Development of Advanced Energy Storage Systems for High Power, Lower Energy – Energy Storage System (LEESS) for Power Assist Hybrid Electric Vehicle (PAHEV) Applications

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Project ID # ES139

Overview

Timeline

- Start: Jan 2011
- Finish: March 2014
- On track, 70% complete*

Budget

- Total Project Funding
  - USABC: $3.43M
  - Maxwell: $3.57M
- Funding in FY12: $3.05M
- Funding for FY13: $1.86M

Barriers Addressed+

- Cell and System Manufacturing Cost
- Performance at Low Temperature
- Power Performance
- Energy Density / Voltage Window

Maxwell LEESS System Targets

- System Weight = 22 kg
- System Volume= 25 L
- Cost/System = $920 (@100K units/year)

Partners

- Porous Power Technologies - *Separator Development*
- University of Rhode Island - *Electrolyte Development*

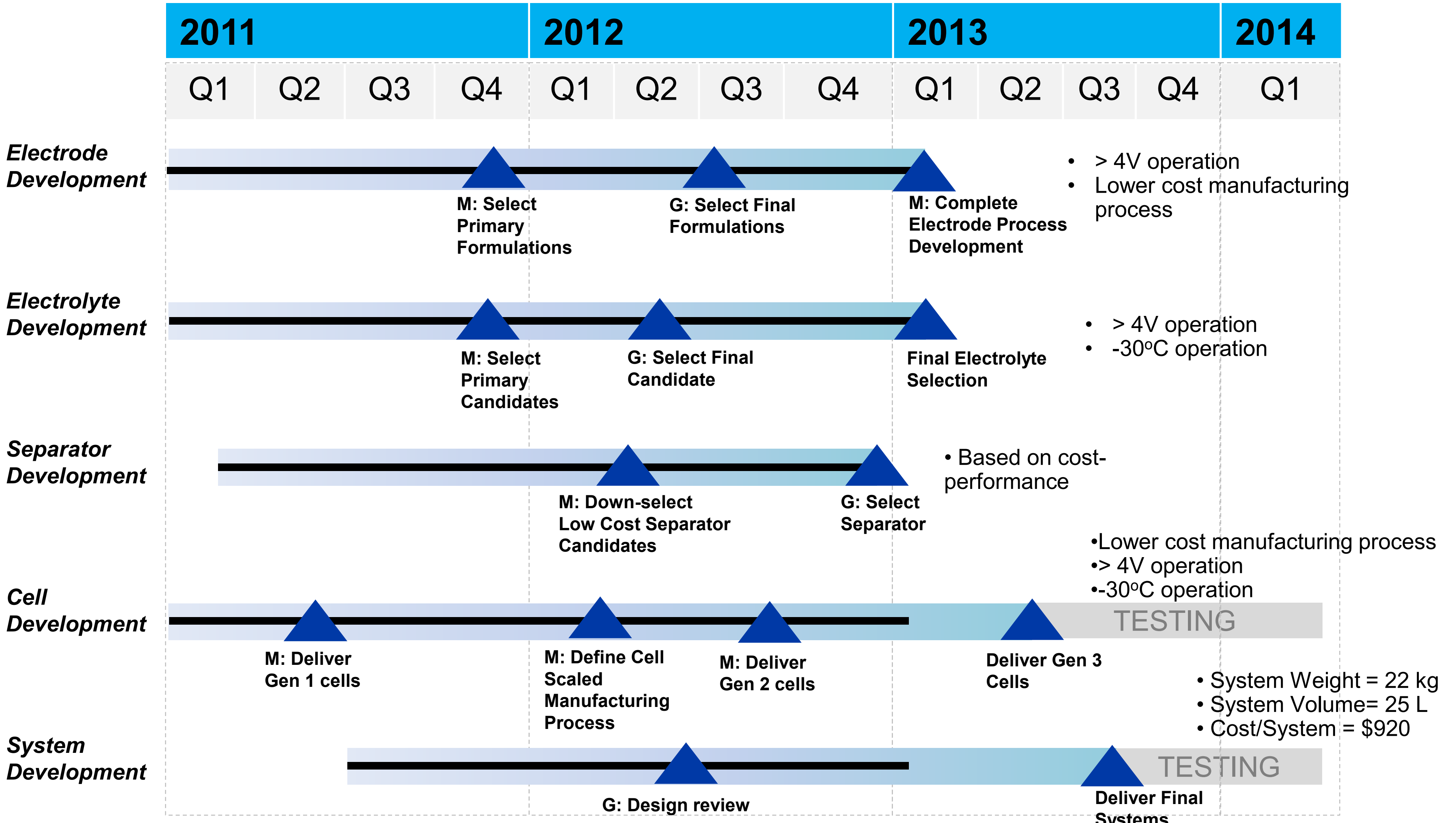
*as of March 2013 + towards *DOE VT Program Multi-Year Program Plan*

Objectives and Relevance

Meet LEESS EOL power and energy requirements through the development of capacitor cells and a system that represents a significant advancement over commercially available capacitive technology.

- **Extend stable upper voltage range** of energy storage device to > 4.0 V
- Achieve LEESS required **low temperature performance** down to -30^{o}C.
- Adapt the technology to a new cell form factor amenable to **low cost manufacturing**
- Develop and demonstrate a new architecture for pack design which is **cost effective, small and light**

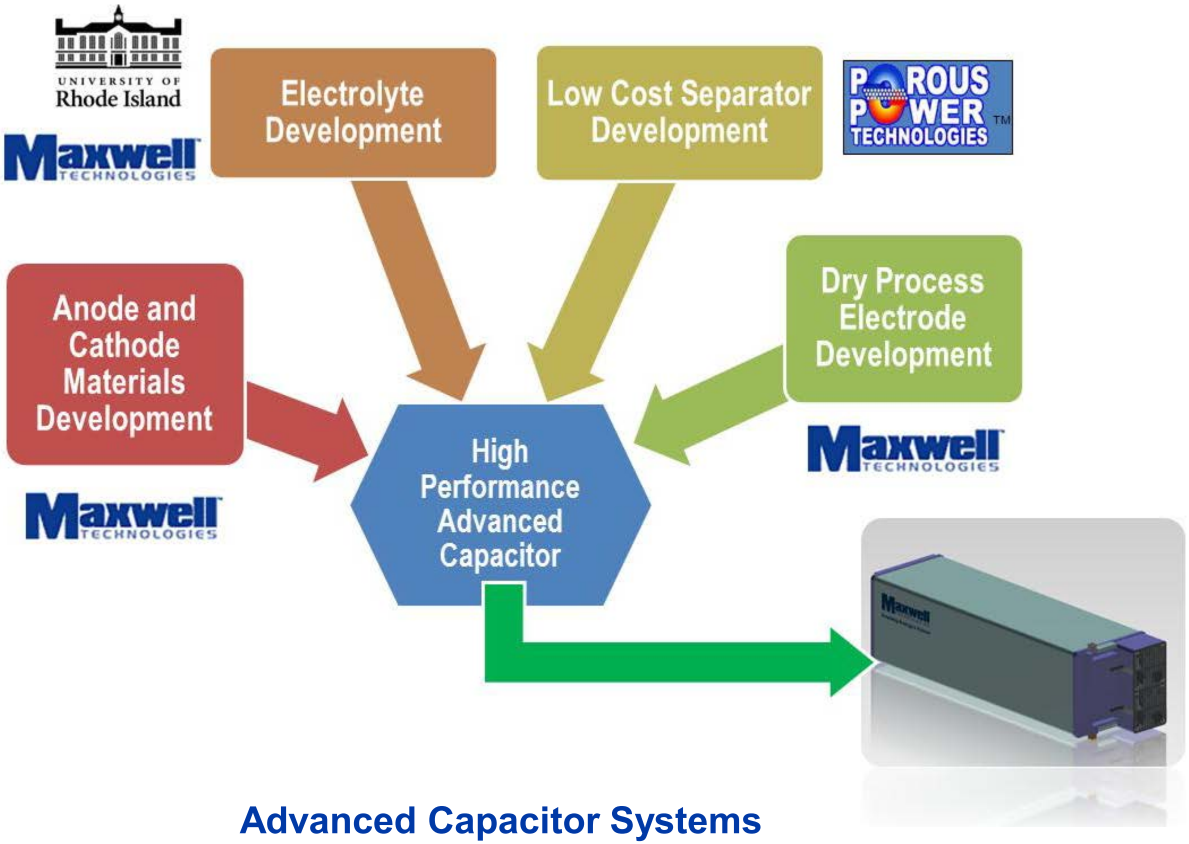
Project Milestones and Gates



Strategy

Meet LEESS Targets by:

- Identifying high performance electrolyte candidates in conjunction with URI (improve voltage window, temp range conductivity, lifetime)
- Identifying and screening low cost separator technology
- Increase cell performance via selection of anode and cathode electrode materials based on discrete structure-property relationships
- Leveraging economical cell design to produce the lowest cost and smallest/lightest system



Advanced Capacitor Systems

- Higher voltage
- Wider temperature window
- Smaller, lighter, more powerful

Technical Approach – Cell Development

Improve from Baseline Cell Performance by:

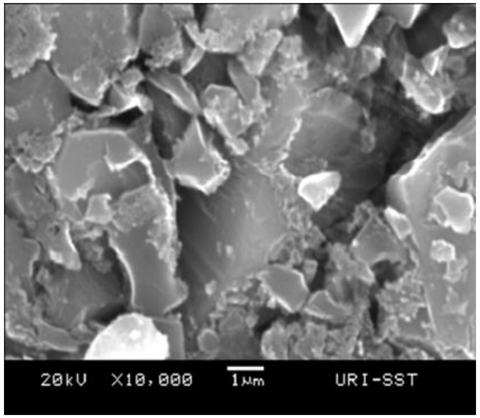
- Identifying and selecting the highest performing anode and cathode carbons using XRD, BET, half- and full-cell testing, as well as high-throughput screening techniques, leveraging over a decade of previous carbon screening work.

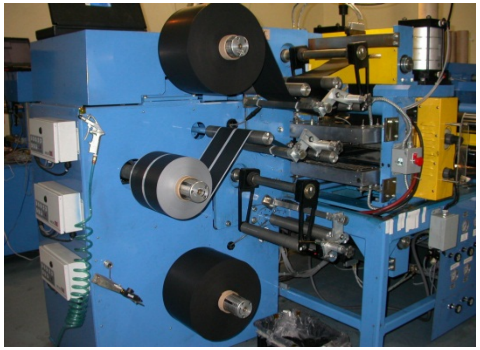
- Identifying and selecting new electrolytes + additives using ex-situ experimentation (CV, conductivity, viscosity) and analyze electrode-electrolyte interface using microscopy (w/URI)

- Identifying and characterizing alternative separator materials with good performance but significant cost reduction

- Use of a completely dry electrode fabrication process (solvent-free, reduced processing) to decrease cell manufacturing cost and increase cell lifetime

- Quantifying performance/weight/size reduction of new cell architecture via cell-level electrochemical and physical testing





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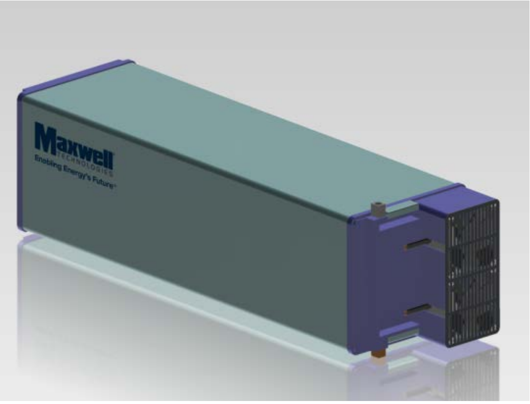
Technical Approach – System Development

- Design modular system leveraging compact cell design for maximum efficiency in cell stacking while meeting LEESS energy and power targets

- Iterate design based on thermal modeling, heat bed testing, and improved cell characteristics.

- Perform system-level electrochemical, physical, and safety tests and identify areas where weight, size and cost savings can be achieved

- Construct and evaluate 15 production-level units to closely approximate cost and performance at volume production (100K units/year)



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FY 2012 Technical Accomplishments – Electrode Development

Materials Selection

- Selected negative and positive electrode carbon materials for Gen 3 cell deliverable based on capacity, power capability, and cost
- Reduced cell ESR 10% by improving active materials mixing method

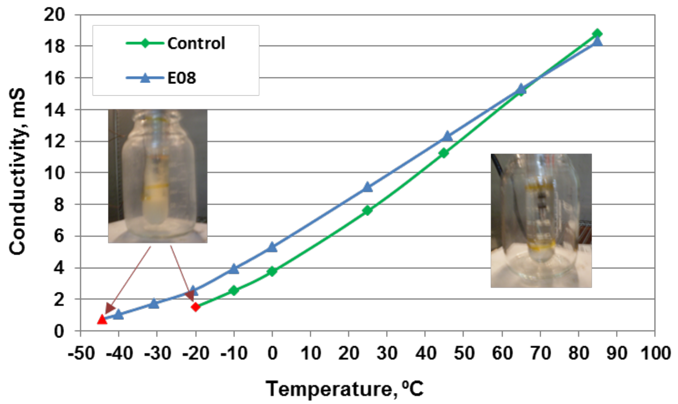
Process Development

- Modified all necessary pilot-line equipment to produce electrodes and initiated electrode process development activities.
- A 47% reduction in electrode thickness was achieved on the pilot electrode manufacturing line, enabling improved power performance.

FY 2012 Technical Accomplishments – Cell Development

Electrolyte Development

- Final two electrolyte candidates selected based on temperature capability and cell electrical performance using Maxwell screening procedures and URI evaluation. Final electrolyte selected for Gen 3 deliverable cell build based on HPPC thermal performance evaluation and cycling.



Separator Development

- Separator selected for Gen 3 deliverable cell build. Porous Power laminated separator demonstrates reasonable performance relative to selected separator, however a new manufacturing strategy would be required to meet cost target.

Gen 3 Cell Development

- Finalized design of Gen 3 cell. A cell screening and qualification plan has been developed. All cells produced will be physically and electrically pre-qualified before testing is initiated. Maxwell will initiate USCAR PAHEV testing in advance of cell set deliver to INL and SNL.

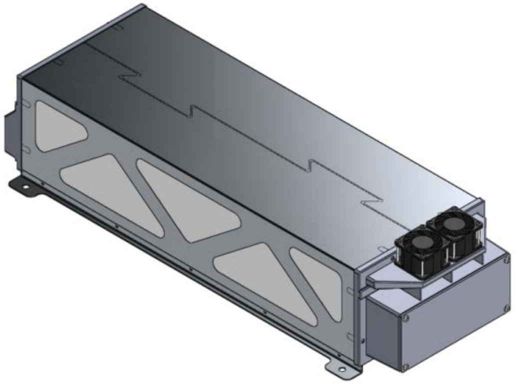
FY 2012 Technical Accomplishments – System Development

- Constructed and tested partial scale prototype modules. All modules completed over 2000 cycles with less then 3% capacity fade, ESR rise was negligible

- Finalized design of production systems, taking into account safety and shipping compliance.

- Based on new design, program system volume target met. System weight reduced by 3.4 kg, further weight reductions anticipated at both the cell and system level through materials reduction and elimination.

	Weight	Size
Beginning of Program (based on Gen 1 cell BOL)	53.9 kg	67.9L
Feb 2012 (based on Gen 2 cell in system)	35.4 kg	33 L
Feb 2013 (based on Gen 2 cell in system)	**32 kg**	**24 L**

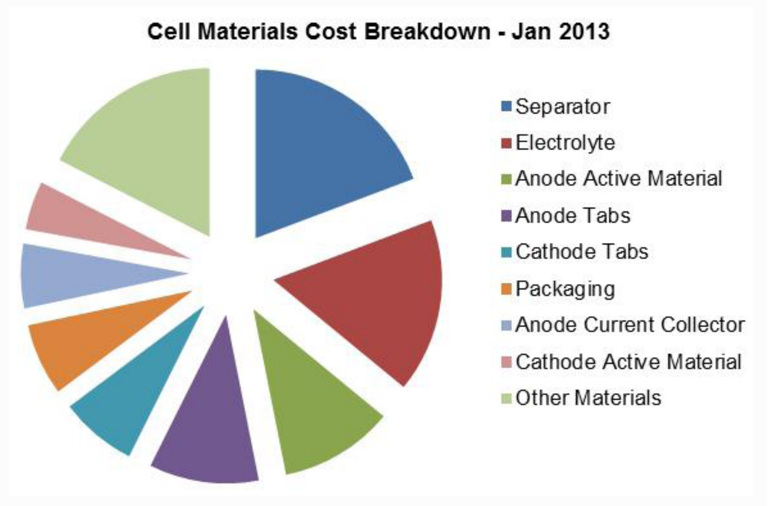


Cost Model

- Developed cost model to reflect both cell and system level costs.

	Est. System Price (100K units/yr)
Beginning of Program	$2585
Jan 2013	$1131
End of Program Target	$920

- To meet target, ongoing work focused on both traditional cost down strategies and innovative new cell manufacturing techniques.



Collaborators

Porous Power Technologies

- Small business subcontractor - developing and providing new, low cost separator materials

University of Rhode Island – Dr. Brett Lucht

- University subcontractor - screening new electrolytes and additives, and performing electrode interface analysis using microscopic and other analytical techniques

INL

- FFRDC, cell and system performance characterization

NREL

- FFRDC, thermal modeling and testing

SNL

- FFRDC, abuse testing

Future Work – FY 2013

- Fabricate Gen 3 hybrid capacitor cells in the final form factor. These cells will implement the best-in class electrode, electrolyte, and separator and be pre-qualified per the designed screening and test plan before delivery to the National Labs for performance, heat modeling ,and abuse testing.

- Construct final deliverable production systems using the Gen 3 cells. As with the cells, the systems will be pre-qualified per the designed screening and test plan before delivery to the National Labs for performance, heat modeling ,and abuse testing.

- Continue development on innovative cell manufacturing cost reduction strategies while also seeking more traditional opportunities for cell and system cost reduction. Results of these efforts will be integrated into the full manufacturing cost model for both cell and system.

Gap Chart

USABC LEESS PAHEV PROGRESS vs. TARGETS

Performance of Gen 1 Cells as of Jan 2013

End of Life Characteristics	Unit	PA (Lower Energy)		P305 Cell 15				P305 Cell 23			
				RPT0		RPT9		BOL		RPT6	
2s / 10s Discharge Pulse Power	kW	55	20	102.19	29.16	96.39	28.61	92.68	26.94	84.35	26.48
2s / 10s Regen Pulse Power	kW	40	30	74.32	43.73	70.10	42.92	67.40	40.42	61.35	39.72
Maximum current	A	300									
Energy over which both requirements	Wh	26		307	137	304	130	292	115	279	104
Energy Efficiency	%	95		92.9%				94.8%			
Cycle-life	Cycles	300,000 (HEV)								180000	
Cold-Cranking Power at -30ºC (after 30	kW	5									
Calendar Life	Years	15				0.79 (to date)					
Maximum System Weight	kg	20									
Maximum System Volume	Liter	16									
Maximum Operating Voltage	Vdc	400									
Minimum Operating Voltage	Vdc	0.55 V_{max}									
Unassisted Operating Temperature	ºC	-30 to +52									
52°	%	100		164%							
0°	%	50		94%							
-10°	%	30		66%							
-20°	%	15		39%							
-30°	%	10									
Survival Temperature Range	ºC	-46 to +66									
Selling Price/System @ 100k/yr)	$	400									
Hardware Level				cell				cell			
Ampere Hour Capacity				0.015				0.015			
Battery Size Factor (BSF)				7165				6468			

Data collected by INL

SUMMARY

This project directly addresses LEESS PAHEV goals:

- Cell materials improvements address power, energy and temperature requirements
  - Higher voltage: extended upper voltage window to >4V
  - Wider temperature window: successful operation at -30^{o}C BOL
  - Smaller and lighter: new cell architecture
- Use of cost as a factor in down-selection drives overall system cost down, and use of large scale manufacturability as a factor in down-selection facilitates production and commercialization.
- Partnerships with Small Business, University, and Govt. laboratories position the project to address all key aspects of HEV power system development
- Focus of FY2013 is to deliverable high-quality Gen 3 cell and system deliverables and qualify them per USCAR PAHEV testing, and provide an updated cost model reflecting both materials and process improvements.