Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications

P. I. Madhuri Thakur
Farasis Energy
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Program Overview

Timeline

- Project Start Date: Feb. 2017
- Project End Date: Sept. 2020
- Percent complete : 75%

Budget

- $5.9M
- 50%/50% USABC/Farasis
- Subcontractors
- LBNL $300K
- ANL $400K

Barriers

- Achieving high energy density with stable chemistry to meet cycle life and calendar life goals.
- Meeting the cost target of ~ $0.10/Wh
- Manufacturing processes compatible with new materials

Partners

- BASF
- 3M/OneD material/Shin-Etsu/XG Science
- Argonne National Lab
- Lawrence Berkley Lab
- Solvay/ Daikin
- Entek/Celgrad

Relevance/Project Objectives

- Project Objective
  - Develop a EV cell technology capable of providing 280 Wh/kg after 1000 cycles at a cost target of $0.10/Wh.
  - To achieve this the BOL cell energy density target will be ~ 330Wh/Kg.

CELL LEVEL ATTRIBUTES	Units	Baseline (BOL)	Final Cells (BOL)- 2017	Final Cells (BOL)-2018
Cell Capacity (C/3 Rate discharge)	Ah	28.5	64	87
Cell Volume (without terminals/tabs)	L	0.222	0.24	0.3984
Cell Mass	kg	0.49	0.58	0.947
Vmin continuous, Vmax continuous (0 and 100% SOC)	V,V	3.0, 4.2	2.5, 4.5	2.75, 4.2
Vmin pulse, Vmax pulse (10 sec pulses)	V,V	2.5, 4.25	2.4, 4.5	2.5, 4.25
Vnominal (Wh/Ah)	V	3.68	3.55	3.6
Energy Density (volumetric)	Wh/L	470	947	786
Specific Energy	Wh/kg	215	392	331
Power Density (10 sec. HPPC power), 50% SOC	W/L	5440	2910	1778
Specific Power (10 sec. HPPC power), 50% SOC	W/kg	2460	1204	748
Target Cost / unit (>10 million cells/annum rate)	$	16 - 19	25 - 31	25 - 31
Cell format (cylindrical/prismatic)		Pouch	Pouch	Pouch
Cell dimensions: (height x width x thickness)	mm	230 x 160 x 6	230 x 160 x 6	294.4 x 100.4 x 14

Relevance/Project Objectives

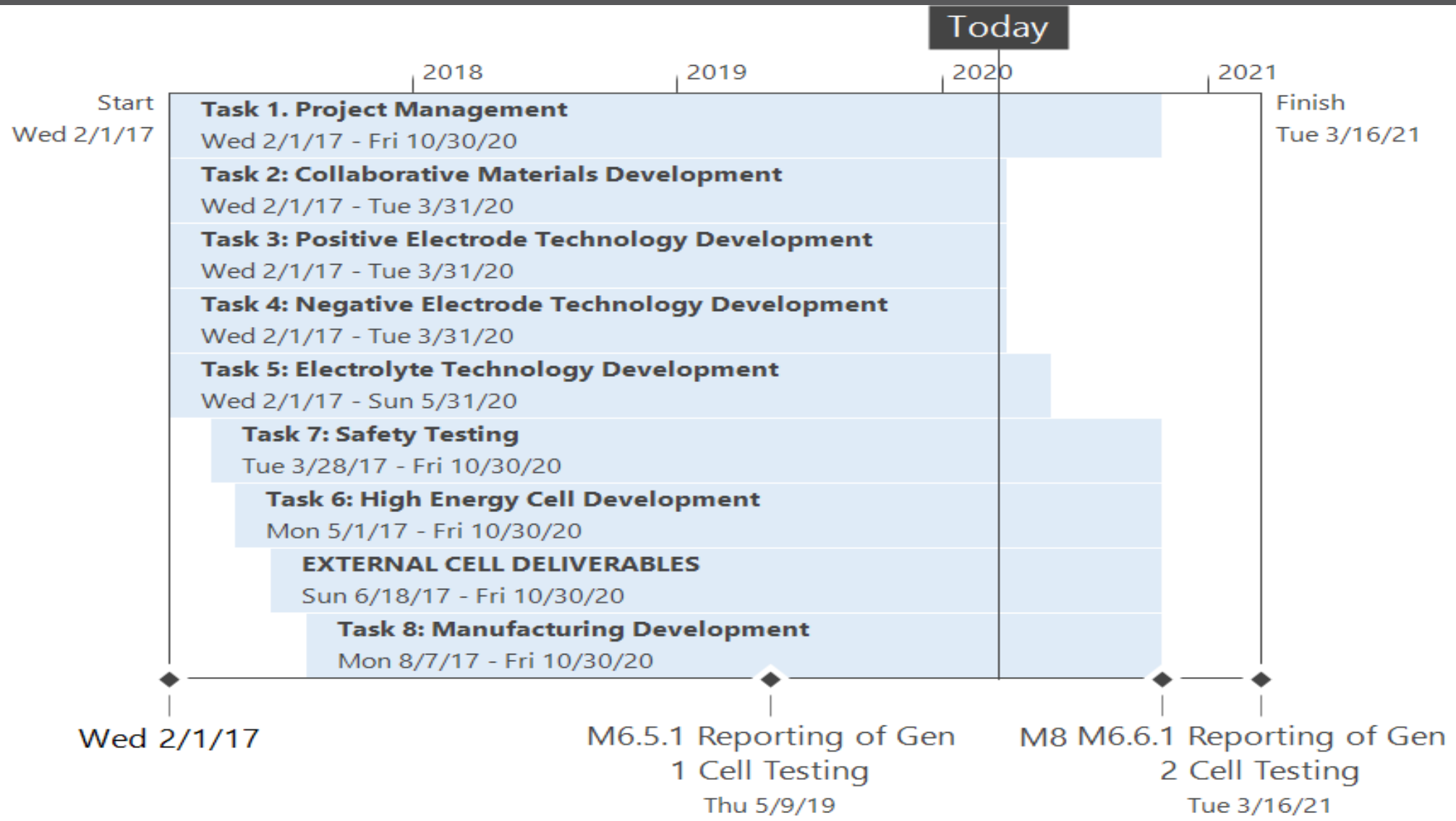
- Project Technical Target
  - Year 1: Baseline deliverable (220Wh/Kg)
  - Year 2: Gen1 Deliverable (300Wh/Kg)
  - Year 4: Gen2 Deliverable (330Wh/Kg)
- Cell Component R&D
  - Comparative evaluation of positive and negative electrode active material blends.
  - Optimization of negative electrode formulation for maximum energy density and cycle life.
  - Investigate effect of Si incorporation on negative electrode conductivity and mechanical stability relative to graphite-only active material electrodes.
  - Additive package development to optimize SEI formation on Si anodes.
  - Stability of Ni rich Cathode
- Risk
  - There are multiple interacting failure mechanisms at the materials and cell level that are barriers to achieving the system level battery performance goals.
  - Calendar life of the Gen1 and cycle life for Gen 2 Cells
  - Safety and cost targets

Project Milestones

- The key Milestones are associated with demonstrating progress towards the goals of the project.

Milestone Summary Table						
Task Number	Task Title	Milestone or Go/No-Go Decision Point	Milestone Number	Milestone Description (Go/No-Go Decision Criteria)	Planned Completion Dates	% Completed
3.3	Positive Electrode Developmental Cell Build	Milestone	M3.3.1	Production of pouch cells representing multiple positive electrode design variants	July, 2017	100%
4.3	Negative Electrode Developmental Cell Build	Milestone	M4.3.1	Production of pouch cells representing multiple negative electrode design variants	July, 2017	100%
6.2	Ongoing Cell Development	Go/No-go	G6.2.1	Demonstration of High-Energy Cells exceeding 300 Wh/kg after RPT2	April, 2018	100%
6.5	Generation 1 Cell Testing	Milestone	M6.5.1	Completed reporting of performance and safety testing results for Generation 1 cells	January, 2019	90%
8.2	Cost Model Development	Milestone	M8.2.1	Submission of detailed cost model based on new materials and processes used in Generation 2 cells.	October, 2020	20%
6.7	Generation 2 Cell Testing	Milestone	M6.7.1	Completed reporting of performance and safety testing results for Generation 2 cells	October, 2020	0%

Milestone Timing



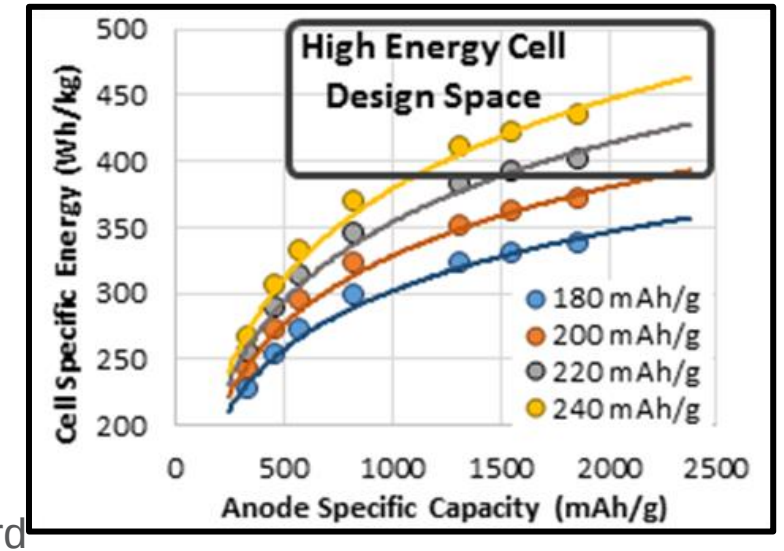
Technology Approach

- Development focused on addressing key current barriers to achieving high capacity, long cycle life and safer Li-ion cells
- **Electrode Chemistry:**
  - Stabilized Ni-rich Cathode: Capacity ~ 220-240 mAh/g
  - Silicon Composites: Capacity ~ 400-600 mAh/g

  Contributors: Argonne National Laboratory, OneD, 3M, Shin-Etsu XG Sciences, BASF, Nanoscale Components
- **Electrolyte Formulation:**
  - Fluorinated solvents
  - Stabilizing additives/salts.

  Contributors: Solvay, Daikin, 3M, BASF
- **Electrodes and Cell:**
  - Optimized, high density, composite active material formulations
  - Low reactivity conductive additives
  - Advanced binder formulations
  - Advanced separators: Coatings, high voltage stability

  Contributors: Lawrence Berkeley National Laboratory, Entek, Celgard



Strategy - Development Plan

Task Status: Colors	
	Done
	Active with some delay
	Stopped
	Non-Active

Cell materials development

New materials sourcing and characterization
New materials improvement, synthesis, development (ANL, LBNL)
Form factor: Coin Cells
Metrics: Capacity, rate, stability

Positive electrode

C1: ~ 11 Materials Variations (~ 300 Wh/Kg)
C2: ~ 3 Materials Variations (shift to 400Wh/kg)
C3 : ~ 2 Materials Variation (Target ~ 330Wh/Kg)
Form Factor: Small Full cells (SLP - <2Ah), fixed anode, electrolyte, energy density
Metrics: Capacity, rate, cycling, safety

Negative electrode

A1: ~ 4 Materials Variations (~ 300Wh/Kg)
A2: ~ 4 Materials Composite Variations (shift to 400Wh/Kg
A3: ~ 3 Materials Variations (Target ~ 330Wh/Kg)
Form Factor: Small Full cells (SLP - <2Ah), fixed anode, electrolyte, energy density
Metrics: Capacity, rate, cycling, safety

Electrolyte

E1: ~ 10 Materials Variations (~ 300 Wh/Kg)
E2: ~ 5 Materials Variations (~ 320 Wh/Kg)
E3 : ~ 5 Materials Variations (~ 330 Wh/Kg)

Form Factor: 18650, <2Ah pouch, single cell design
Metrics: Capacity, rate, cycling, calendar life, safety

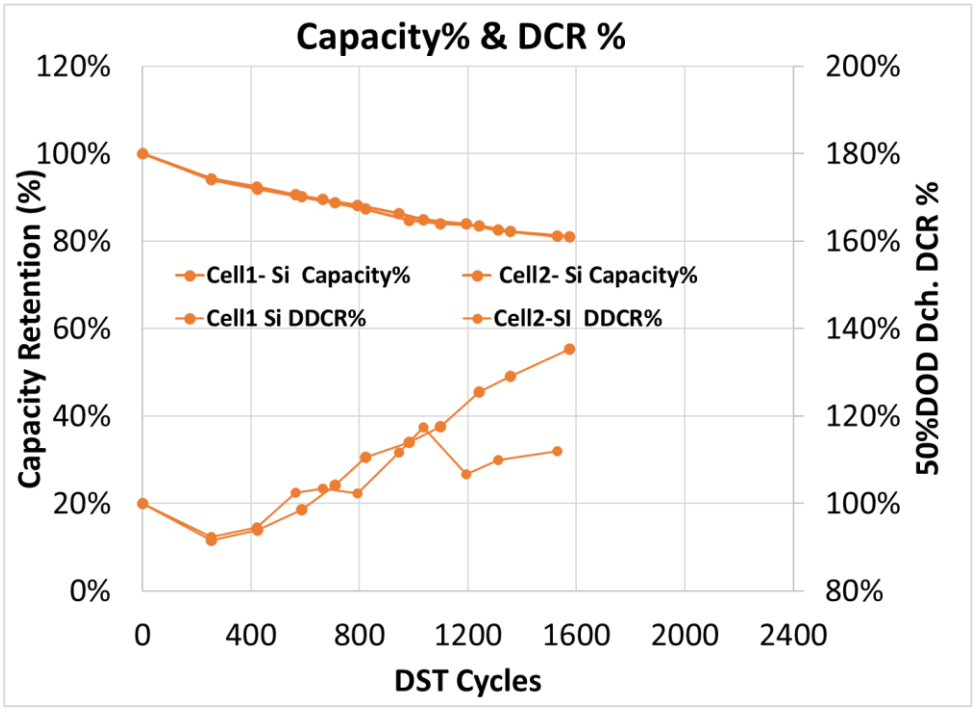
Cell

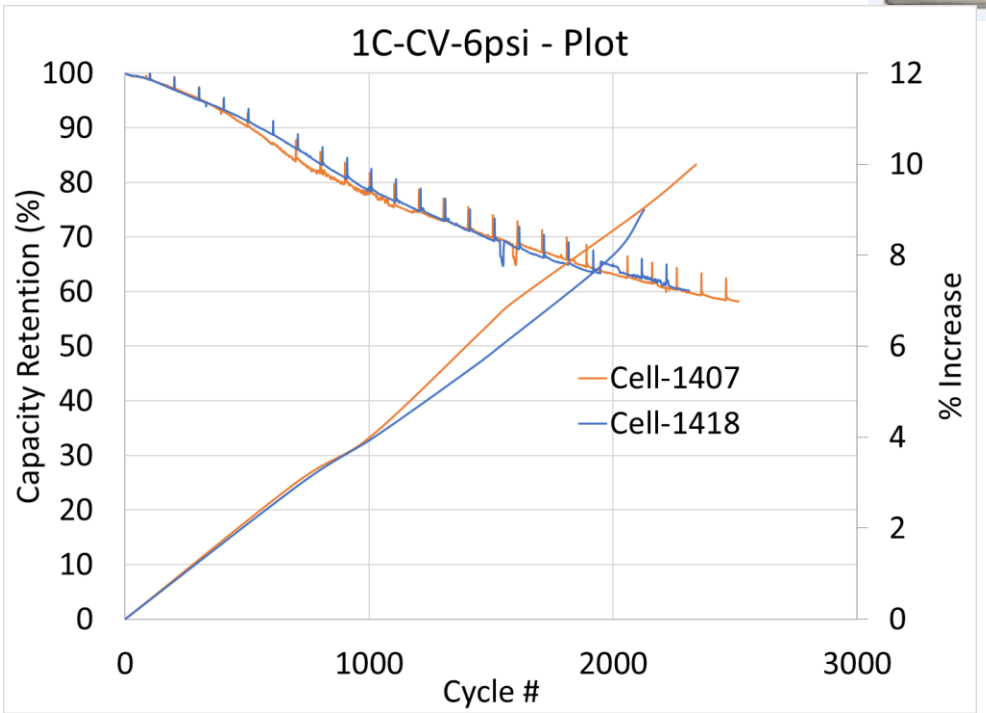
DOE1: ~ C1 & A1 (Optimized formulation for 3 C1 & 2 A1 with 5 E1)
DOE2: ~ C2 & A2 (Optimizedformulation for 2 C1 & 2 A1 with 5 E1)
DOE3: ~ 7 Materials Variations
Form Factor: Full cells, fixed anode, electrolyte, energy density
Metrics: Capacity, rate, cycling, safety

Deliverables:
Baseline: Baseline (30Ah) NCM/Graphite
Gen1: Gen 1 Cells (40Ah) Chemistry from **DOE 1**
Gen 2: Gen 2 Cells (87 Ah) Chemistry from DOE3

Technical Accomplishments
Gen1 Delivered to National Labs: Test Summary

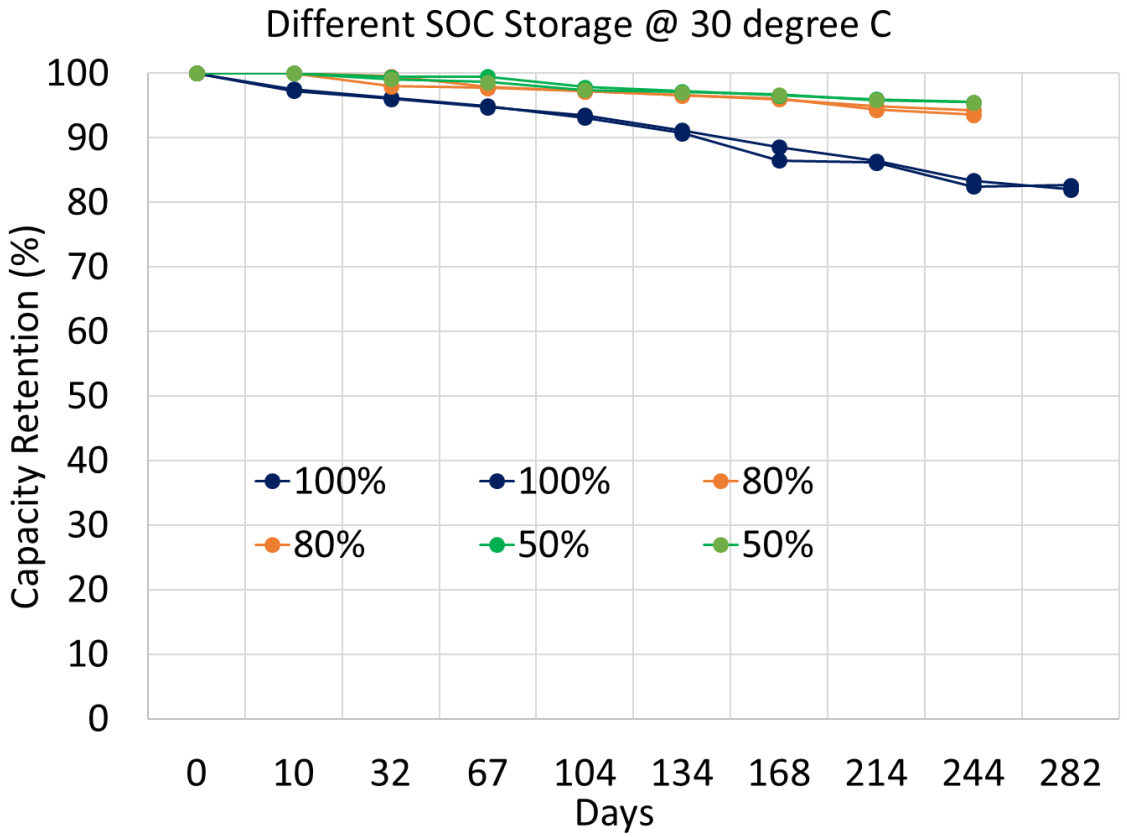
- Dynamic Stress Testing (DST) : Si/C composite with Ni rich NCM @ 30°C
- Cycle life: 1C/1C CV C/20
- Capacity of Cell 40 Ah with targeted specific energy of 310Wh/Kg for 80Ah Cell
- Cycle per RPT is 160-170
- DCIR : 50%DOD DDCR

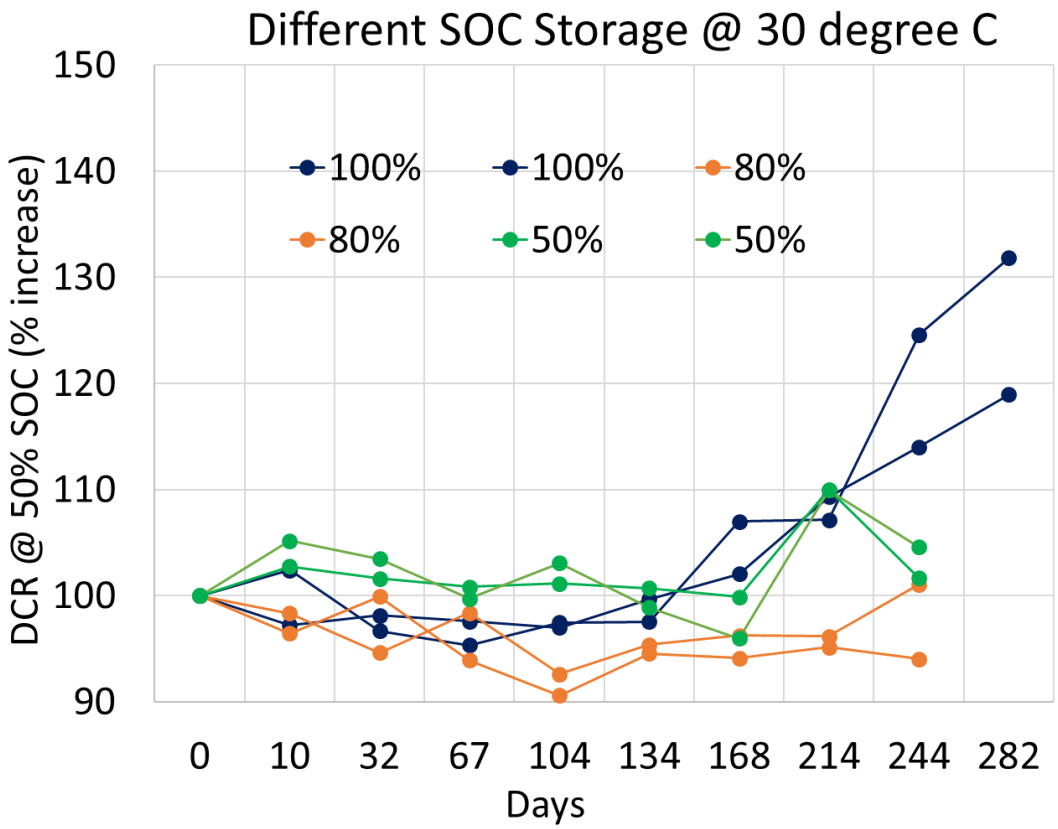




Technical Accomplishments
Gen1 Delivered to National Labs: Calendar Life

- Impedance, thickness and capacity



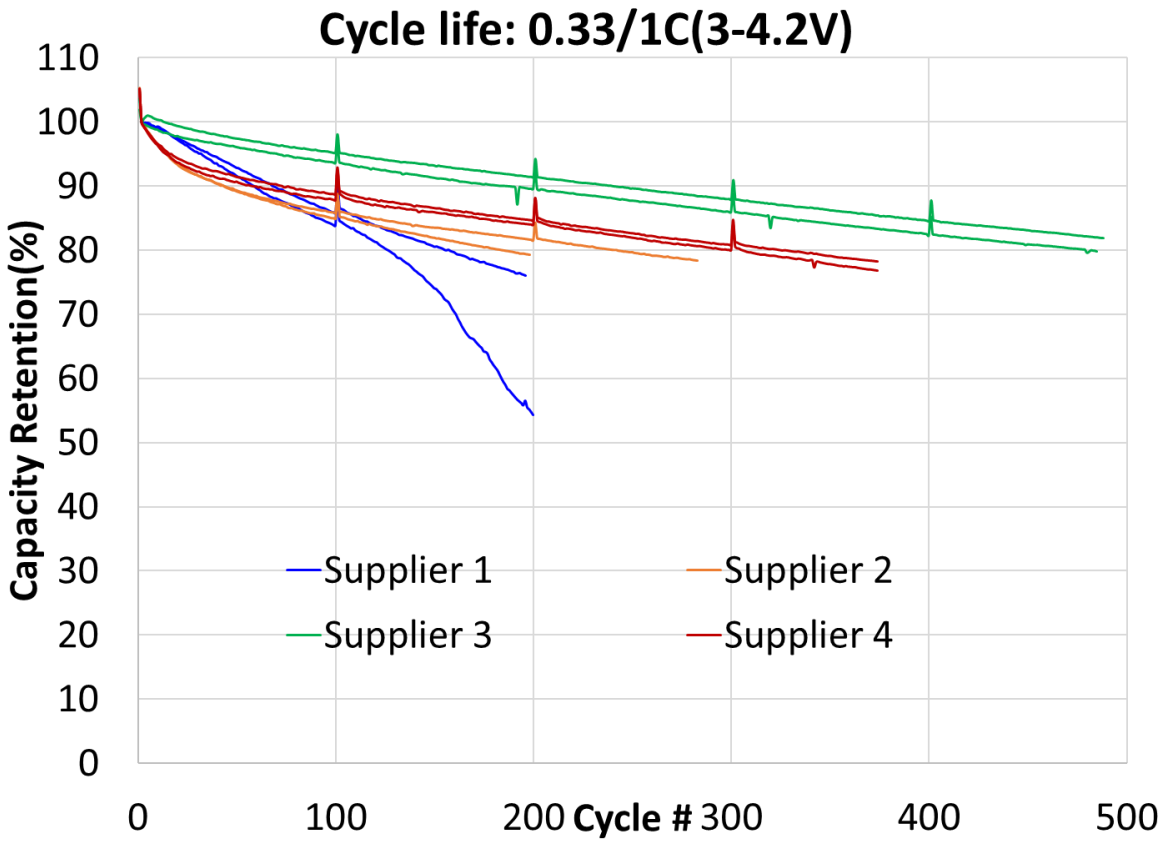


Technical Accomplishments
Gen2 : Cathode and Anode Challenge and Development

- **Development Plan for Cathode Active materials for Final Deliverable (Gen2):**
  - **Evaluation Criteria for the cathode for Final deliverable**
    - Reversible capacity ≥ 200mAh/g
    - Stability of the Ni rich NCM
    - Other composite electrode formulations balancing properties of different materials (particles size, reactivity, capacity etc).
- **Development Plan for Anode Active materials for Final Deliverable (Gen2):**
  - **Evaluation Criteria for the anode for Final deliverable**
    - Reversible capacity ≥ 500mAh/g
    - Swelling less then 10% at the cell level
    - Cycle life
    - 1st cycle efficiency for comparable to graphite materials.
    - Using silicon higher then 10% needed different binders

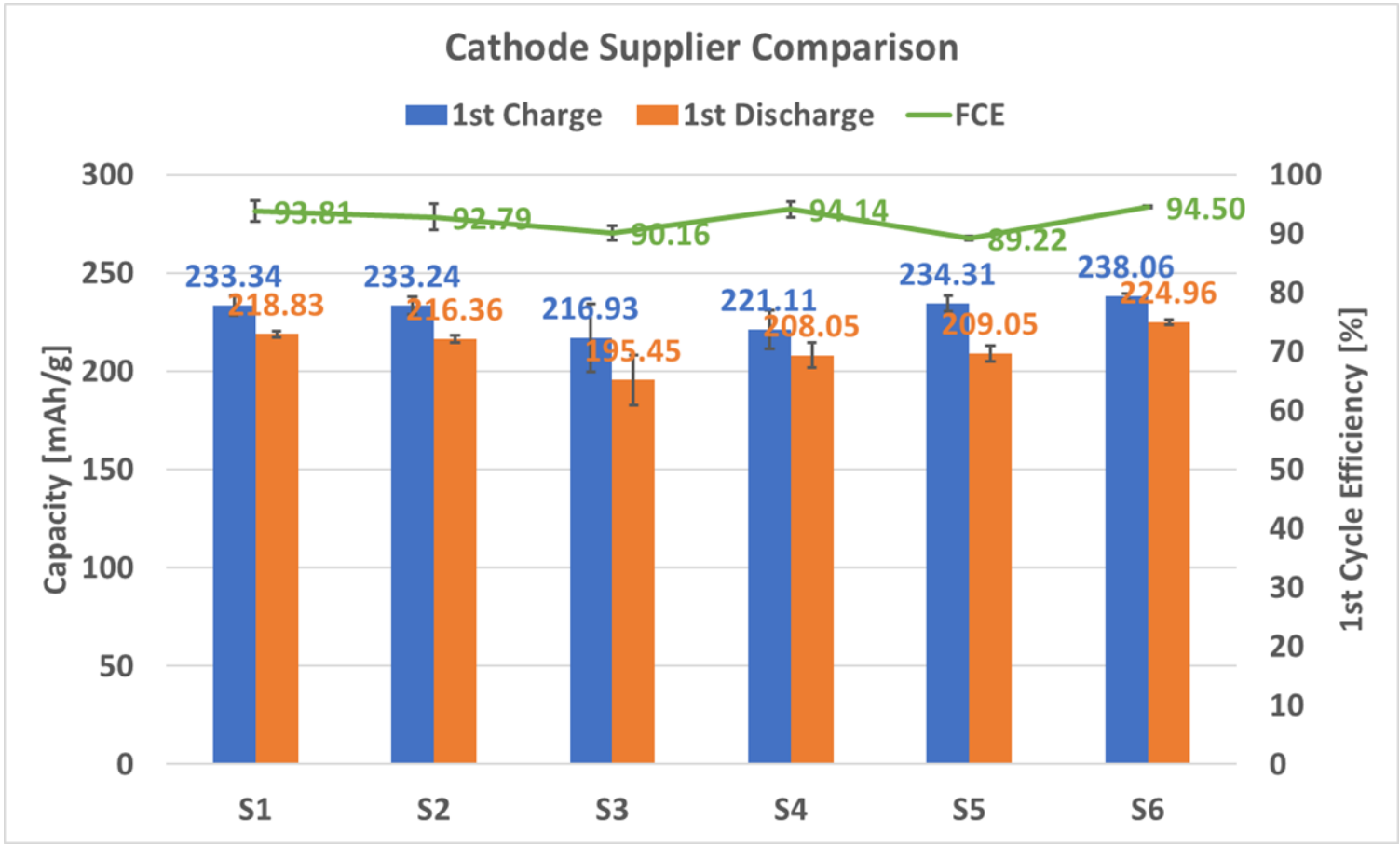
Technical Accomplishments
Gen2 : Test Summary for low efficiency Si

- Low efficiency SiO <10% have cycle life > 1000 – Gen1
  - Advantage: Low cost and more stable cycle life
  - Disadvantage : Low 1st cycle efficiency
- Using low efficiency SiO > 10% can have good cycle life but impact the energy density of the cell. To achieve the targeted energy density of 330Wh/Kg still need pre-lithaition if we want to use these materials.
- Cycle life of Single layer pouch cell build for higher amount of low 1st cycle Si.



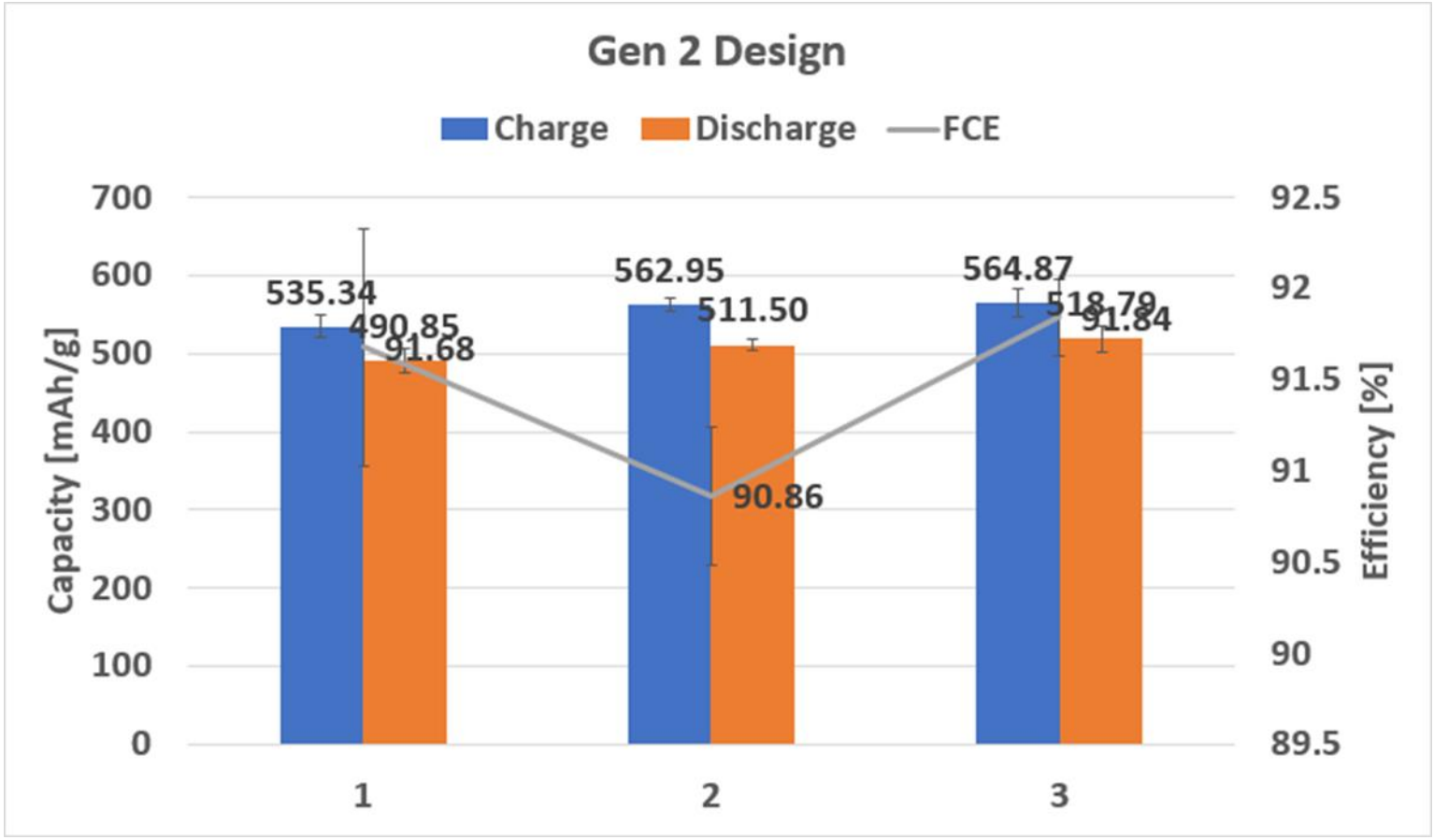
Technical Accomplishments
Gen2 : Cathode targeting 330Wh/Kg

- Cathode : Reversible capacity ≥ 200mAh/g



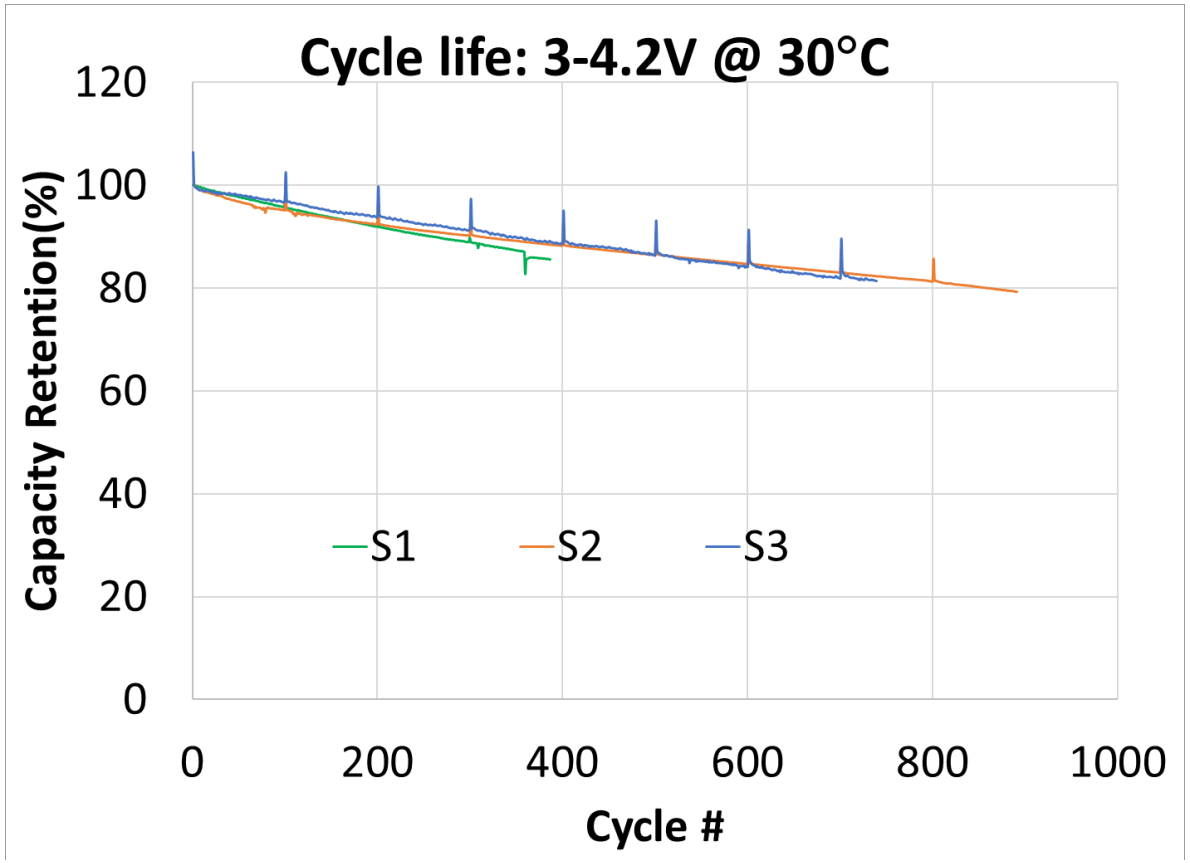
Technical Accomplishments
Gen2 : Anode targeting 330Wh/Kg

- Anode (1st Cycle CE ≥90%):



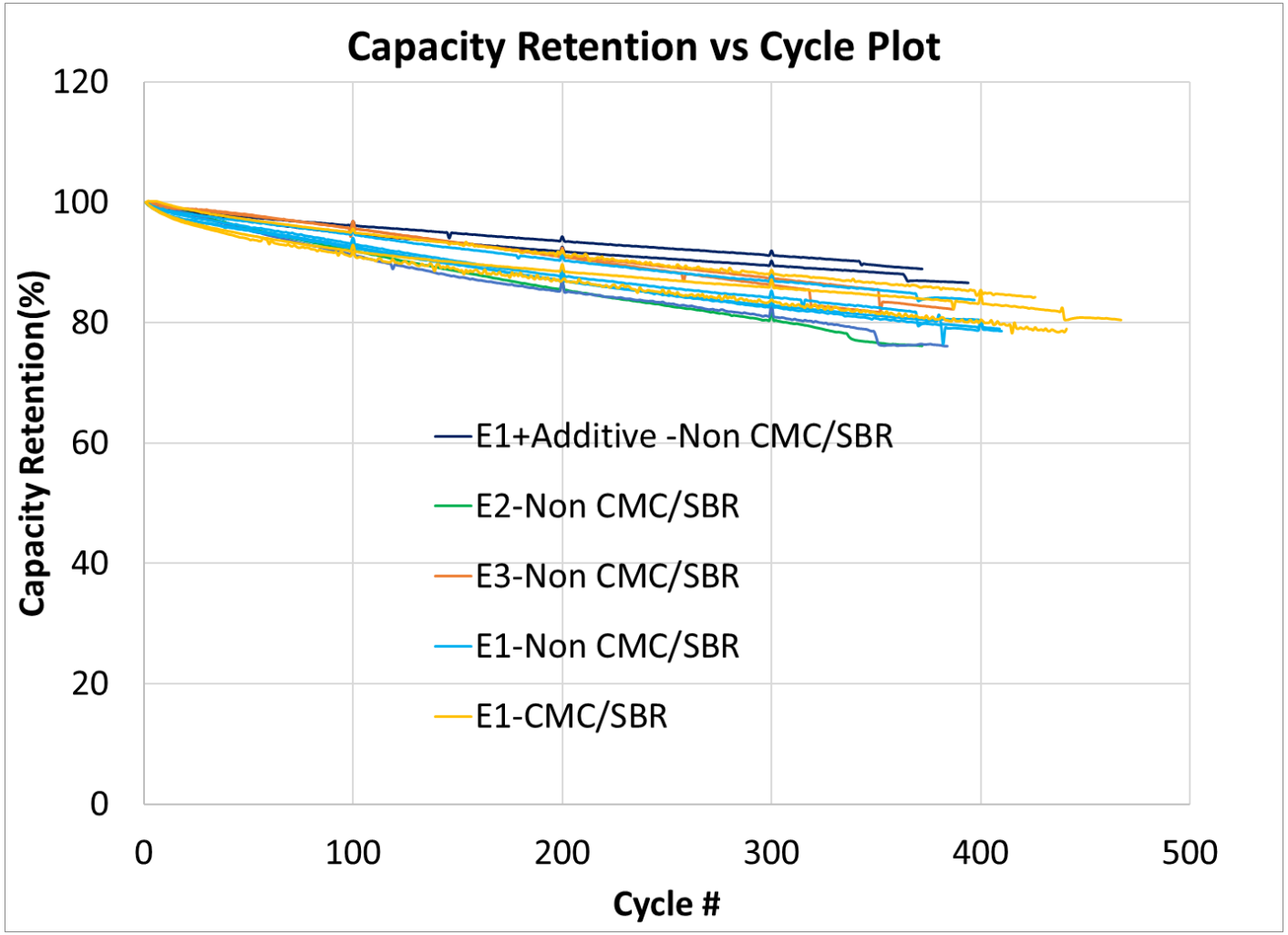
Technical Accomplishments
Gen2 : Targeting ~330Wh/Kg

- Evaluation of **Ni Rich cathode** with **three different type of Si anode** in a single layer pouch cells (at fixed anode capacity, same cathode & targeting 330 Wh/kg): Cycle life



Cathode: Ni Rich (same supplier)
Anode : Fixed Capacity (Different type of Silicon from different supplier
Form Factor: 500mAh
Energy Density : ~330Wh/Kg in deliverable form factor
Testing Condition:
0.5C/1C CV C/20 (3-4.2V) @ 30°C

Technical Accomplishments
Gen2 : Electrolyte and Binder Optimization



Technical Accomplishments
Summary Cell Development: Gen1 & Gen2

- **Gen 1 (300Wh/Kg)**
  - Delivered to National Labs
  - Tested internally
  - Test data of National lab is comparable to the internal data
  - Work is going on further improving the calendar life of the cells

- **Gen2 (330Wh/Kg)**
  - **Cell design optimization**
    - C3: Optimized cathode formulation
    - A3: Optimized anode formulation
    - E3: Selected electrolyte formulation
    - Tested 500mAh capacity single and double-layer pouch cells
    - Collected cycle life data
  - Next step
    - Building 40-50Ah cell in production facility to further analyze the down-selected chemistry

Responses to Previous Year Reviewers' Comments

Comment: "The reviewer found that the approach appears excellent, adding there is good organization and testing protocols. Use of cells at different scales is well done. The reviewer concluded that DOE barriers are being addressed in cell development of increasing scales".

Response: All the comments from the reviewer is positive about the management of the program, cell development as well as the funding of the project

Comment: "Project is directly pushing vehicle battery technology and seeing how far we can tweak the NMC technology". The review suggested that there was not much optimization done on anode.

Response: During year 2019 the focus of the project was to optimize an anode to achieve The targeted energy density in deliverable form factor.

Comment: "Reviewer showed concern about taking care of the swelling of the Si"

Response: We have done the comparison between the swelling of the Si and graphite cells with same cathode where the anode have different porosity. We have seen that there was no difference in the swelling for the amount of Si we are using during the cycle life of the cells. The swelling increase during the formation is taken during the design of the cell.

Responses to Previous Year Reviewers' Comments

Comment: "results reported are focused on the Gen1 cells but based on the project plan timing it appears substantial reporting of work on Gen2 cells should also be done"

Response: During year 2019 all the work is done on the down-selecting the chemistry for Gen2 cell and testing Gen1 cells. The cell design is ready to build the cell with 330Wh/Kg specific energy.