Electric Vehicle Battery Degradation Under Electric Grid Operations: Vehicle to Grid Strategies.

George Baure & Matthieu Dubarry

HNEI Hawai'i Natural Energy Institute
School of Ocean and Earth Science and Technology
University of Hawai'i at Mānoa

Matthieu.Dubarry@gmail.com

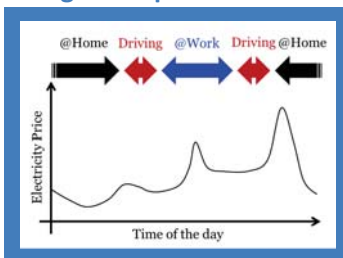
Introduction

Mass adoption of electric vehicles (EVs) could have a number of impacts, including the ability to assist in the integration of renewable energy into existing electric grids by sourcing/sinking energy to/from the grid known as **vehicle-to-grid (V2G)** and **grid-to-vehicle (G2V)**, respectively.

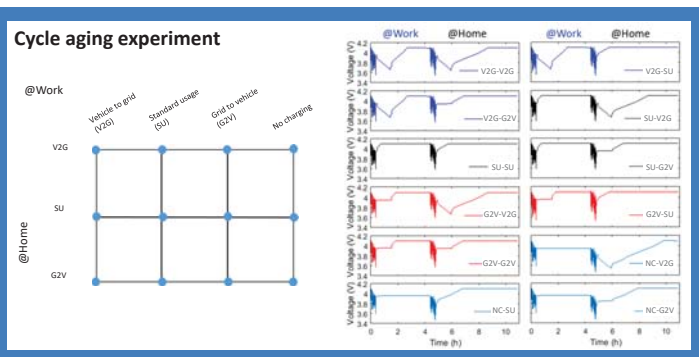
The potential benefits of V2G and G2V have been heavily investigated in recent years. However, their impact on vehicle battery degradation has not been investigated in detail.

The aim of this work is to understand the effect of bidirectional charging on the degradation mechanisms of commercial Li-ion cells used in electric vehicles today and use that knowledge to suggest practices that will improve capacity retention.

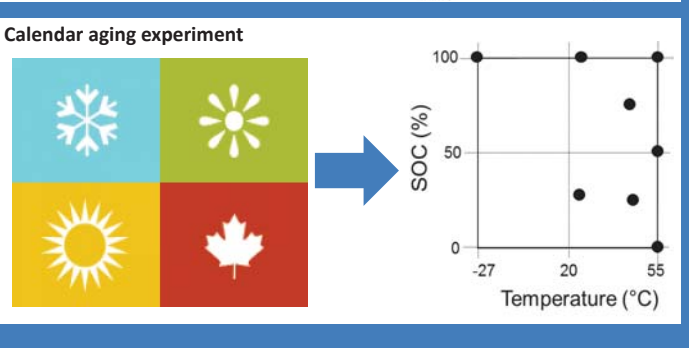
Design of experiment

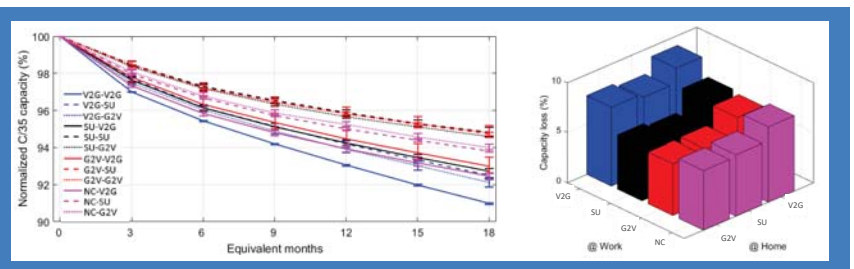


Cycle aging experiment

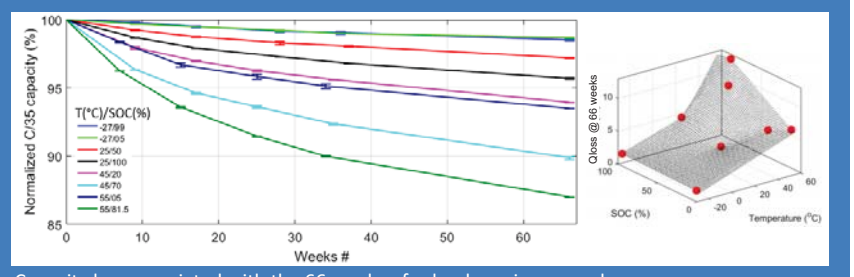


Calendar aging experiment





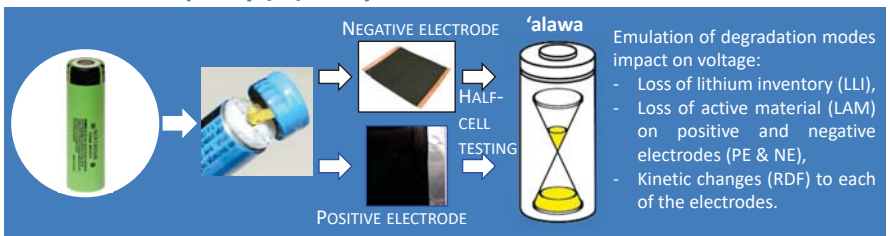
Cells lost between 5 and 9% capacity after an equivalent 18 months of driving
V2G strategy induced 2% extra degradation per daily occurrence (@work and/or @home)



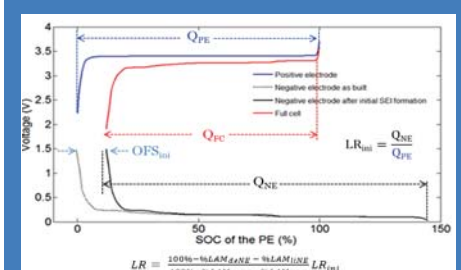
Capacity loss associated with the 66 weeks of calendar aging ranged from 1% (-27°C/99% SOC) to 13% (55°C/81.5% SOC)

J. Power Sources 358 (2017) 39-49, doi:10.1016/j.jpowsour.2017.05.015

Incremental capacity (IC) analysis



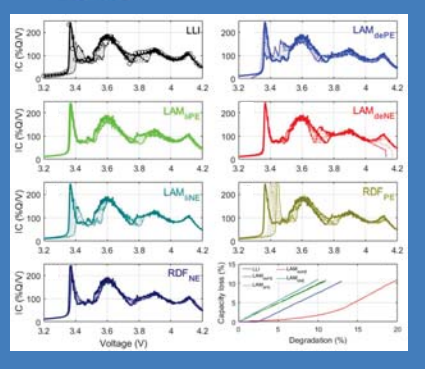
Emulation of degradation modes impact on voltage:
- Loss of lithium inventory (LLI),
- Loss of active material (LAM) on positive and negative electrodes (PE & NE),
- Kinetic changes (RDF) to each of the electrodes.



$$LR = \frac{100\% - \%LAM_{deNE} - \%LAM_{iiNE}}{100\% - \%LAM_{dePE} - \%LAM_{iiPE}} LR_{ini}$$

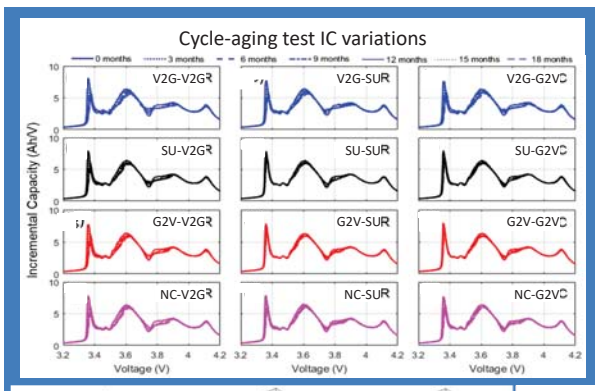
$$OFS = OFS_{ini} + LR\ \%LAM_{iiNE} - \frac{LR}{LR_{ini}}\ \%LAM_{dePE} + \%LLI_{cyk} - \%LLI_{dis}$$

M. Dubarry et al. Journal of Power Sources 219 (2012) 204-216

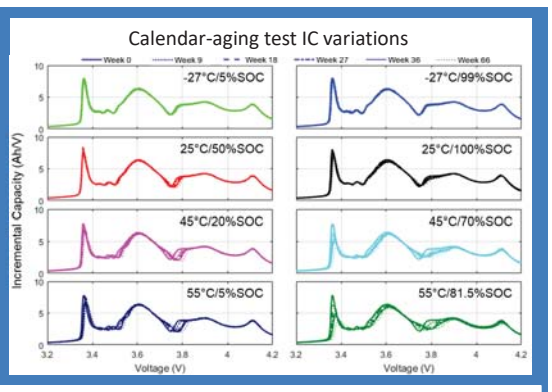


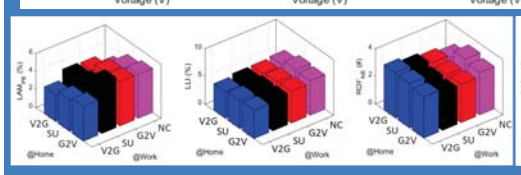
J. Power Sources 219 (2012) 204 doi:10.1016/j.jpowsour.2012.07.016
Batteries 2016, **2(3)**, 28 doi:10.3390/batteries2030028

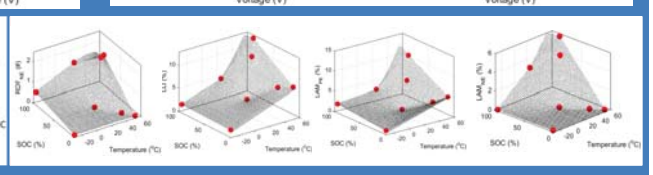
Cycle-aging test IC variations



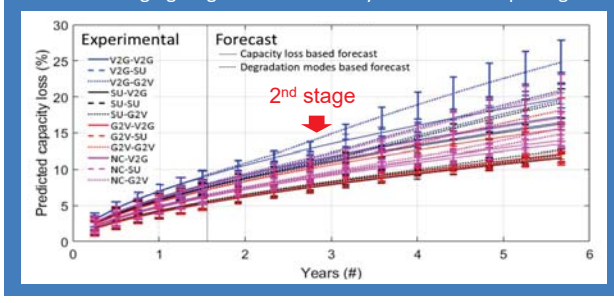
Calendar-aging test IC variations

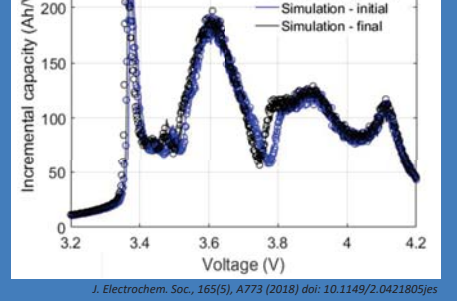






For cycle aging experiment, under some conditions, LAM_{NE} was faster than LLI (LAM_{NE} : LLI ratio ≈ 1.5) This is a sign that some cells will enter an advanced aging stage characterized by the onset of Li plating.



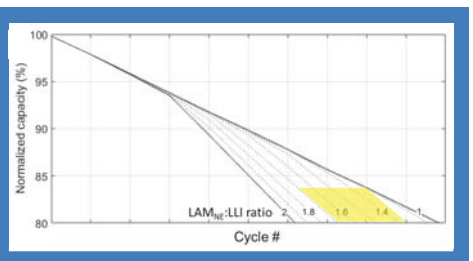


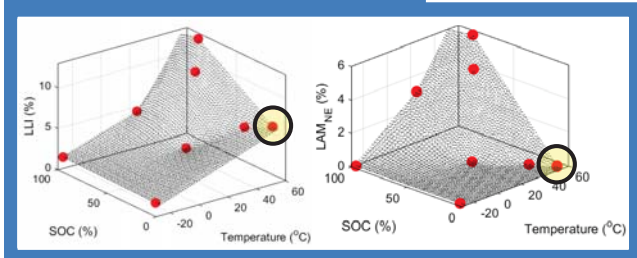
J. Electrochem. Soc., 165(5), A773 (2018) doi: 10.1149/2.0421805jes

Outlook

Performing V2G induces additional usage on the cell and modifies degradation path.

Degradation mechanisms for driving seems to induce more LAM_{NE} than LLI. This will lead to accelerated aging. Timing will depend on ratio. The higher, the faster the cell will enter the 2nd stage of capacity loss.





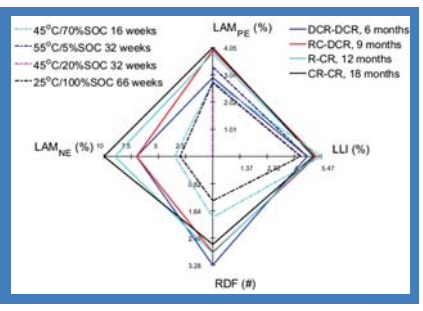
Calendar aging results show resting at low SOCs & high temperatures induces LLI without LAM_{NE}. These conditions will lower their ratio and thus may prevent the apparition of the 2nd stage of capacity loss

This shows that V2G with intelligence could benefit both EV owner and utility. By using V2G to get the battery in a calendar aging condition that lowers the LAM_{NE}/LLI ratio, the overall durability of the battery might increase despite the additional usage.

Energy Policy, 113, 342-347 (2018) doi: 10.1016/j.enpol.2017.11.015 *J. Electrochem. Soc., 165(5), A773 (2018) doi: 10.1149/2.0421805jes*

Conclusions

Results led to prediction of a second accelerated aging stage characterized by the onset of lithium plating.
The accelerated aging stage was induced by faster LAM_{NE} relative to LLI.
Resting at low SOCs & high temperatures facilitates LLI and impedes LAM_{NE} which may avert accelerated aging.
Findings suggest V2G / G2V strategies does not invariably lead to reduced battery lifetimes.
Intelligent control algorithms can be used to adjust duty cycles and rest conditions depending on the battery chemistry to avoid accelerated aging.



Acknowledgments

The authors are grateful for the funding from the State of Hawai'i and from the Florida Solar Energy Center (FSEC), University of Central Florida, awarded as part of grant number DTRT13-G-UTC51 from the U.S. Department of Transportation's University Transportation Centers Program.

Funding was also provided by the Office of Naval Research (ONR), Hawaii Energy and Environmental Technologies (HEET), and Asia Pacific Research Initiative for Sustainable Energy Systems (APRISES) Initiatives (award numbers N00014-11-1-0391, N00014-13-1-0463, N00014-16-1-2116, and N00014-17-1-2206).

The authors are grateful to the Hawaiian Electric Company for their ongoing support to the operations of the Hawaii Sustainable Energy Research Facility and to Katherine McKenzie, Keith Bethune, Jack Huizingh and Richard Rocheleau (HNEI) as well as David Block and Paul Brooker (FSEC).

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the sponsor.

Florida Solar Energy Center — A Research Institute of the University of Central Florida — http://evtc.fsec.ucf.edu/research/
EVTC Electric Vehicle Transportation Center
Hawaiian Electric

University of Hawai'i Mānoa
School of Ocean and Earth Science and Technology
HNEI Hawai'i Natural Energy Institute
School of Ocean and Earth Science and Technology
University of Hawai'i at Mānoa
HiSERF