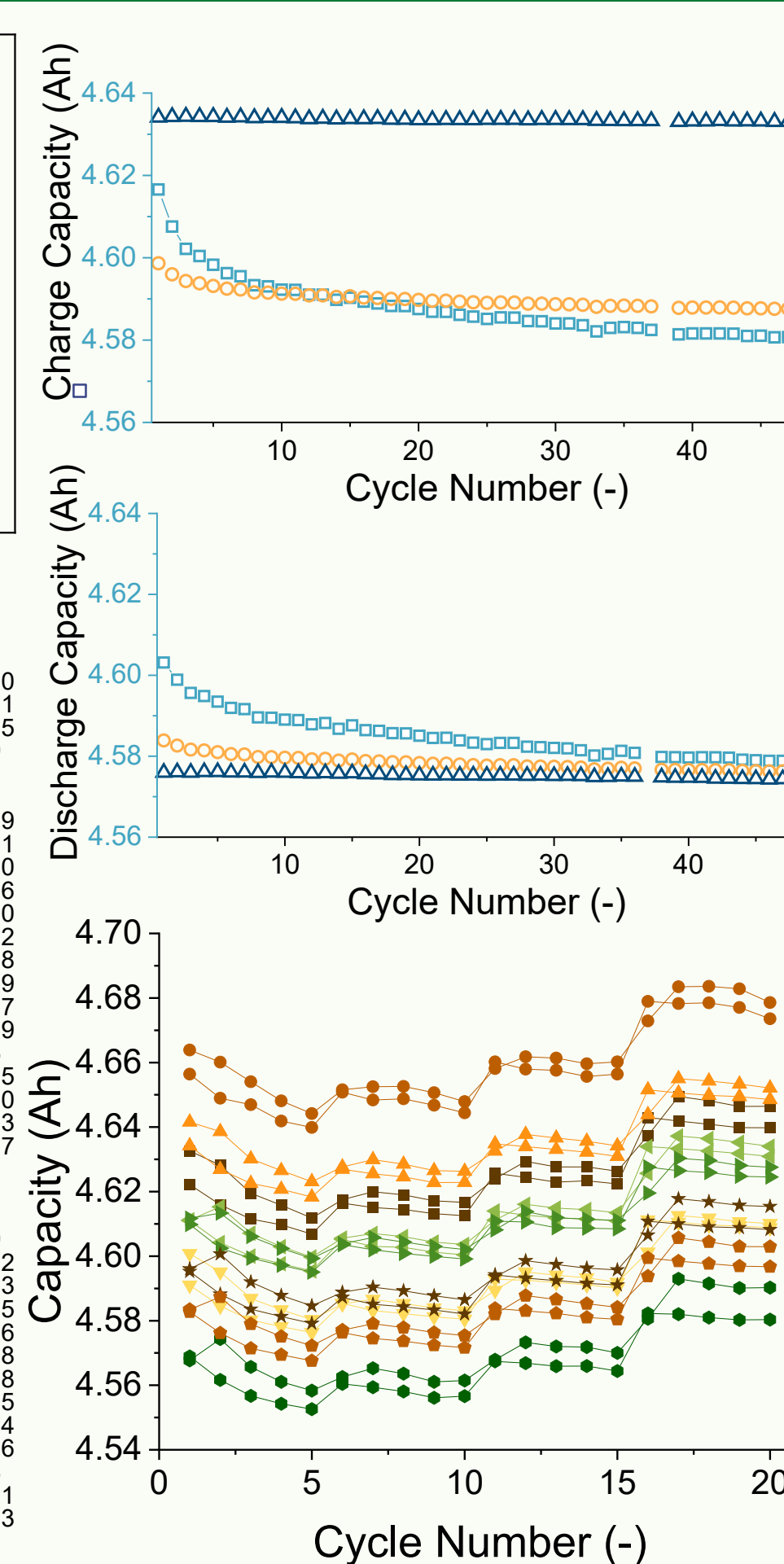
Thirty-eights, 5 Ah rating, prismatic cells from end-of-life hybrid car module extracted



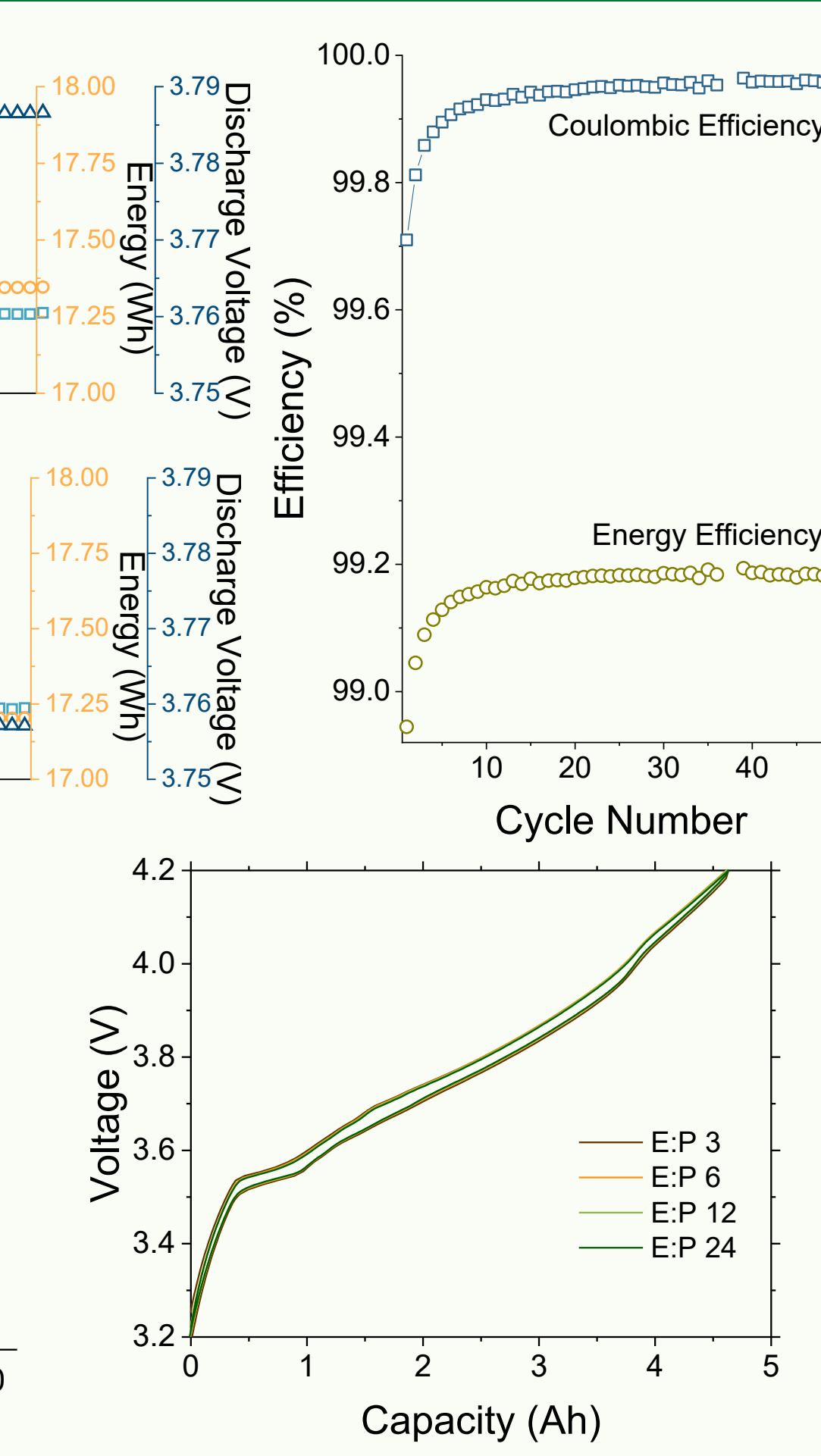
Impedance spectroscopy and capacity benchmarking was carried out on all cells from both modules



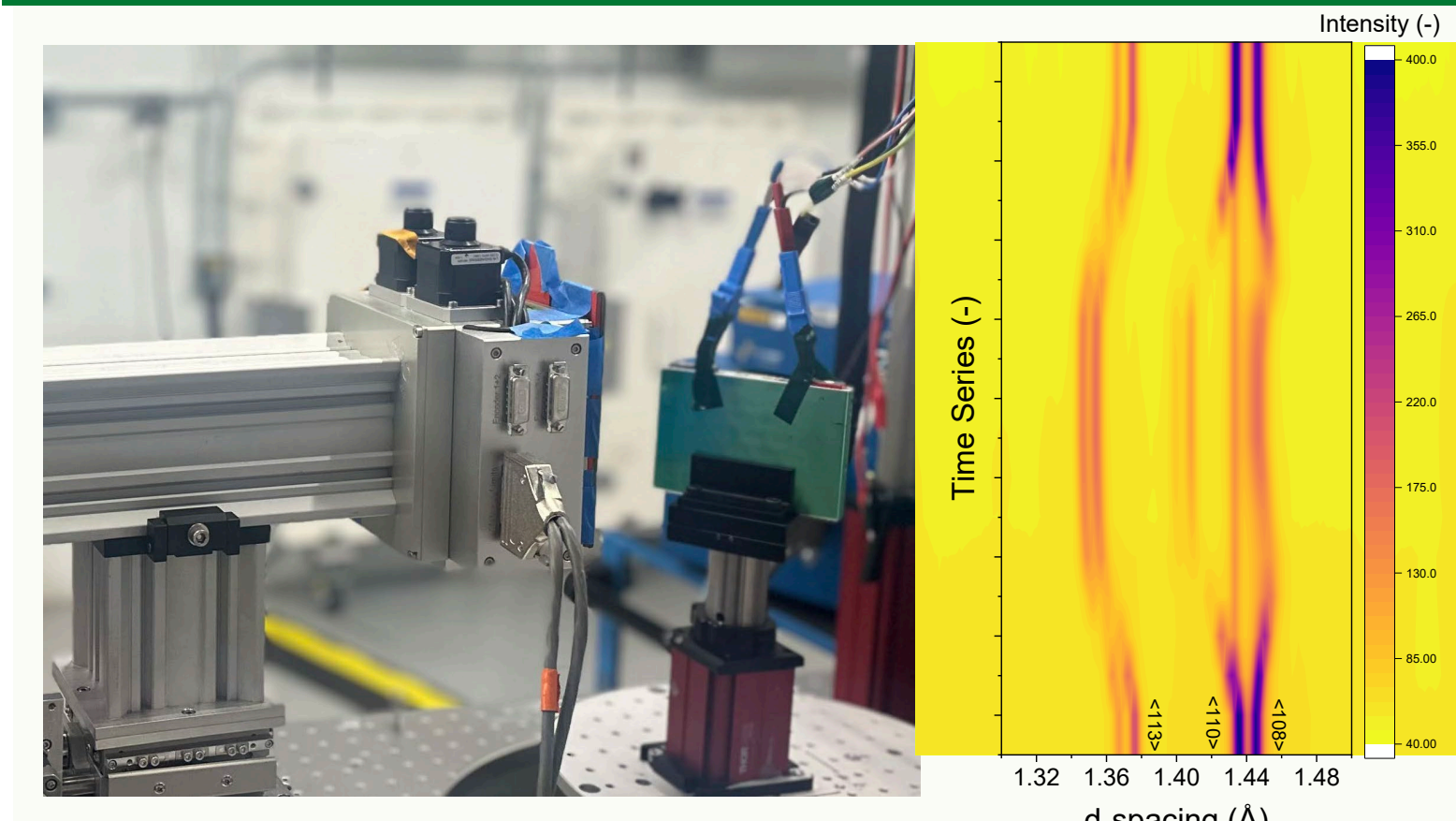
**Discharge Capacity and Polarization as a Metric For Grouping Cells!**



**End-of-life cells retain ~92% of rated capacity (~4.5–4.6 Ah) with ~99.9% coulombic efficiency; Excellent power conditioning under PNNL–Sandia protocol; Very low polarization, indicating strong high-power performance for grid demands**



## Advanced Characterization



We use synchrotron X-ray diffraction to study commercial end-of-life prismatic cells under thermal and electrochemical stress. The custom setup enables time-resolved measurements of internal phase evolution of commercial end-of-life prismatic cells, providing insights into thermal behavior and safety risks critical for grid-scale second-life applications

## Next Steps

- Expand cycling studies on prismatic and pouch cells and groups under realistic grid profiles with real-time voltage/temperature monitoring
- Test EDF-defined protocols on mixed-age/mixed-chemistry cell sets
- Develop predictive models linking degradation to cycling history

## Acknowledgements

- This research was carried out at Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the US Department of Energy (DOE) under contract DE-AC05-00OR22725
- This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE), Energy Storage Division.
- This research was performed on APS beam time award(s) (DOI: //doi.org/10.46936/APS-188668/60013227) from the Advanced Photon Source, a U.S. Department of Energy (DOE) Office of Science user facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357.
- This research used HEX Beamline of the National Synchrotron Light Source II, a U.S. Department of Energy (DOE) Office of Science User Facility operated for the DOE Office of Science by Brookhaven National Laboratory under Contract No. DE-SC0012704.