

A Brief Discussion of Battery Properties and Goals for Plug-in Hybrid and Electric Vehicles

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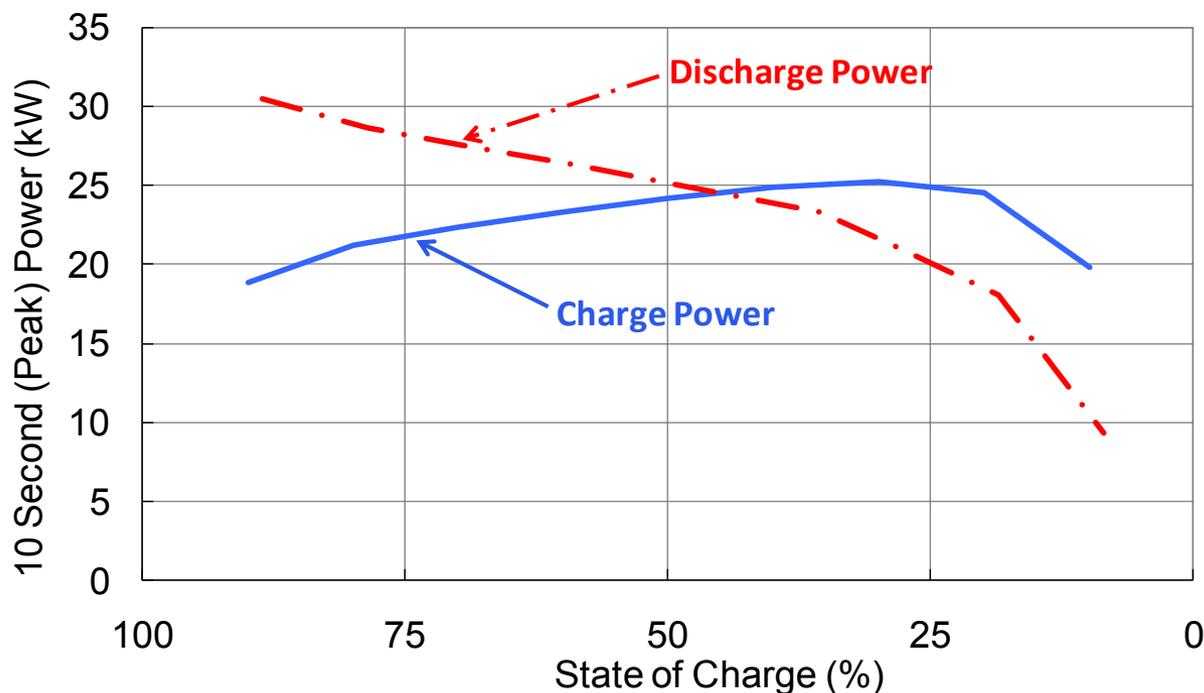
DOE VT Goals for Battery kW Performance: Much Higher “Pulse Power” than Continuous Charge Rate

Table 2.1-1. End of Life Targets for Energy Storage Systems for HEVs, PHEVs, and EVs.

DOE Energy Storage Goals	HEV(2010)	PHEV(2015)	EV(2020)
Characteristics			
Equivalent Electric Range, miles	N/A	10-40	200-300
Discharge Pulse Power, kW	25-40 for 10 sec	38-50	80
Regen Pulse Power (10 seconds), kW	20-25	25-30	40
Recharge Rate, kW	N/A	1.4-2.8	5-10
Cold Cranking Power @ -30 °C (2 seconds), kW	5-7	7	N/A
Available Energy, kWh	0.3-0.5	3.5-11.6	30-40
Calendar Life, Years	15	10+	10
Cycle Life, cycles	300k, shallow	3,000-5,000, deep discharge	750, deep discharge
Maximum System Weight, kg	40-60	60-120	300
Maximum System Volume, l	32-45	40-80	133
Operating Temperature Range, °C	-30 to 52	-30 to 52	-40 to 85
Selling Price @ 100k units/year, \$	500-800	1,700-3,400	4,000

Source: Multi-Year Program Plan 2011-2015. U.S. DOE Vehicle Technologies Program (Dec. 2010)

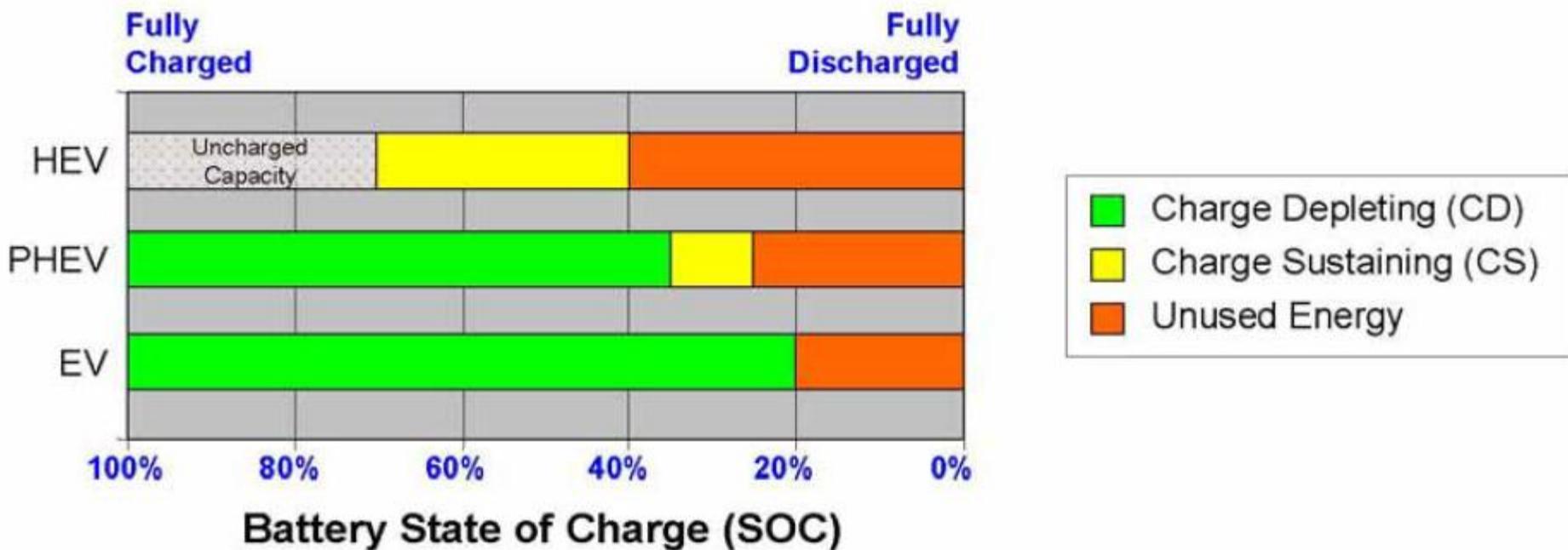
Generic Battery Property? Challenges at High and Low SOC



10-Second Input and Output Pulse Power vs. SOC, Ford Escape NiMH Pack

(Original Source: U.S. Department of Energy, undated. See Santini, Highway Vehicle Electric Drive in the United States, 2009 Status and Issues, Argonne National Laboratory Report ANL/ESD/10-9, July 2010)

**Ideally Used, PHEVs Fully Discharge Each Day.
To Assure Cycle and Calendar Life, PHEVs Cannot
Make as High a Share of kWh Available as an EV.**



Battery Operation

Source: D. Howell. Plug-in Hybrid Electric Vehicle Battery Research and Development Activities.
Presented at U.S. Department of Energy PHEV Stakeholder Workshop, June 13, 2007

PHEV10 2009 Status: No Extra Cycles for V2G Services

Battery Attribute	Goals		Current Status (10-mile)	Notes
	2012	2014		
Available Energy	3.4 kWh (10 mile)	11.6 kWh (40 mile)	3.4 kWh	
Cost	\$1700	\$3400	\$3400 (10-mile)	@ 100,000 batteries /year
Cycle life (EV Cycles)	5,000	5000	>2,000	For mature technologies
Cycle life (HEV Cycles)	300,000	300,000	300,000	At low states of charge?
Calendar Life	10+ years	10+ years	3+ years	Life prediction is difficult
System Weight	60 kg	120 kg	80-120 kg	10 mile system
System Volume	40 liters	80 liters	50-70 liters	10 mile system

Key challenges: (1) Reducing cost, (2) Extending life (while operating in 2 discharge modes), and (3) Weight & volume.

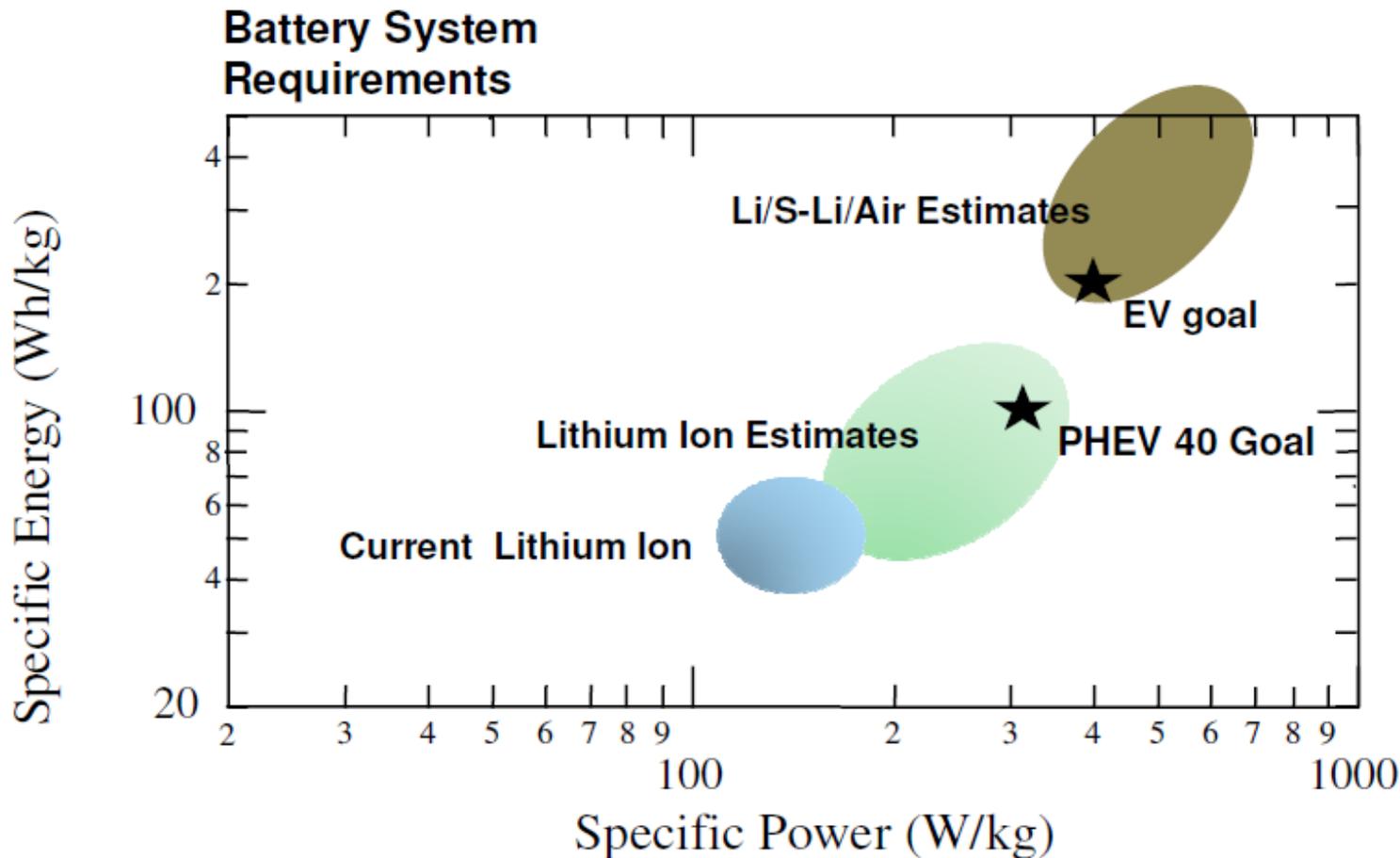
PHEV-40 performance targets are more challenging.

Source: D. Howell. *Electrochemical Energy Storage* U.S. DOE Vehicle Technologies Program (Nov. 3. 2009)

DOE VT '09: New Chemistry Needed for EVs Success

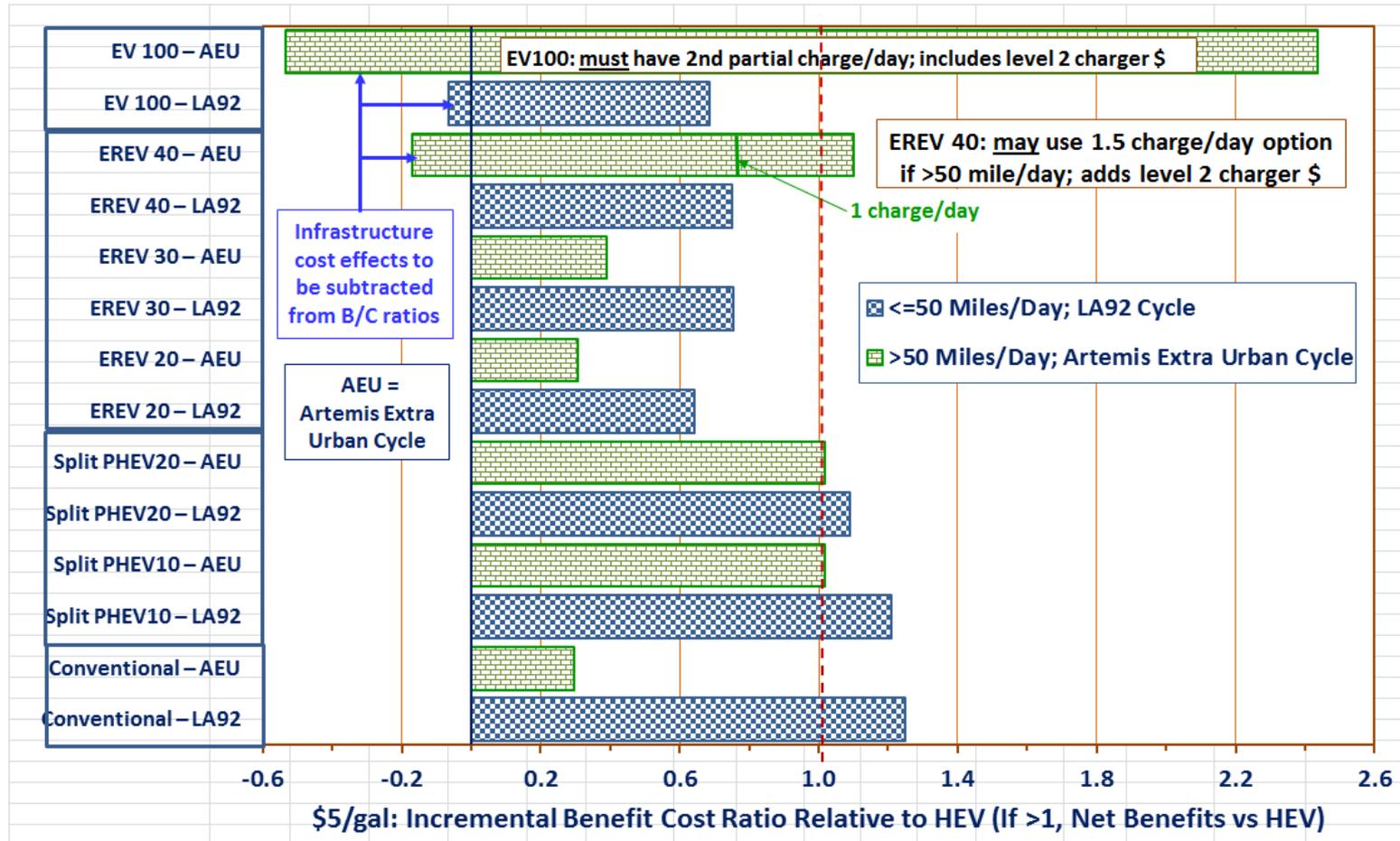
End of Life EDV Battery Requirements and
Technology Status/Potential

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Source: D. Howell. *Electrochemical Energy Storage* U.S. DOE Vehicle Technologies Program (Nov. 3, 2009)

Benefit/Cost Evaluation Implies an EREV40 and EV Must Exceed 50 mpd and Charge 1+ Times/Day



Source: D. Santini et al; Where are the market niches for Electric Drive Passenger Cars? Transportation Research Board 2011 Annual Meeting Paper 11-3733

Smart Charging: Don't Charge on Summer Peak (G2V). Please Discharge to Reduce the Peak (V2G)

- Problem: Time of day rates look like they will increase the cost of afternoon summer peak charging more than they will cut costs of off-peak (overnight) charging.
- If my EREV or EV candidate consumer who could save the nation fuel cannot charge on peak, when could a second charge be squeezed in?
- If I cannot squeeze in extra charges before the afternoon, could I help economics by selling for peak reduction in the afternoon? Concern: worst case for battery life – charging (or discharging) on hot asphalt at the summer peak.