Advanced Cathode Material Development for PHEV Lithium Ion Batteries

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May 10, 2011

Project ID # ES006

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Overview

- Timeline
  - *start: 4/06/2009*
  - *finish: 4/1/2011*
  - *100% complete*
- Budget
  - *Total project funding*
  - *USABC share: $1,137,726*
  - *Contractor share: $1,137,726*
  - *Funding received in FY09: $185,264*
  - *Funding received in FY10 : $674,349*
  - *Funding to Feb in FY11: $208,477*
- Barriers

  Cost, Capacity, Rate and Thermal Control.
- Targets
  - *Increase capacity 5-10%*
  - *Reduce Cost >10%*
  - *Maintain thermal stability and cycle life*
- Partners
  - *Major automakers*
  - *DOE Labs*

Project Objective

To design an advanced cathode materials with the following performance improvement compared to MNC 111 for PHEV applications:

- *5 ~ 10% higher capacity improvement (mAh/g)*
- *~ 15% lower raw material cost*
- *Comparable or higher thermal stability*
- *Comparable or higher cycle life*

Achieving Objectives will Result in a New Cathode Material with Cost and Performance Advantages for Vehicle Applications

Milestones

Jan 2010

- Phase I – Identify Material Candidate
  - *Lab scale material R&D - two compositions meetings program objectives*
  - *Optimized & validated 18650 test vehicle (≥ 1250 cycles)*

July 2010

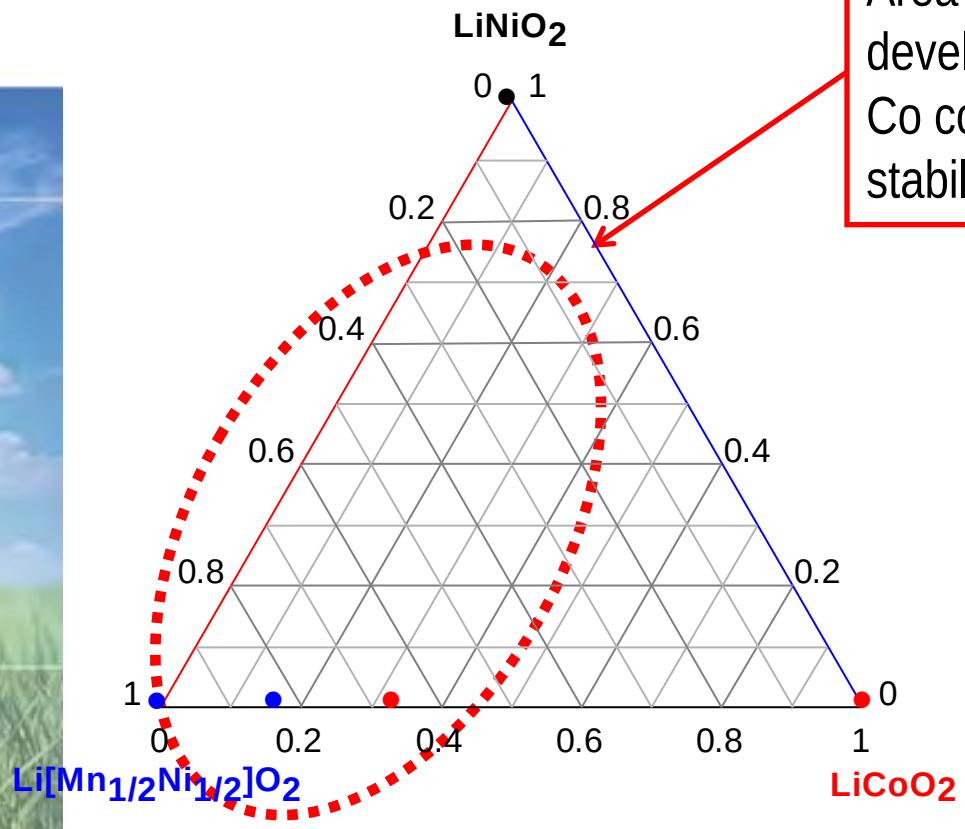
- Phase II – Material Scale Up
  - *Optimize, validate & verify process parameters on pilot plant scale*
  - *Pilot plant production & validation of final cathode material*

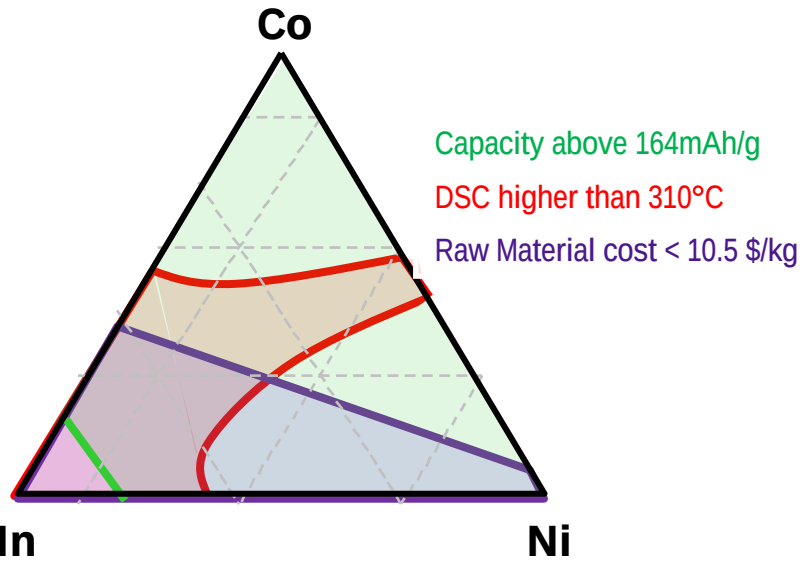
Feb 2011

- Phase III – Material Validation in 18650 Cells
  - *Build and evaluate 18650 cells with advanced cathode materials*
  - *18650 data package generation & performance validation*
  - *18650 shipment to DOE labs for performance verification*

Approach – Cathode Material Development

Area of interest for new cathode development because of the low Co content – cost, thermal stability and energy density



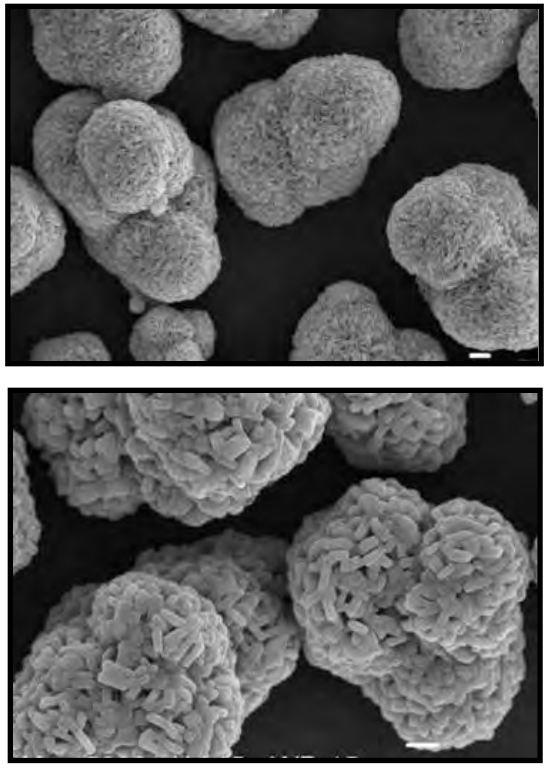


Mixture Design and Statistical Modeling used to Identify most Promising Compositions

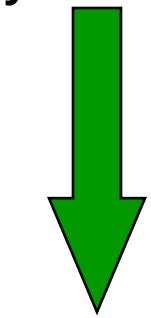
Approach – Process Optimization

Process Optimization

- *Reactor Temperature*
- *Reactor pH*
- *Rate of material addition*
- *Reaction Time*
- *Residence Time*
- *Sintering condition*
- *Lithiation*



Hydroxide



Oxide

Best Composition and Process Conditions Identified from over 50 Samples

Approach – Performance Validation

- Lab Scale Material / Coin Cell Evaluation
- Pilot Scale Material / 18650 Cell Evaluation
  - *Comparative Cell Design*
  - *Electrolyte Additives*
  - *Electrode capacity (mAh/cm²)*

	Baseline	Advanced Material
Cathode	3M BC618 (MNC 111)	Advanced MNC 2
Anode	Graphite	Graphite
Separator	Celgard 2325	Celgard 2325
Electrolyte	1M $LiPF_6$ EC/EMC/DMC	1M $LiPF_6$ EC/EMC/DMC
Additive	A and B	A and B
Cell	18650-Size	18650-Size

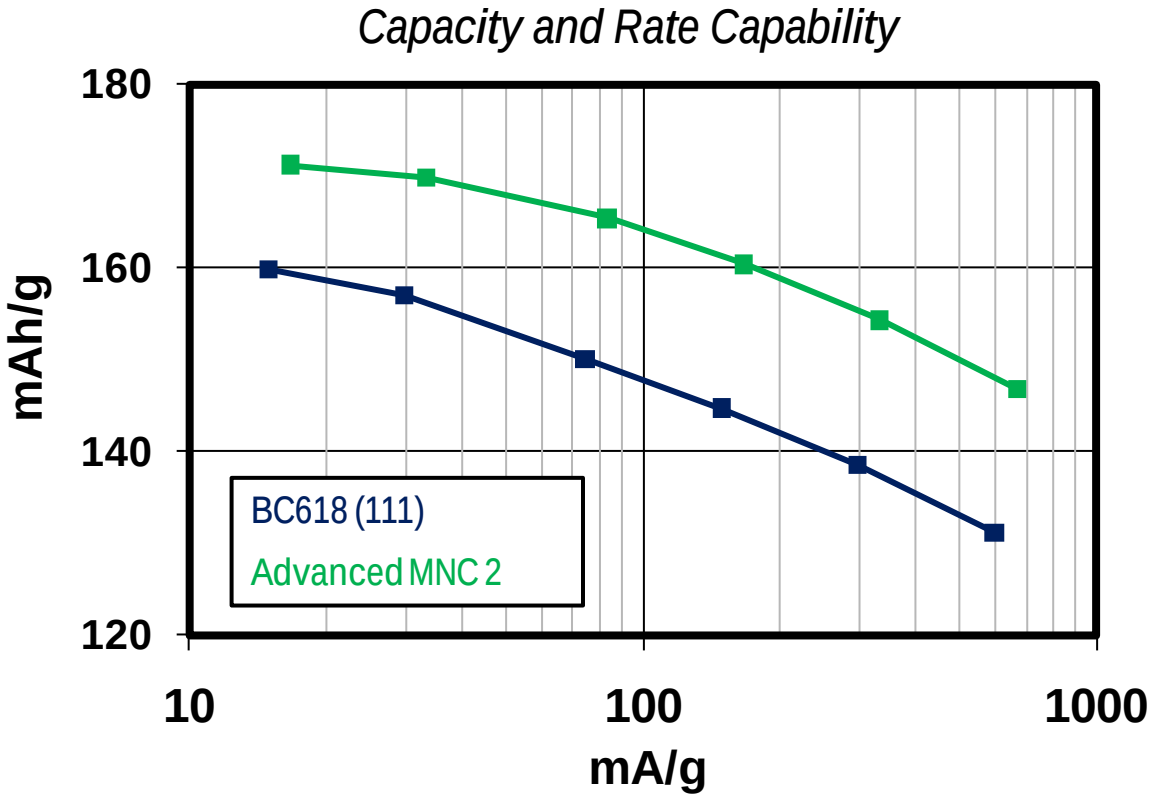
- Evaluation Methods
  - *18650 Abuse Testing*
    - *Thermal Ramp, Hot Block, Nail Penetration Tests*
  - *18650 evaluation in accordance with "Battery Test Manual for Plug –In Hybrid electric Vehicle"*
    - *Static Capacity Test, HPPC, Self Discharge Test, Charge Depleting Cycle Life Test & Cold Crank Test*

Accomplishment – Lab Scale Material Identification

Requirement	BC618 (111)	Target	Adv. MNC 1	Adv. MNC 2
Capacity C/10 (mAh/g)	***156***	***>172***	***173***	***174***
Capacity C/2 (mAh/g)	***145***	***> 161***	***164***	***163***
Thermal Stability DSC (ºC)	***315***	***≥ 315***	***321***	***315***
Materials Cost (relative)	***100%***	***≤ 85%***	***81%***	***72%***

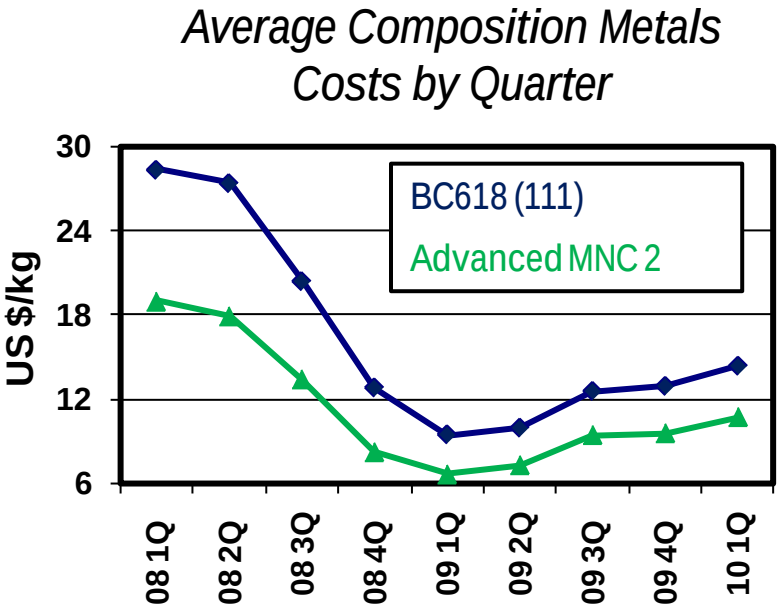
2 Advanced MNC Candidates Meet Primary Objectives.
Material Down Selected on Storage Capacity Retention & Cost

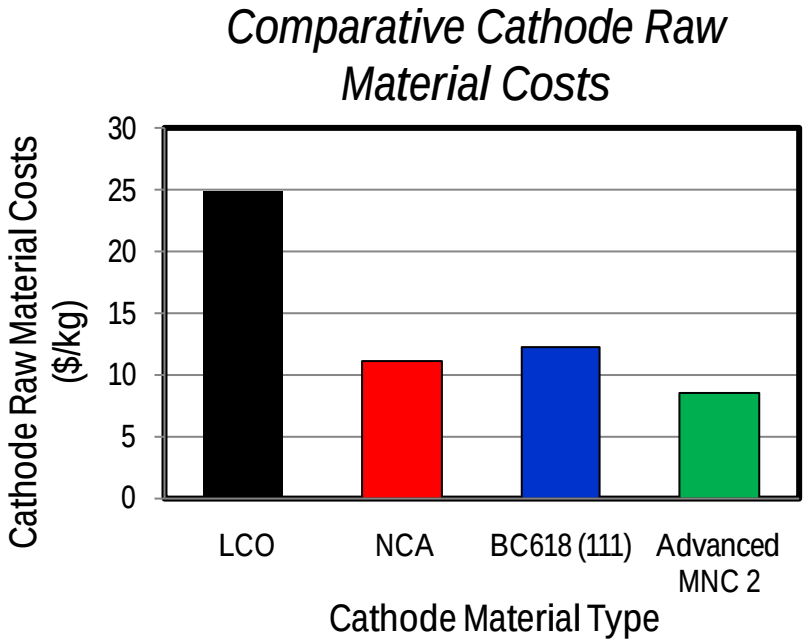
Accomplishment - Material Capacity Improvement



Advanced MNC 2 Demonstrates ~8% Increase in Capacity

Accomplishment - Material Cost Reduction



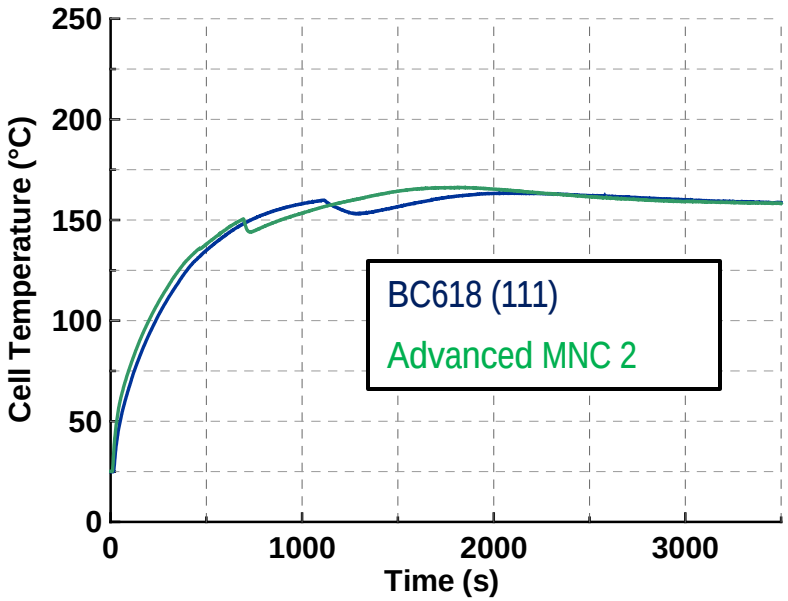


Advanced MNC 2 Offers >20% Lower Raw Material Cost

Accomplishment - Thermal Stability

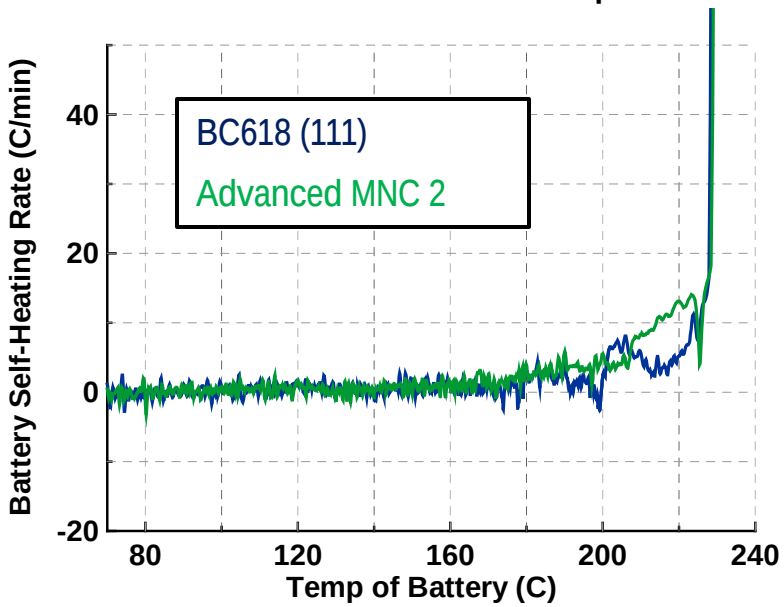
18650 Cell -

160ºC Hot Block Test



18650 Cell -

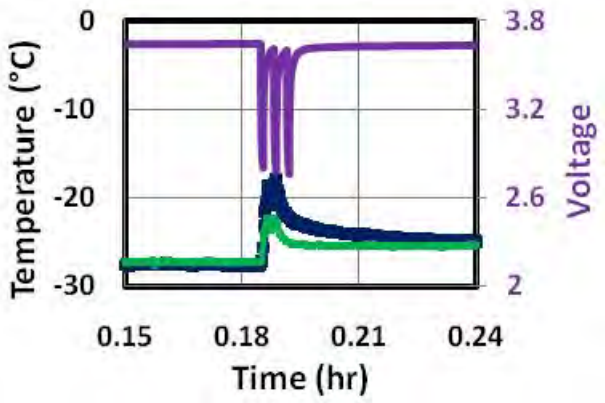
6ºC/min Thermal Ramp



Advanced MNC 2 Demonstrates Equivalent Thermal Stability

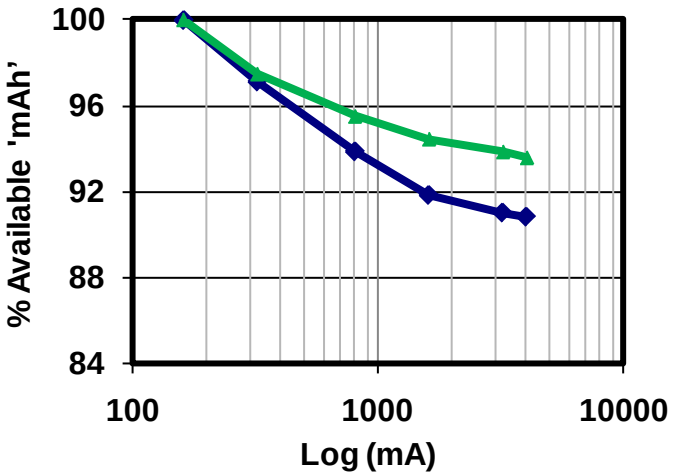
Accomplishment - Low Temperature Performance

18650 Cell - Cold Crank Test



Cathode Material	3rd Discharge Pulse Resistance (mΩ)	Cold Crank Power (kW)
BC618	412.0	9.67
Adv. MNC 2	374.4	10.98

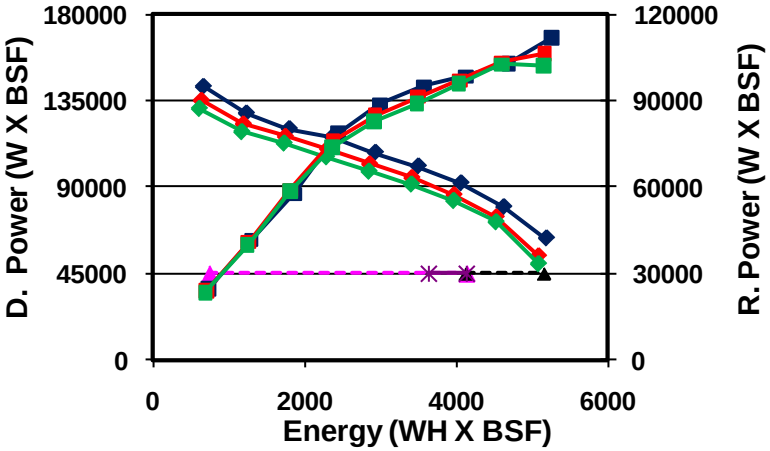
18650 Cell - Rate Test (-30 C)



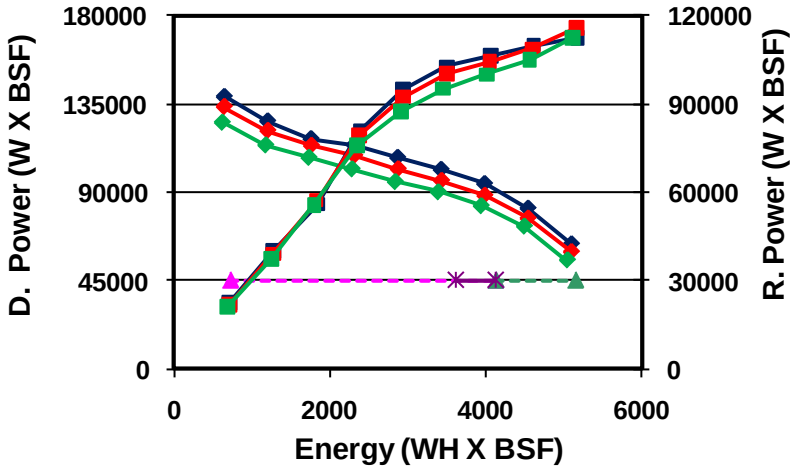
Advanced MNC 2 Demonstrates Better Performance at Low Temp

Accomplishment – Cycle Life Performance

18650 Cell - BC618 (111)



18650 Cell - Advanced MNC 2



BOL, 250 Cycles , 500 Cycles

Advanced Material 2 Demonstrates Equivalent Cycle Life Performance after 500 Cycles

Accomplishment – Gap Analysis

Requirement	BC618 (111)	Target	Adv. MNC 2
Capacity C/10 at 30ºC (mAh/g)	156	≥ 172	174
Capacity 2C at 30ºC (mAh/g)	135	≥ 149	150
Irreversible Capacity at 30ºC	10%	≤ 15%	9
Raw material Cost	100%	≤ 85%	72%
DSC Peak Max (ºC)	317	≥ 317 ± 3	320
18650 Thermal Ramp Runaway (ºC)	227	≥ 227 ± 2	229
18650 Cold Cranking Power at -30°C, 2 sec, 3rd Pulse (kW)	10	≥ 7	11
18650 Maximum Self Discharge (Wh/day)	15	≤50	15
18650 Charge Depleting Cycle Life (Cycles)	500*	≥ 500	500 *
18650 Available Energy for CD Mode, 500 Cycles, (kWh)	4.1	≥3.4	4.1
18650 Peak Discharge Pulse Power, 10sec, 500 Cycles, (kW)	101	≥45	100

* Testing Meets Goal. Continued Cycling in Progress

Collaboration & Co-ordination with Other Institutions

- 18650 shipment to DOE labs
  - *10 cells with BC618 (111) material*
  - *10 cells with advanced MNC 2*
- Electrochemical PHEV tests at ANL
  - *Static capacity tests, HPPC, self discharge test, cold crank test & cycle life test*
- Abuse tests at SNL
  - *Thermal & nail penetration test*

Proposed Future Work

- Continue charge depleting cycle life study in 18650 cells till End Of Life conditions are reached
  - *Cell analysis after EOL is reached*
- Collaborate with Argonne National and Sandia National Laboratories to complete performance verification in 18650 cells

Summary

- Developed advanced cathode material meeting all project objectives.
  - *5-10% Increased Capacity*
  - *10% Reduced Cost*
  - *Equivalent Thermal stability*
  - *Cycle Life > 500 cycles*
- Optimized pilot scale material production (≥ 25kg)
- Demonstrated advanced cathode material performance in 18650 cells
- Prepared and shipped 40, 18650 cells to Sandia & Argon National Laboratories for performance verification

All Project Goals Met or Exceeded