A123Systems, Inc.
USABC HEV and PHEV programs

DOE Annual Merit Review

Richard K. Holman, Ph.D.

06-08-10

PHEV program

Global Locations

Corporate Headquarters and R&D: Watertown, Massachusetts

- 1600+ employees in multiple locations worldwide
- >1,000,000 square feet of manufacturing facilities in United States, China and Korea

Corporate Headquarters, Research and Development
- Watertown, Massachusetts

Systems Design and Manufacturing
- Hopkinton, Massachusetts
- Livonia, Michigan

Materials Research
- Ann Arbor, Michigan

Powder, Coating, and Cell Plants
- Livonia, Michigan
- Icheon, Korea
- Changzhou, China
- Changchun, China
- Zhenjiang, China

Supplier Quality
- Shanghai, China

Focus on 3 Diversified Markets

Transportation

Passenger Hybrids, PHEVs and EVs

Commercial Hybrids, PHEVs and EVs

Electric Grid

Smart Grid Stabilization Systems

Network Energy Storage

Commercial & Industrial

Portable and Mobility

Stationary

- Fuel economy
- Reduced emissions
- Energy independence
- Lighter-weight components
- Fuel efficiency

- Increase grid reliability
- Enable Wind and Solar
- Increase plant efficiency/utilization

- Improve performance
- Reduce emissions
- Reduce toxic battery chemicals

Drivers

Transportation

Delivering high power and energy density, long life, and excellent safety

Passenger Vehicles

Hybrids, Plug-In Hybrids and Electric Passenger Vehicles




Commercial Vehicles

Hybrids, Plug-In Hybrids and Electric:

Trucks


- Fuel efficiency
- Reduced emissions
- Lighter-weight components
- Energy independence

Buses


- Reduced maintenance and lower life cycle costs
- Quieter operations and better acceleration
- Reduce emissions and fuel consumption

Off-Highway Vehicles


- Reduction in idle times
- Reduce emissions and fuel consumption

Drivers

PHEV Program Overview

- Program Duration: 36 months
- Program Timing: March 2008 – February 2011
- Battery System: Doped Nanophosphate
- Program Objective – Develop prismatic cell using Nanophosphate chemistry to support both 10 mile PHEV and 40 mile PHEV applications:
  - Long calendar life (15+ years)
  - Long charge sustaining and charge depleting cycle life
  - Abuse tolerant
- Total program value - $12.5 M at 50%/50% cost share

PHEV Program Key Accomplishments

- PHEV prismatic cell design
  - Have met targets for power and available energy, cycle life and calendar life testing are in progress
- Reduced cost
  - Estimated 10 mile PHEV pack decreased 49% from January 2009 to 2010 through more efficient design and lower BSF
  - Estimated 40 mile PHEV pack decreased 25% from January 2009 to 2010 through more efficient design and lower BSF
- Production Scale Up
  - Pilot and small scale production was demonstrated in Korea
  - High volume production scale up in process in Michigan plant, with estimated 2010 product launch data

PHEV Product Progression

	AP 3	Gen 1	Gen 1.5	Gen 2.0
Capacity Energy	16.5 Ah, 51.7 Wh	19.6Ah, 65.4 Wh	19.6Ah, 65.4 Wh	19.6 Ah, 65.4 Wh
	Initial Prototypes for Materials Development	- New electrode and packing design - DVP&R 80% complete	- Lower cost materials - Design freeze DVP&R 10% complete	-Lower cost materials
		Cell validated	Cell delivery to ANL in 10/10	Design freeze target
Mass Production Start		2009 Pilot production	June 2010 SOP with multiple global OEM's	Jan 2012 next generation system

10 Mile PHEV Gap Analysis
PHEV testing was initiated in Q4'09

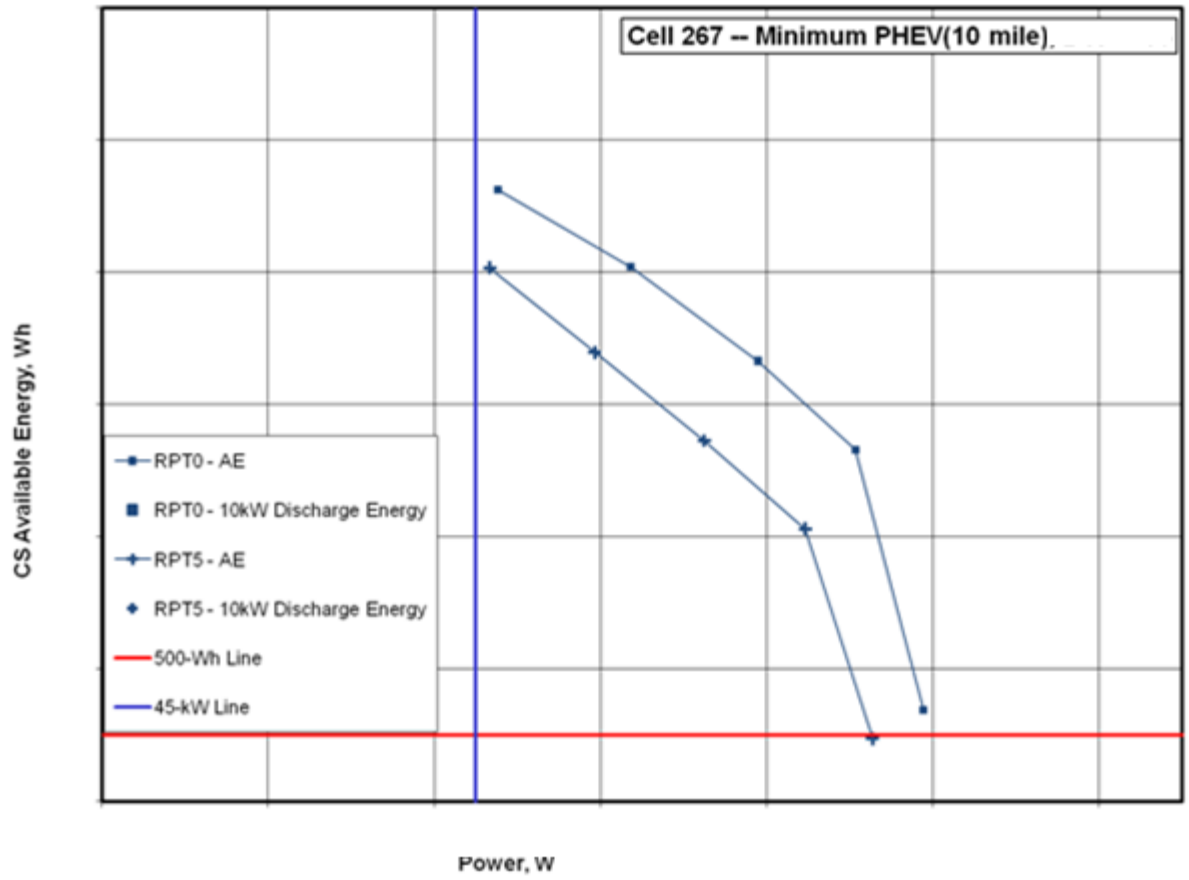
2s Discharge Pulse Power	kW	50	
10s Discharge Pulse Power	kW	45	
10s Regen Pulse Power	kW	30	
Available Energy for CD Mode	kWh	3.4	
Available Energy for CS Mode	kWh	0.5	
Min Round Trip Energy Efficiency	%	> 90	
Cold-Cranking Power at -30 deg C	kW	7	
Charge Depleting Cycle-life	Cycles	5,000	
Charge Sustaining Cycle Life	Cycles	300k	
Calendar-life (At 35 deg C)	Years	15	
Maximum System Weight	kg	60	
Maximum System Volume	Liter	40	
Selling Price/System @ 100k/yr)	$	1700	
Maximum Operating Voltage	Vdc	≤ 400	
Minimum Operating Voltage	Vdc	$\geq 0.55\ V_{max}$	
Self-discharge	Wh/day	50	
System Recharge Rate at 30 deg C	kW	1.4	
Operating Temperature Range	°C	-30 to 52	TBT
Survival Temperature Range	°C	-46 to 66	TBT

40 Mile PHEV Gap Analysis
PHEV testing was initiated in Q4'09

Characteristics	Unit	USABC Goal	Projected EOL
2s Discharge Pulse Power	kW	46	
10s Discharge Pulse Power	kW	38	
10s Regen Pulse Power	kW	25	
Available Energy for CD Mode	kWh	11.6	
Available Energy for CS Mode	kWh	0.3	
Min Round Trip Energy Efficiency	%	> 90	
Cold-Cranking Power at -30 deg C	kW	7	
Charge Depleting Cycle-life	Cycles	5,000	
Charge Sustaining Cycle Life	Cycles	300k	
Calendar-life (At 35 deg C)	Years	15	
Maximum System Weight	kg	120	
Maximum System Volume	Liter	80	
Selling Price/System @ 100k/yr)	$	3400	
Maximum Operating Voltage	Vdc	≤ 400	
Minimum Operating Voltage	Vdc	$\geq 0.55\ V_{max}$	
Self-discharge	Wh/day	50	
System Recharge Rate at 30 deg C	kW	1.4	
Operating Temperature Range	ºC	-30 to 52	TBT
Survival Temperature Range	ºC	-46 to 66	TBT

Gen 1.0 Prismatic
Charge Depleting Cycle Life

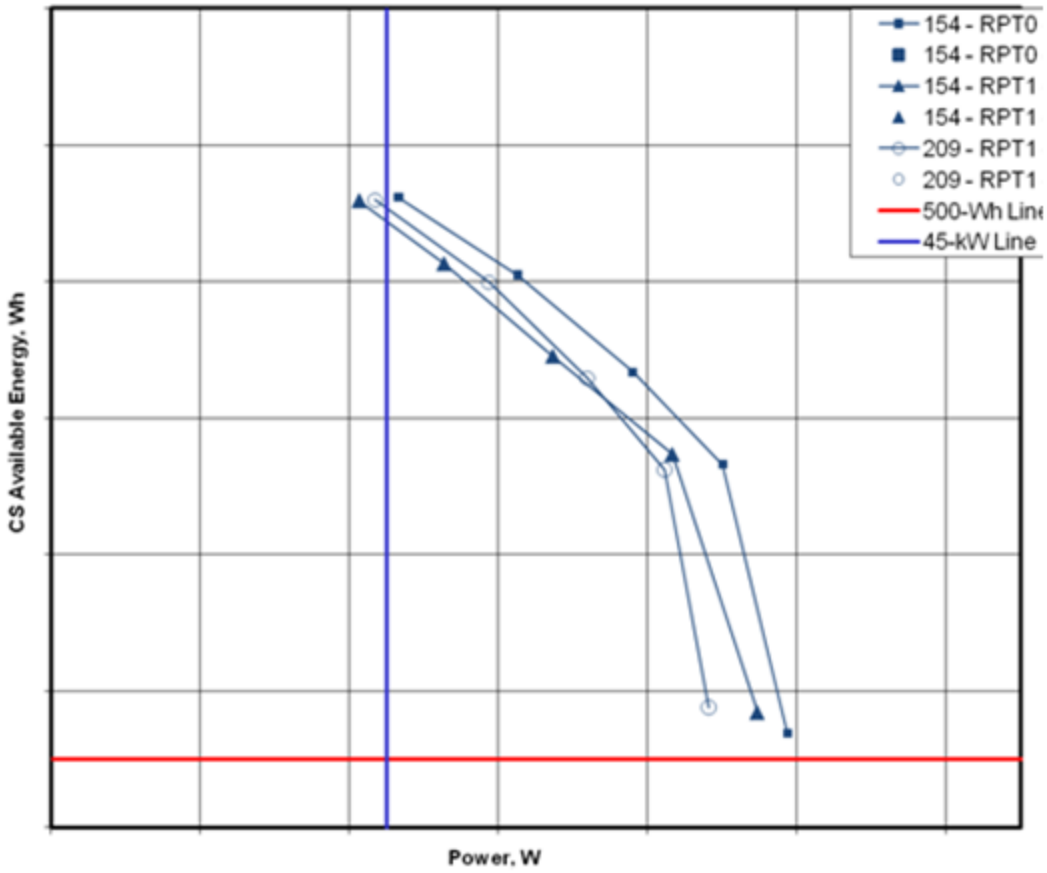
Scaled Available Energy vs. Scaled Power - Charge Depleting Cycle Life, 10-Mile PHEV



- At 2513 cycles, capacity retention ~ 85%, impedance growth < 20%.

Gen 1.0 Prismatic
Charge Sustaining Cycle Life

Scaled Available Energy vs. Scaled Power – Charge Sustaining Cycle Life,10-Mile PHEV



- At 54,745 cycles, capacity retention > 98%, impedance growth ~ 4%

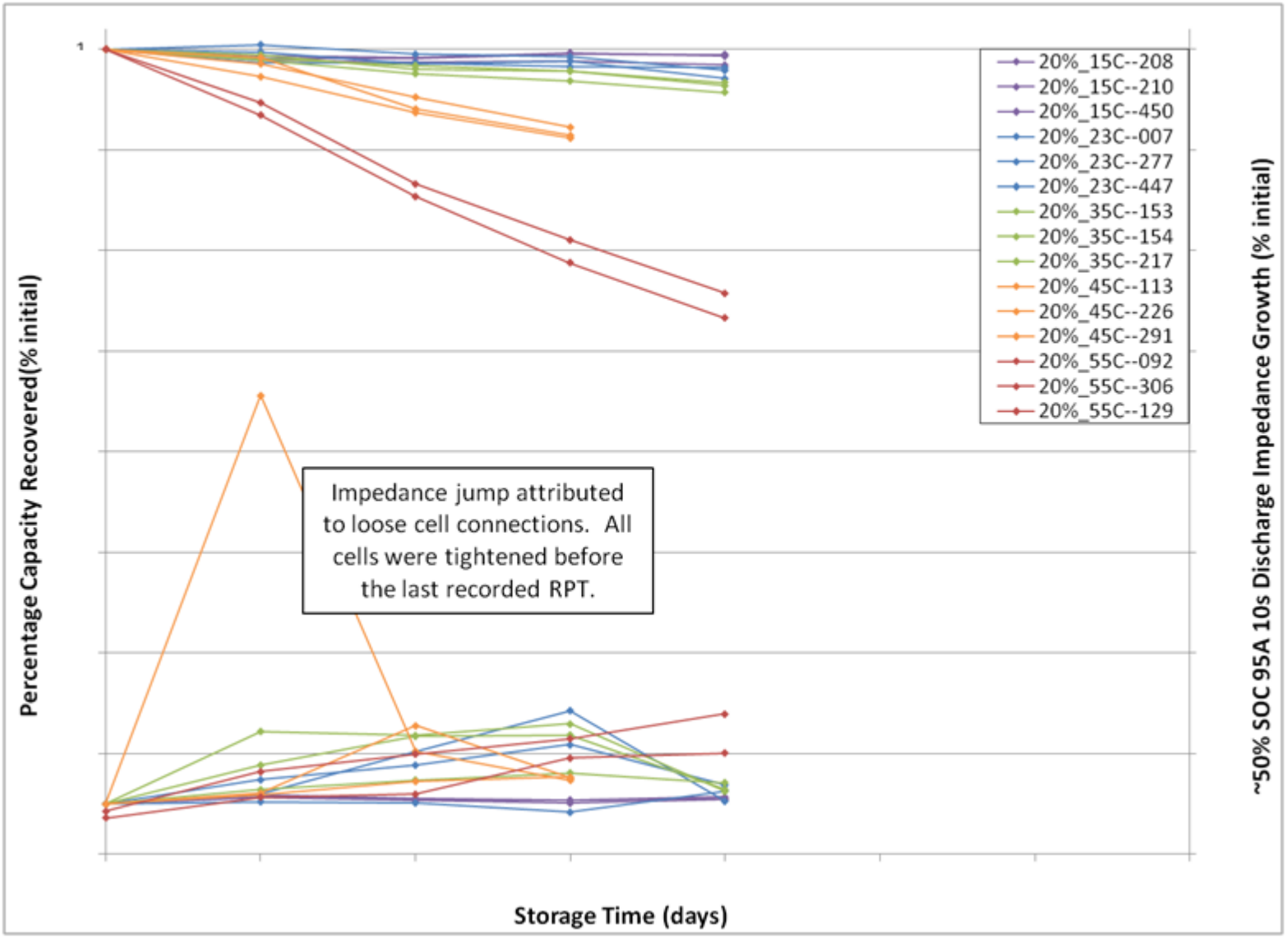
Gen 1.0 Prismatic
USABC Calendar Life

Overview of Conditions

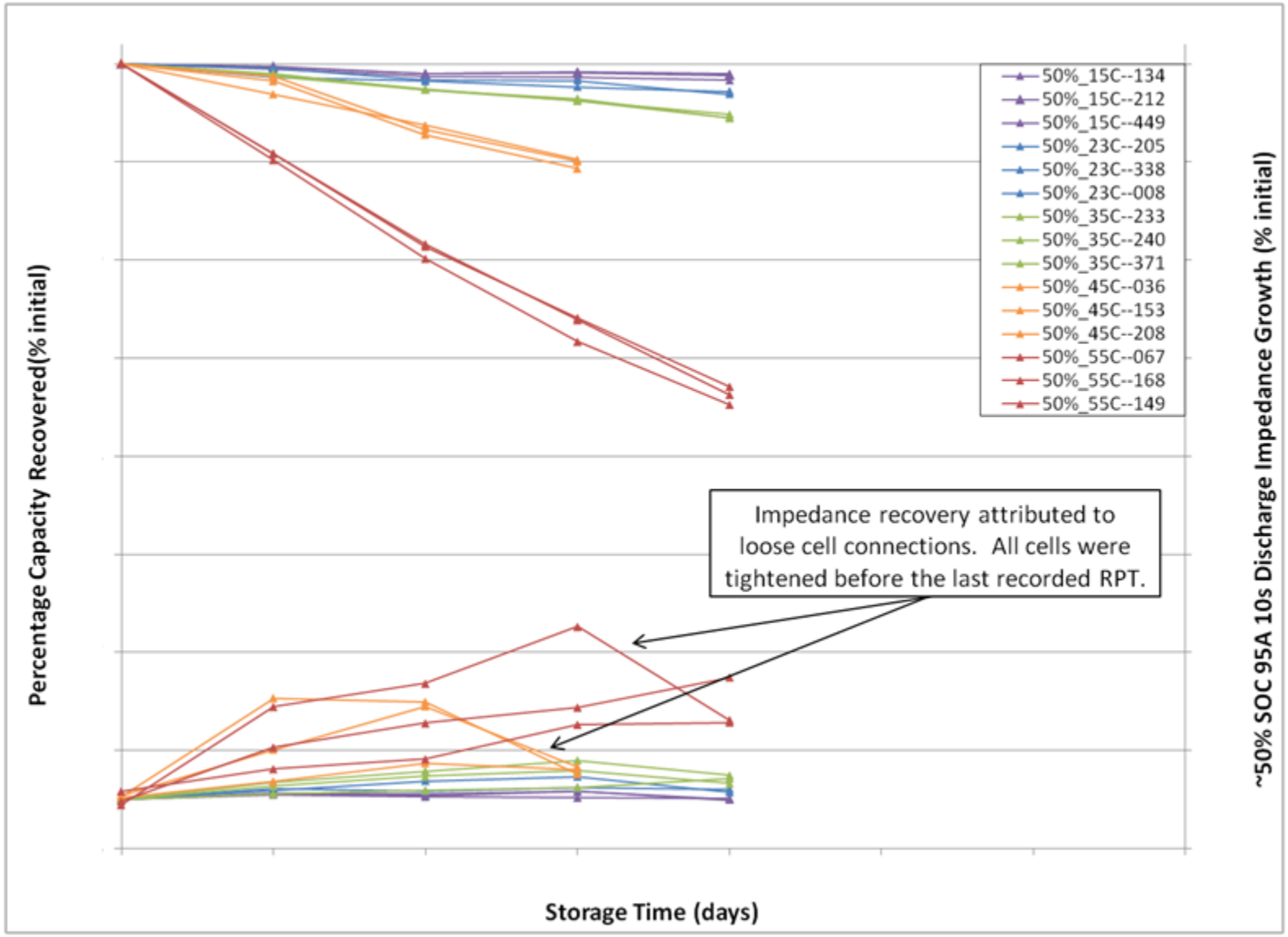
SOC for storage (as defined by USABC)	Storage Temperatures					
		15C	23C	35C	45C	55C
	20% SOC	3	3	3	3	2
	30% SOC	3	3	3	3	3
	40% SOC	3	3	3	3	2
	50% SOC	3	2	3	3	3
	80% SOC	3	3	3	2	3

- Cells perform an initial RPT at 30˚C consisting of a 10kW/bsf constant power discharge capacity, 10pt HPPC, setting initial SOC and 1 iteration of the daily pulse profile
- Cells are then put into storage at test temperature for 32 days where once a day 1 iteration of the daily pulse profile is performed
- After each 32 day storage, the cells are brought to 30˚C to perform the RPT which consists of a daily pulse profile at 30˚C, 10kW/bsf power discharge capacity, 10 pt HPPC, and resetting the SOC.

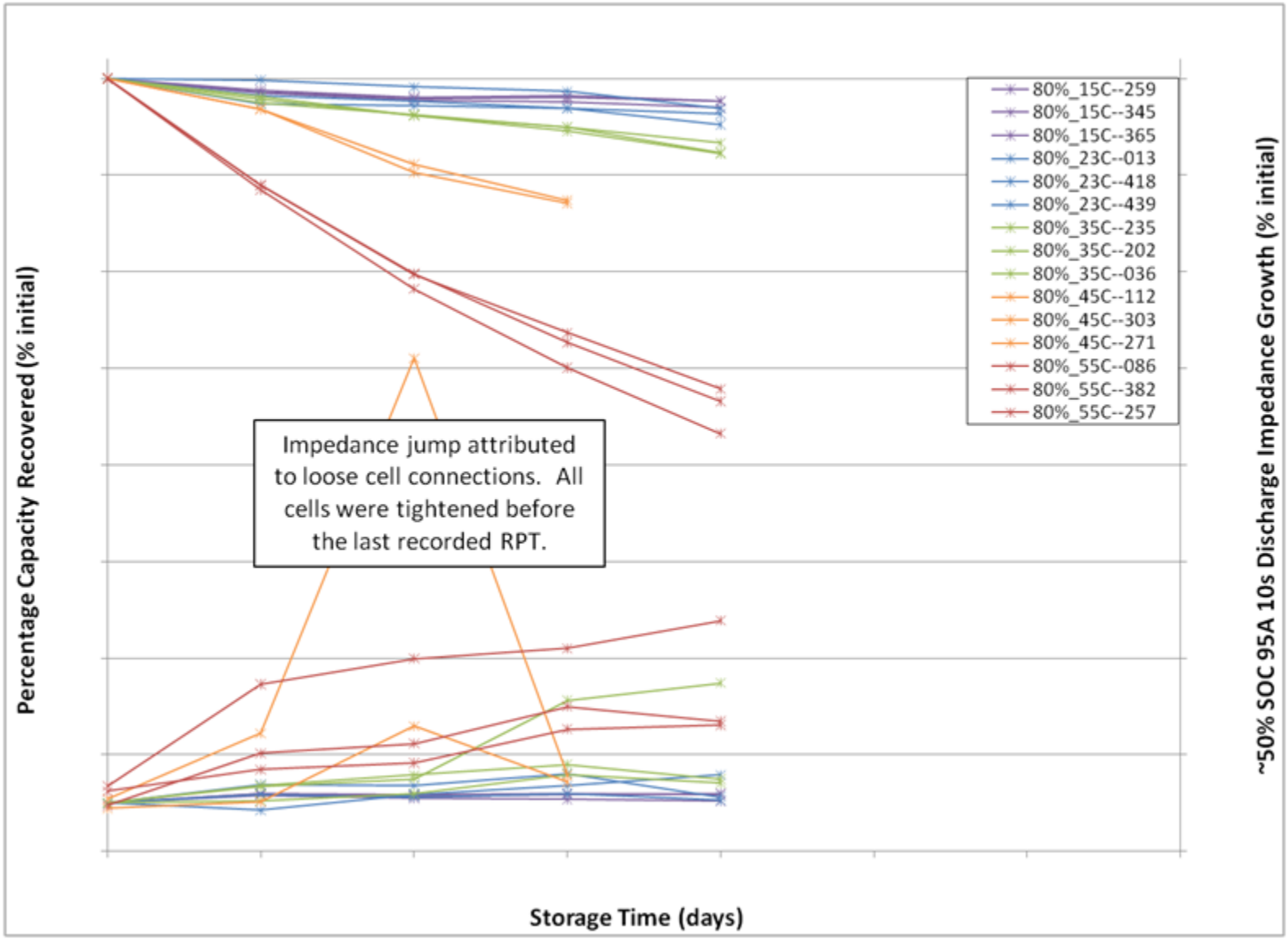
20% SOC Storage



50% SOC Storage



80% SOC Storage



PHEV Abuse test results

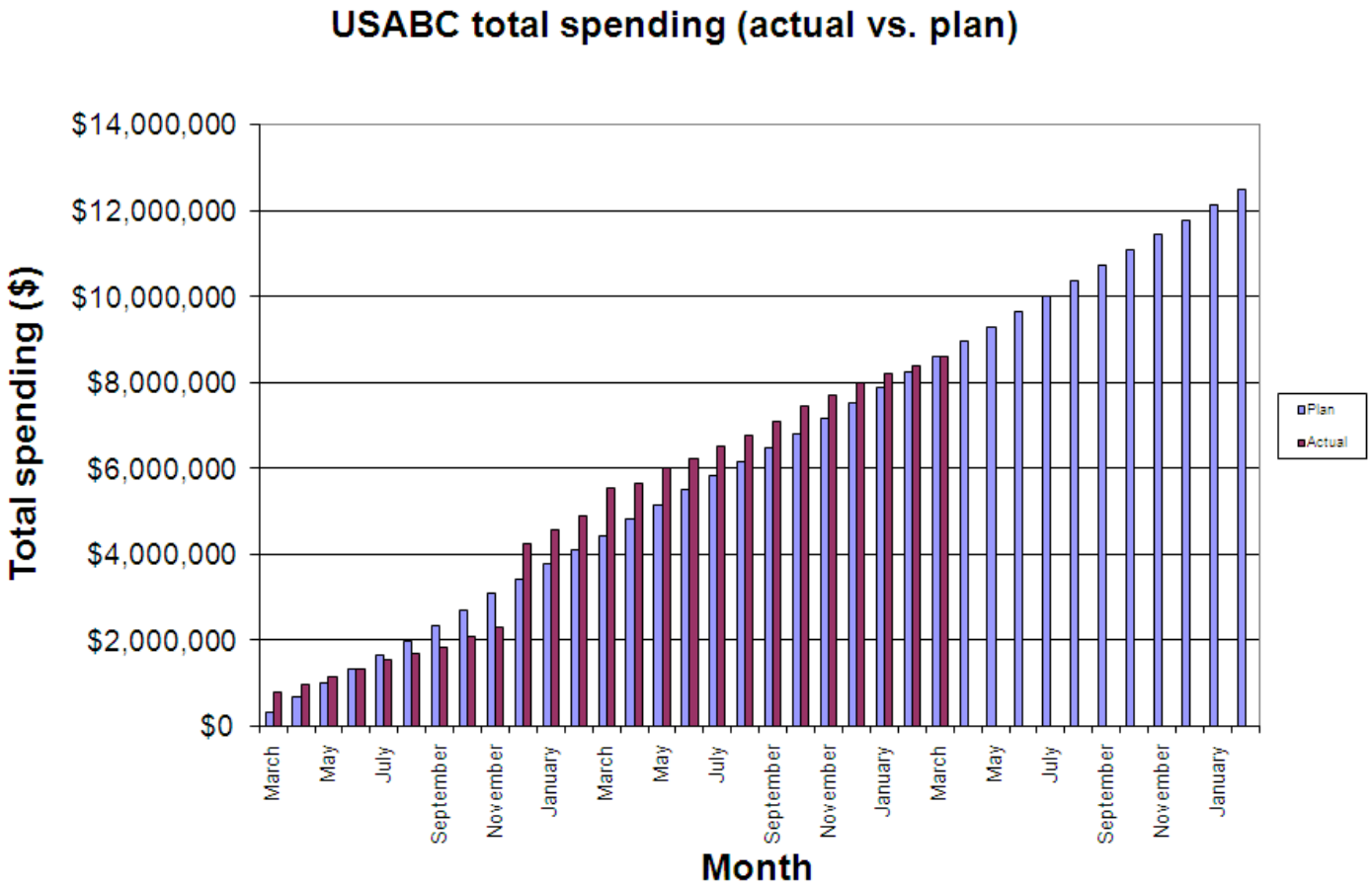
Gen 1.5 Abuse Test Result Summary

- Standard abuse test protocols were completed on Gen 1.5 PHEV prismatic cells, all cells passed with EUCAR 3 or 4

  - Nail penetration **Meet Eucar 3**
  - External Shorting **Meet Eucar 4**
  - Overcharge **Meet Eucar 4**
  - Thermal Ramp **Meet Eucar 4**
  - Crush **Meet Eucar 3**

PHEV Spending and Deliverables

Spending versus program goals



- Spending is in line with budget

PHEV Cell Module Delivery Schedule

Delivery Tasks	2010			2011	
	Oct	Nov	Dec	Jan	Feb
Deliver (38) Gen 1.5 Cells to ANL	★				
Deliver (12) Gen 1.5 Cells to Sandia	★				
Deliver (5) Gen 1.5 Cells to NREL	★				
Deliver (3) single cell modules to ANL				★	
Deliver (3) 3P cell modules to ANL				★	
Deliver (4) 3P cell modules to Sandia				★	
Deliver (1) 3P cell modules to NREL				★	
Deliver one 10mile PHEV pack					★

SOW Compliance

- Completed materials development, electrode, and cell design for 10 mile and 40 mile product
  - Completed abuse tolerance testing for Gen 1.5 cells
  - Long term cycle life and calendar life testing for the 10 mile program is in process
  - Long term cycle life testing for the 40 mile program to be started in June
- Completed development of Next Gen Multifunction Separator, testing in large prismatic cells will be initiated in June
- Met most objectives for development of High Voltage Cathode material in small format prismatic cells
- Have module and pack design to support either 10 mile or 40 mile PHEV programs

SOW Checklist

Cell Development

Active Materials, Electrode Design	Develop and test anode, cathode, electrolyte, separator Materials selection confirmed	✓
Cell Packaging Design	Cell packaging development complete, seal integrity testing in process	✓
Cell Fabrication Capability	Production scale demonstrated in Korea, Michigan production in progress	✓
DFMEA	Completed for Gen 1, update in process for Gen 1.5	⇨

Cell Characterization

HPPC @ 30C	Testing conducted for both 10 mile and 40 mile BSF	✓
Charge Depleting Cycle Life	Testing in progress for 10 mile, 40 mile to start June, 2010	⇨
Charge Sustaining Cycle Life	Testing in progress for 10 mile, 40 mile to start August, 2010	⇨
USABC Calendar Life	Have completed through four months, at five temps and SOC's	⇨
Crush Test	Completed, all cells passed with Eucar 4	✓
Thermal Abuse Test	Completed, all cells passed with Eucar 4	✓
Short Circuit Test	Completed, all cells passed with Eucar 4	✓
Overcharge Test	Completed, all cells passed with Eucar 4	✓
Blunt Rod	Completed, all cells passed with Eucar 3	✓

✓ Completed ⇨ In Process

SOW Checklist

Module / Pack Design

Electrical System	Completed design, need to apply to USABC prototypes	⇨
Mechanical System	Have completed module design	✓
Reference Performance Testing	Completed for generic system	✓
Abuse Testing	In progress	

Smart Materials

High Energy Cathode	Demonstrated performance in small format cells	⇨
High Energy Anode	Scaled up, included in production design	✓
High Voltage Electrolyte	Have downselected to critical formulations, testing in progress	⇨
Next Gen, Multifunction Separator	Demonstrated in small format cells, scale up in progress	⇨

✓ Completed ⇨ In Process

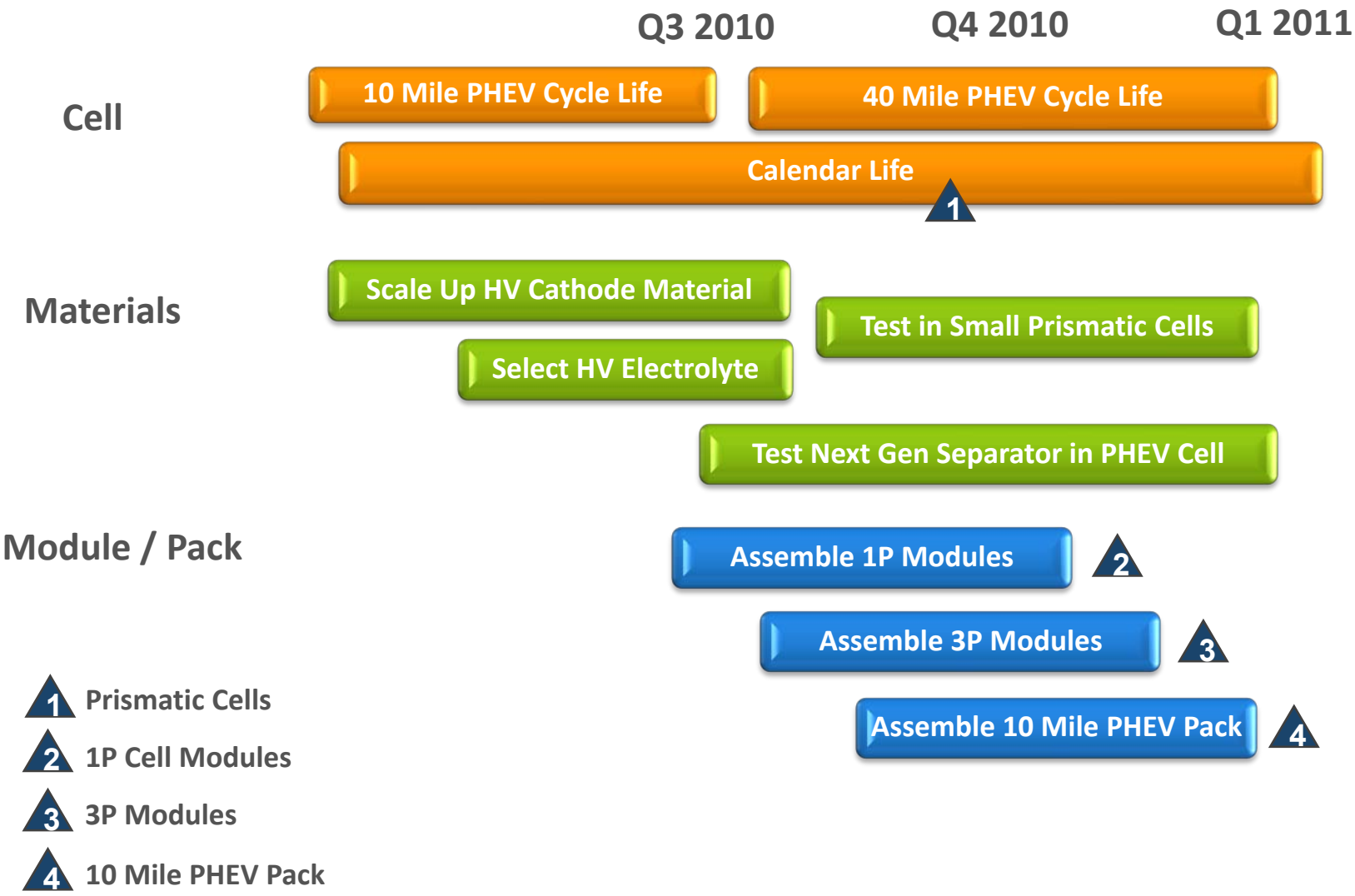
Summary

- Power, energy, storage, abuse on target or exceeding targets
- Cycle life tracking well, but projected to fall short of program goals
- System cost and system volume expected to fall short of program goals
- Spending progressing according to plan; early under spend has been corrected

2010 Q3-Q4, 2011 Q1 Plans

• Materials Development	
+ Scale up high voltage cathode material, complete testing in small format prismatics with selected high voltage electrolyte	• Q3-2 ’10
+ Scale up next generation separator, conduct cycle life and storage testing in PHEV cells	• Q3-Q1’10/11
• Cell Characterization	
+ Complete Charge Depleting and Charge Sustaining tests in 10 mile PHEV cell	• Q3’10
+ Complete Charge Depleting and Charge Sustaining tests in 40 mile PHEV cell	• Q1’11
+ Continue calendar life testing to EOP	• Q2’11
• Cell, Module, and Pack Deliveries	
+ Assemble and deliver 55 PHEV cells to National Labs for evaluation	• Q1’11
+ Assemble and deliver 11 single cell and 3P cell modules to National Labs	• Q1’11
+ Assemble and deliver 1 10 mile PHEV pack	• Q2’11

2010 Q3-Q4, 2011 Q1 Plans



HEV Program

HEV Program Summary

- Program Duration –42 months
  - 6 month no cost extension for module deliverables
- Program Timing –December 2006 to June 2010
- Battery System –Doped Nanophosphate Chemistry
- Program Objective: Develop Nanophosphate cell and system with the following characteristics
  - Improved Calendar Life (15 Years)
  - Increased Cycle Life Capability
  - Increased Power
  - Abuse Tolerance at Cell Level
- Total Program Value –$15M at 50%/50% cost share

HEV Program Key Accomplishments

- Developed and produced a production-ready 32113 cell which can meet USABC HEV power and energy targets
  - All testing complete, with the exception of ongoing cycle life and storage testing, which will be continued until program end
  - Over 2 years of cycle life data, expected to exceed program goal of 300k cycles
  - 6 months of storage data expected before end of program
- Developed a 10-cell 32113 HEV prototype module
  - All cell and module deliverables completed
  - Module volume, mass significantly under program goals
- Designed a built a 6Ah HEV Prismatic cell to greatly improve on cost, energy, and power targets, delivered as prototypes to USABC

HEV Product Progression

	Gen-0	Gen-1	Gen-2
Capacity (Ah)	3.4 - 3.6	3.8	4.4 - 4.6
Timing	Up to Q4 2007	Late Q1 2008 Early Q2 2008	First results received DVP&R – Q3'09
Notes	Pre-DV, proto materials and equipment	Final cell materials - DVP&R 95% complete PV – Q3'09	Improved electrode and hardware design
	Cells delivered to ANL	Design freeze, cell validated and in limited production	In validation, cells delivered to ANL & NREL

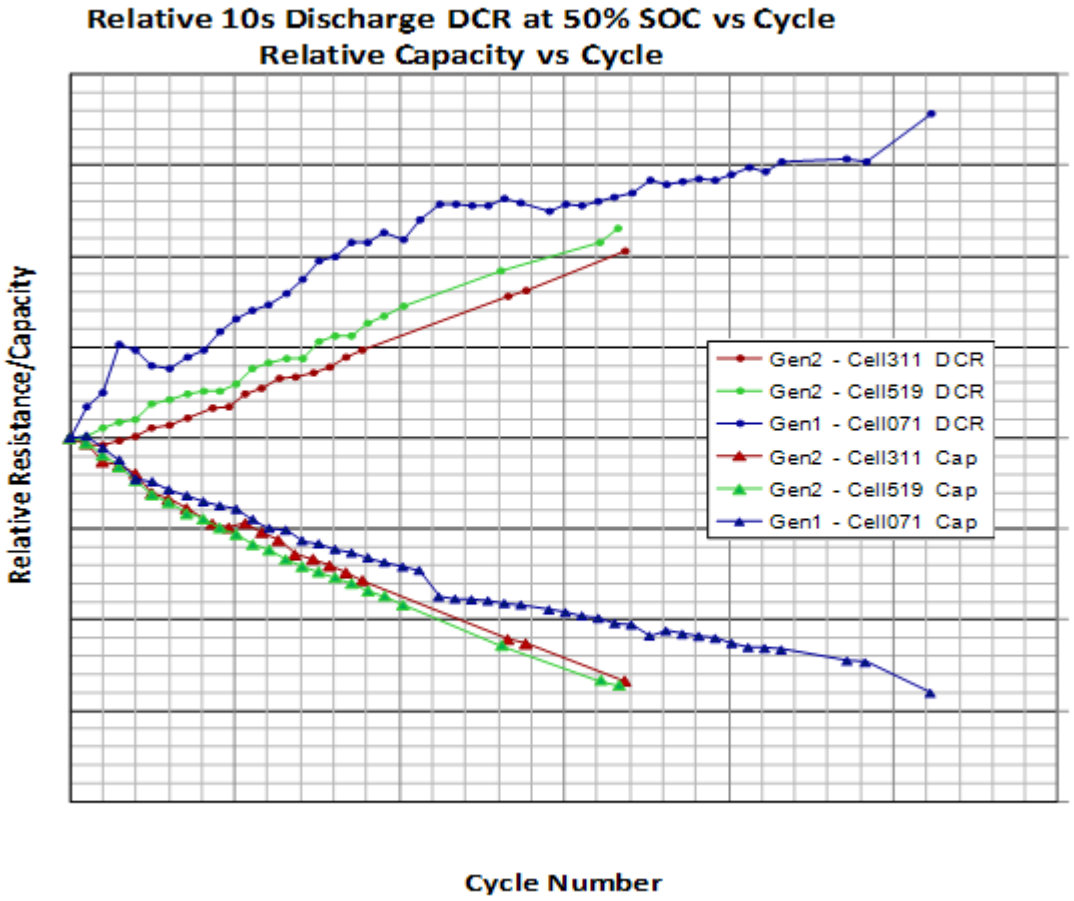
32113 Gen 2, B1 HEV Gap Analysis

Characteristics	Unit	USABC Goal	Program Goals	Projected EOL
10s Discharge Pulse Power	kW	25	25	
10s Regen Pulse Power	kW	20	20	
Total BOL Available Energy	kWh	0.30	0.30	
Min Round Trip Energy Efficiency	%	> 90	>90	
Cold-Cranking Power at -30 deg C	kW	5	5	TBD
25 Wh Cycle Life	Cycles	300k	300k	
Calendar-life (At 35 deg C)	Years	15	15	
Maximum System Weight	kg	<<40	21	
Maximum System Volume	Liter	<<32	15	
Selling Price/System @ 100k/yr)	$	500	780	
Maximum Operating Voltage	Vdc	≤ 400	190	
Minimum Operating Voltage	Vdc	≥ 0.55 V_{max}	105	
Self-discharge	Wh/day	50	<3.3	
Operating Temperature Range	°C	-30 to 52	-30 to 52	
Survival Temperature Range	°C	-46 to 66	-46 to 66	
Capacity				

*Test results are based on Gen 2 Design. Price is based on a lower cost Gen 2.5, available in Q2 '10.

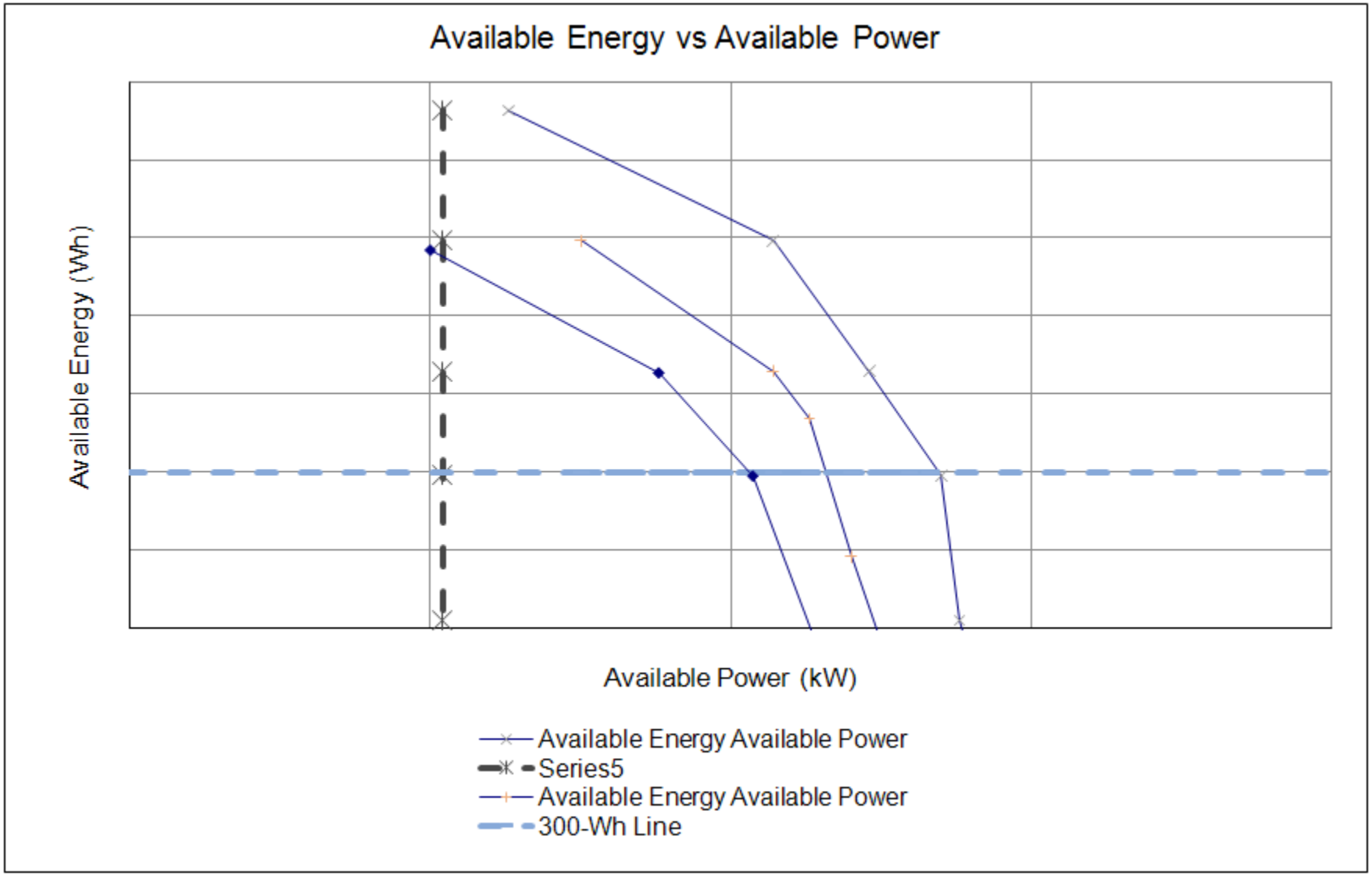
HEV Cycle Life Testing

Cycle Life Testing on 32113 – Gen 1 & Gen 2 25Wh Cycling at 30'C, 50% SOC



- Pack sized for 20% impedance growth at EOL

Cycle Life Testing on 32113 Gen2 (Combined BOL, 90k,167k)



HEV Calendar Life

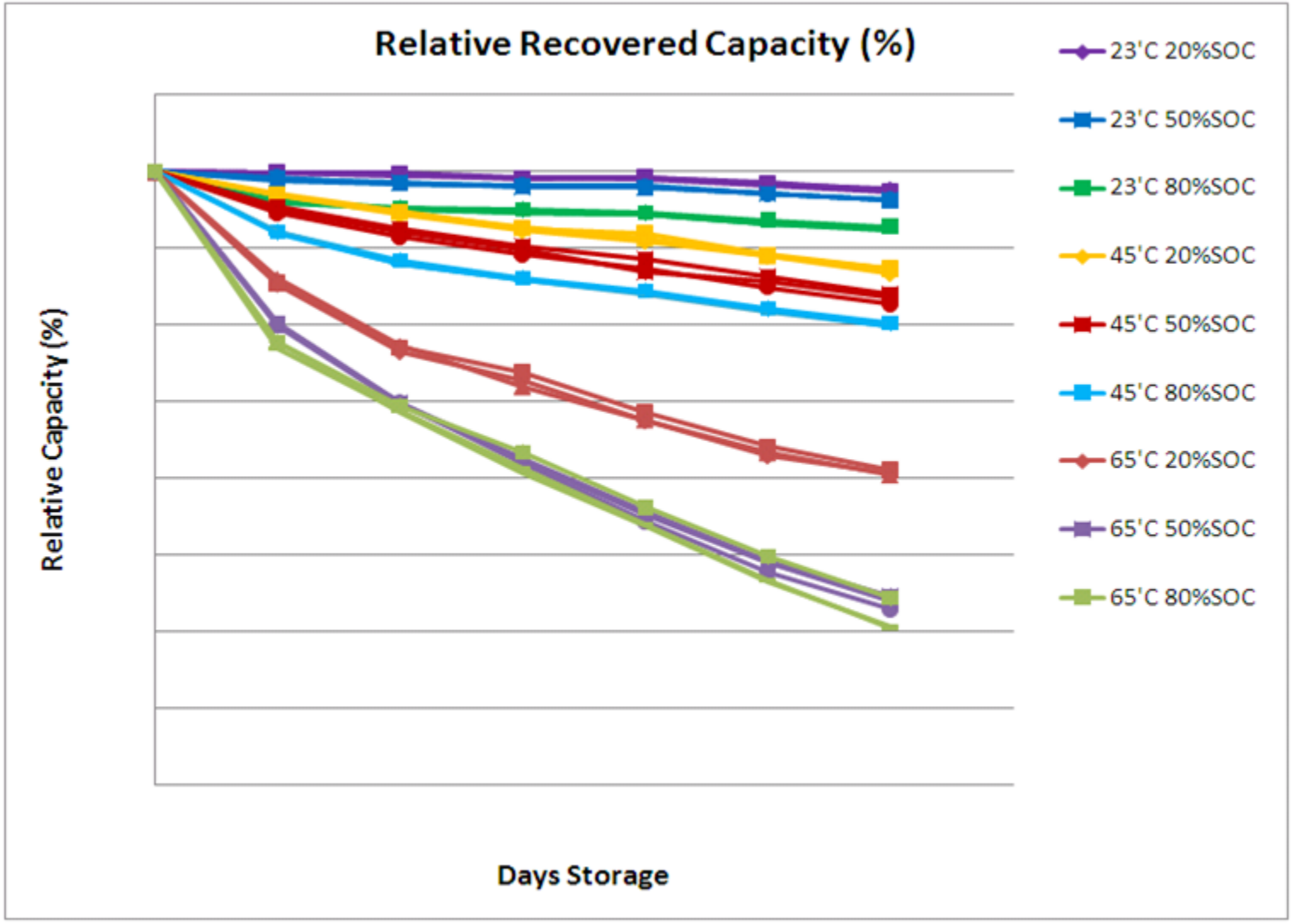
USABC Calendar Life Test

- USABC Calendar Life
  - The following conditions are used to measure calendar life of the cells for a total of 27 cells for a total of 175 storage days (with RPT interval of 25 days, as specified in USABC)
    - 23°C, 20% SOC
    - 23°C, 50% SOC
    - 23°C, 80% SOC
    - 45°C, 20% SOC
    - 45°C, 50% SOC
    - 45°C, 80% SOC
    - 65°C, 20% SOC
    - 65°C, 50% SOC
    - 65°C, 80% SOC

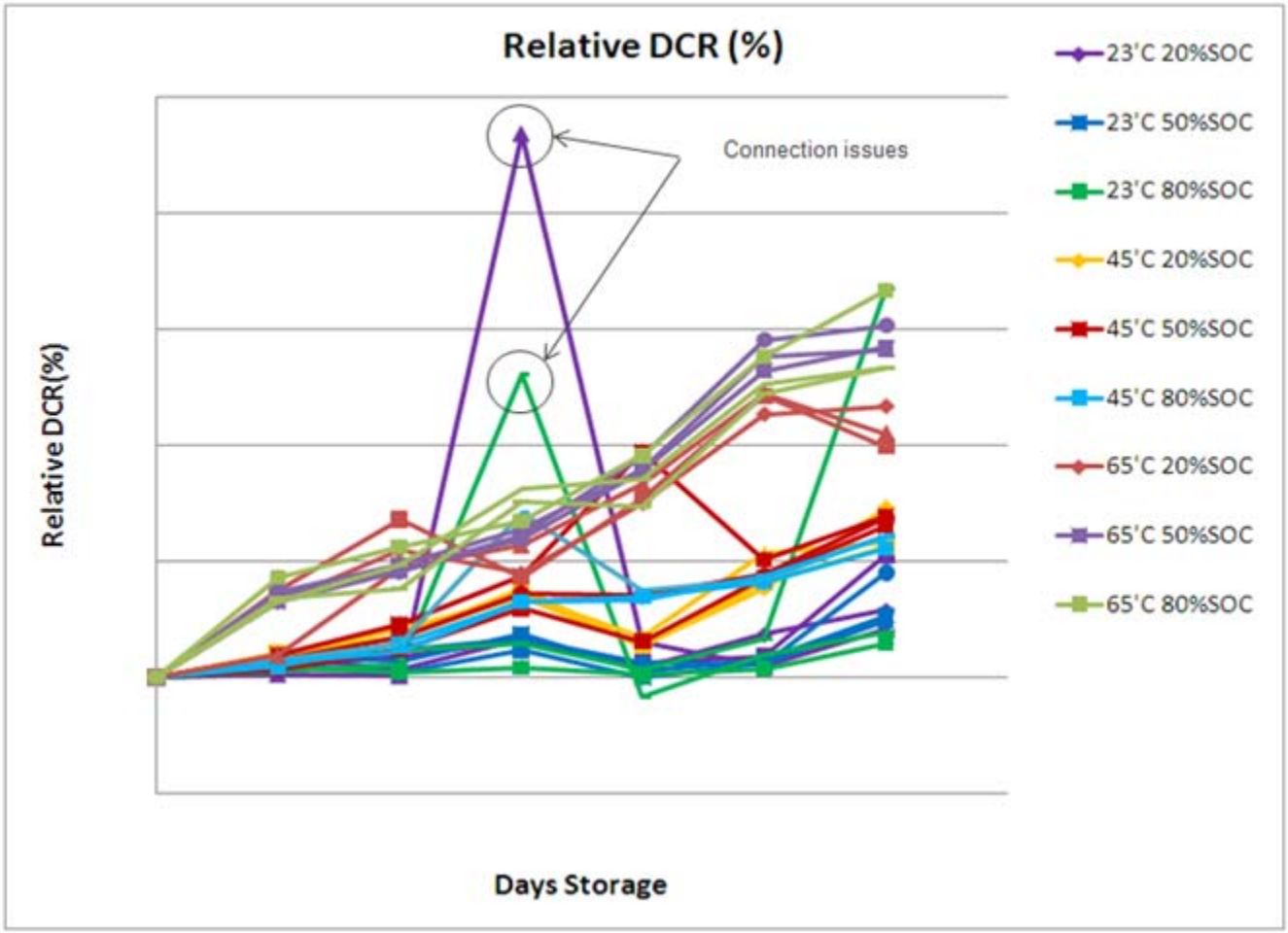
SOC \ Temp	RT	45°C	65°C
20%	X	X	X
50%	X	X	X
80%	X	X	X

  - The test is completed up to a total of 150 storage days.

USABC Calendar Life Test



USABC Calendar Life Test



- Similar to the PHEV, connection issues have plagued the impedance monitoring

HEV Abuse Test Results

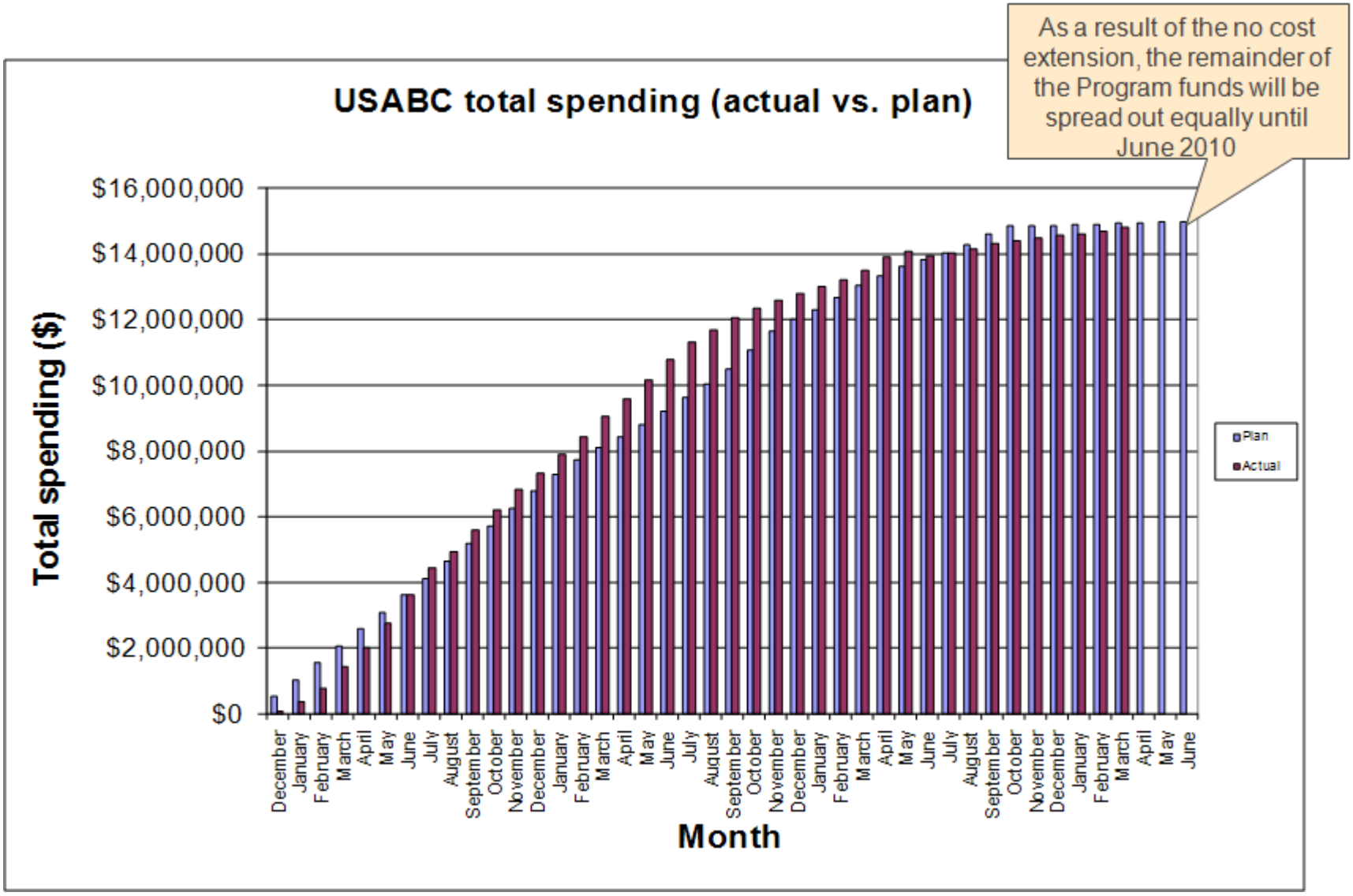
USABC Abuse Testing - HEV

- Standard abuse test protocols were completed on Gen 1 and Gen 2 HEV 32113 cells, all cells passed with EUCAR 3 or 4

  - Nail penetration **Meet Eucar 3**
  - External Shorting **Meet Eucar 4 (Gen1), 2 (Gen 2)**
  - Overcharge **Meet Eucar 2**
  - Thermal Stability **Meet Eucar 2**
  - Crush **Meet Eucar 2**
  - Overdischarge **Meet Eucar 2**
  - Mechanical Shock **Meet Eucar 2 (Gen 1), 0 (Gen 2)**

HEV Spending and Deliverables

HEV Spending Versus Program Goals



SOW Compliance

- ✓ 23, 32113 Gen 2, B0.1 cells – March 2009 (complete)
- ✓ 23, 32113 Gen 2, B1 Cells – August 2009 (complete)
- ✓ 32113 Pack Paper Study – January 2010 (complete)
  - Includes the following:
    1. Thermal management system
    2. Electronics and Controls
    3. Estimated Cost

SOW Compliance (cont.)

- ✓ 10, 32113 Modules - April 2010 (complete)
  - ✓ Test Plan determined
  - Ten (10) HEV modules to USABC
    - Two (2) for (NREL)
    - Four (4) for Performance Testing (ANL)
    - Four (4) for Abuse Testing (SANDIA)
  - Module operating instructions/interface control document
  - USABC/ANL Test Plan Questionnaire

- ✓ 30, A-sample cell delivery April 2010 (complete)
  - USABC Test Plan TBD
    - Test fixture needs TBD

- Final report for HEV Program – June 2010
  - To include all USABC test data to-date

HEV - Plans

- Submit final report to USABC in June 2010