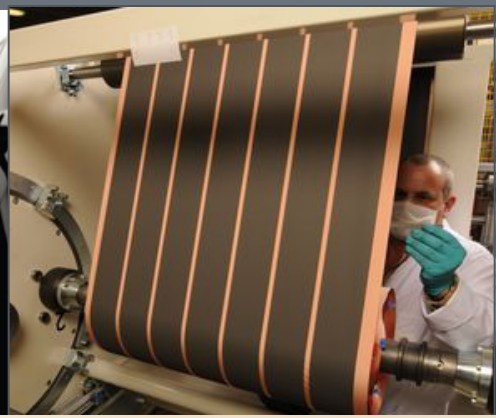
US-China Bilateral Electric Vehicle Initiative

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

6th US-China Electric Vehicle and Battery Technology Workshop



Update on US DOE Electric Drive Vehicle R&D and Deployment Activities

August 23, 2012

David Howell
Team Lead, Hybrid & Electric Systems
Vehicle Technologies Program
U.S. Department of Energy
1000 Independence Avenue
Washington DC 20585

U.S.-China Bilateral Agreement

Presidents Barack Obama and Hu Jintao announced the launch of a U.S.-China Electric Vehicles Initiative – November 17, 2009

- Shared interest in accelerating the deployment of electric vehicles to
  - Reduce oil dependence
  - Cut greenhouse gas emissions
  - Promote economic growth
- Activities under the initiative will include:
  - Joint standards development
  - Joint demonstrations
  - Joint technical roadmap
  - Public awareness and engagement

U.S.-China Bilateral R&D Initiative

US-China Electric Vehicle and Battery Technology Workshops

- Sponsored by:
  - U.S. Department of Energy
  - China's Ministry of Science and Technology
- Three focus areas
  - Battery Technology Road-mapping
  - Battery Test Procedures
  - Vehicle Demonstrations and Infrastructure
- Previous Workshops
  - August 2010: Argonne National Lab.
  - March 2011: Beijing
  - August 2011: Argonne National Lab.
  - April 2012: Hangzhou

5th China-U.S.
Electric Vehicle and Battery Technology Workshop

16/17 April 2012
Hangzhou

Workshop Sessions

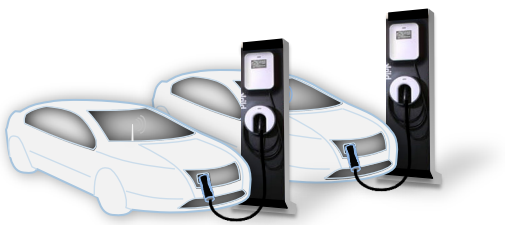
	Ballroom A	Ballroom B
Thursday, August 23	**1** (Plenary)	
	2A (Beyond Li-Ion)	**2B** (Demonstrations & Standards)
	3A (Beyond Li-Ion)	**3B** (Demonstrations & Standards)
	4A (Testing & Safety)	**4B** (Demonstrations & Standards)
Special Dinner Event (Univ. of Massachusetts Club)		
Friday, August 24	**5A** (Testing & Safety)	**5B** (Demonstrations & Standards)
	6 (Group Discussion & Next Steps)	

EV Everywhere Grand Challenge

A DOE Clean Energy Grand Challenge with the goal of *enabling U.S. companies to produce electric vehicles that are as affordable and convenient for the average American family as today's gas-powered vehicles* within the next 10 years (by 2022).

President Obama announced the EV Everywhere Challenge on March 7, 2012

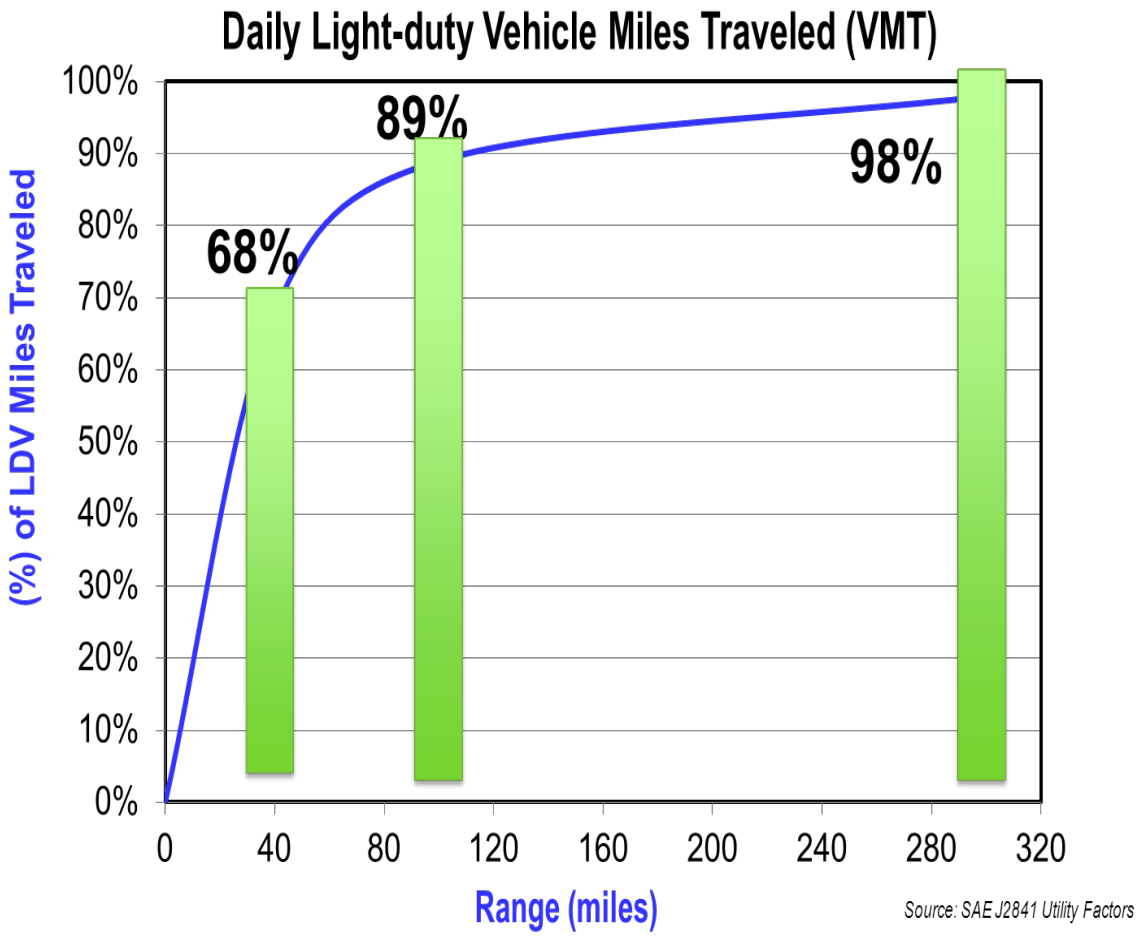
The EV Everywhere Challenge



- Benchmark: 5-passenger vehicle suitable for an average American family
- Majority of vehicle-miles-traveled powered by electricity under standard drive cycles
- 5-year simple payback vs. equivalent gasoline powered vehicle
- Vehicle range-Charging infrastructure scenarios must support the adoption of the EV as a primary vehicle
- No reduction in grid reliability

What EV range should DOE target for the Grand Challenge

1. **PHEV40** with limited fast-charge infrastructure?
2. **AEV100** with significant intra-city and inter-city fast charge infrastructure?
3. **AEV300** with significant inter-city fast charge infrastructure?



Vehicle-level analysis provides a starting point for setting EV Everywhere technical targets for these vehicles.

EV Everywhere Battery Targets

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Battery affordability and performance are critical advances that are needed in order to achieve the *EV Everywhere* Grand Challenge

Chevy Volt

- ~40 mile electric range
- HEV: 32 mpg /300 miles
- 16 kWh / 120 kW battery
- Battery Cost: ~$8,000

Nissan Leaf

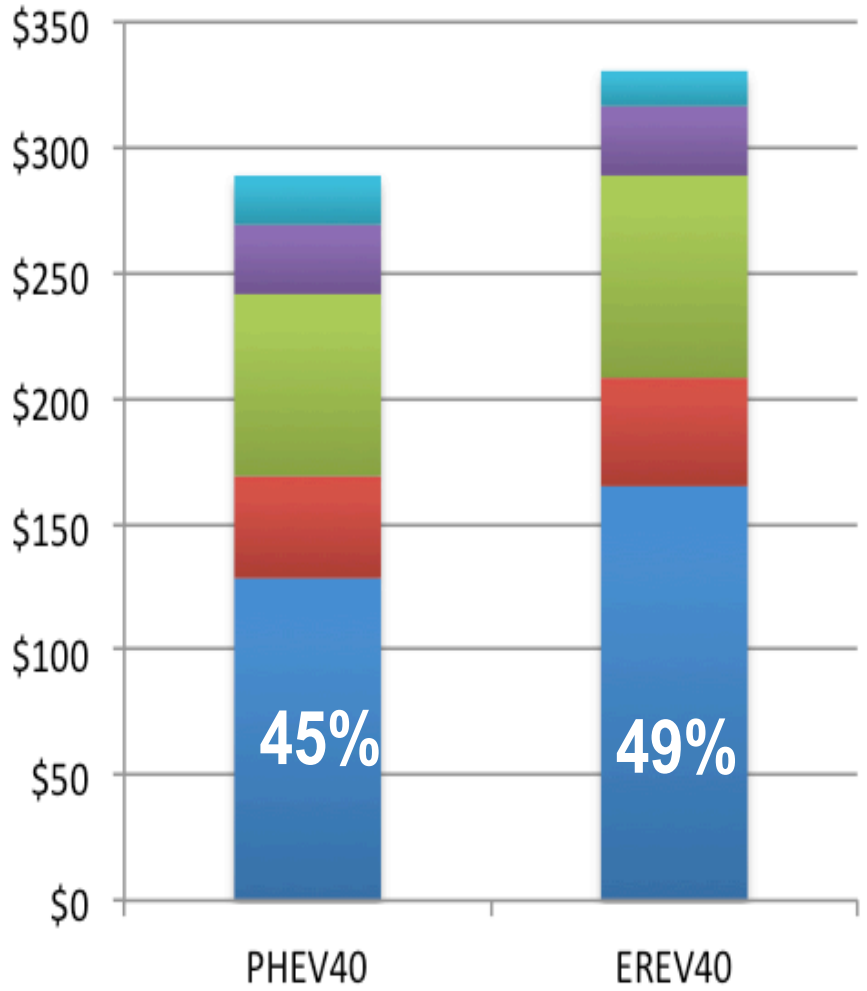
- ~75 mile electric range
- ≥ 24 kWh / 80 kW battery
- Battery Cost: ~$12,000

Tesla

- ~ 250 mile electric range
- ≥ 85 kWh / 270 kW battery
- Battery Cost: ~$35,000

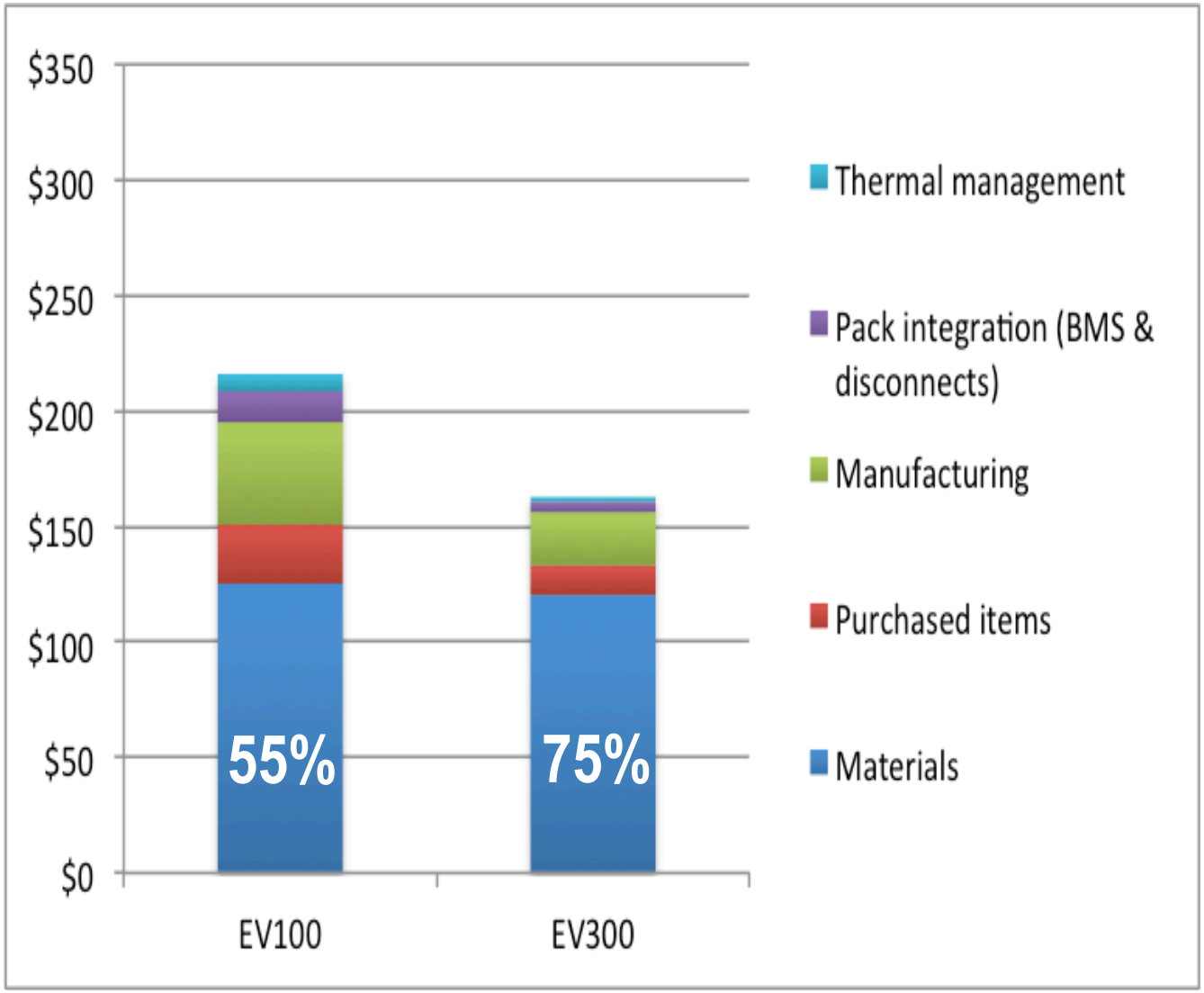
EV Everywhere Target Analysis		Current Status	PHEV40	AEV100	AEV300
Battery Cost	**$/kWh (usable)**	**< 600**	**190**	**300**	**110**
Pack Specific Energy	Wh/kg	80-100	150	180	225
Pack Energy Density	Wh/L	200	250	300	425
SOC Window	%	50	80	90	90

PHEV Cost Estimates, $/kWh



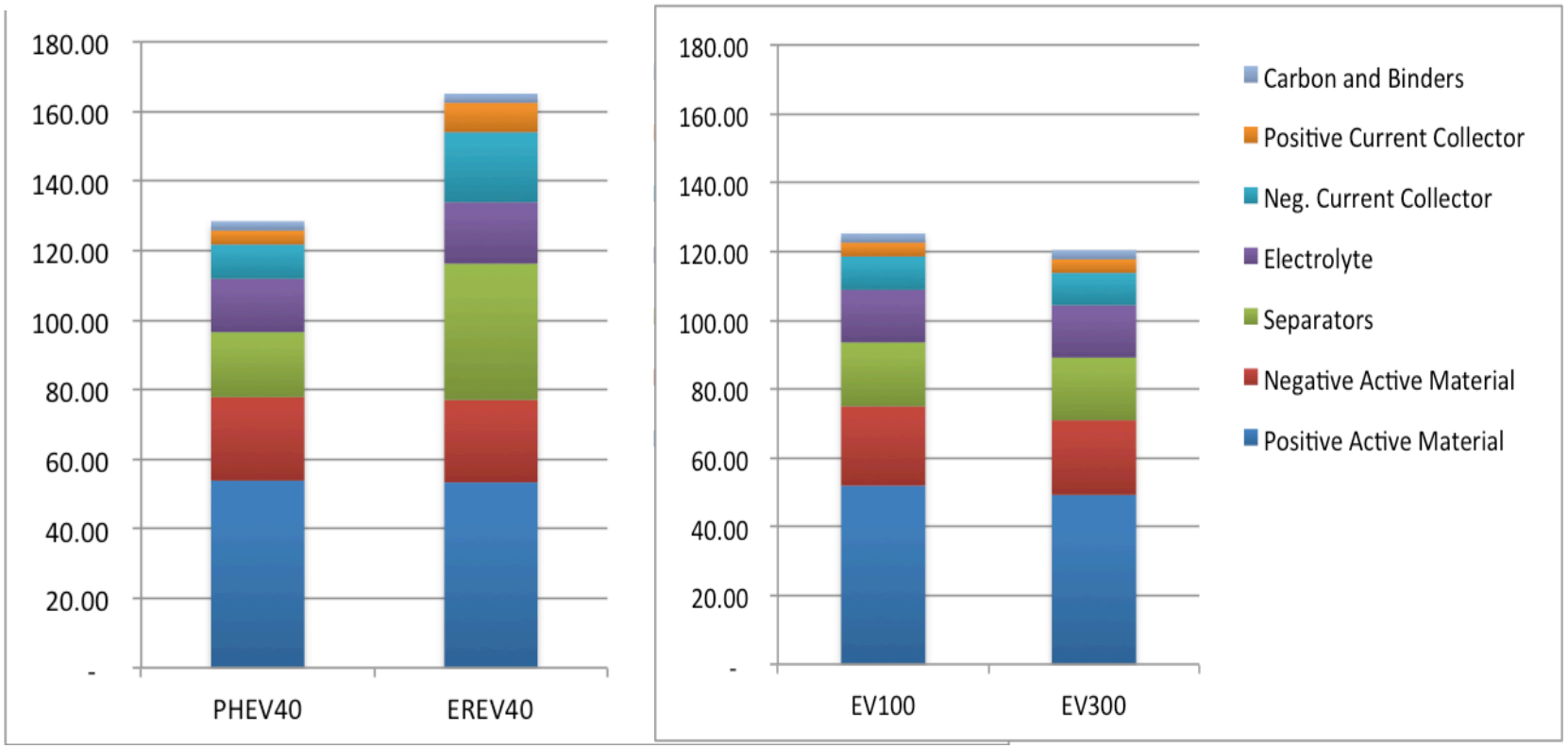
- Estimates from ANL's BatPaC model.
- Based on 2020 production year & annual production of 100k packs
- Chemistry
  - graphite anode
  - NMC441 cathode
  - EC-EMC-$LiPF_6$ electrolyte
- Liquid cooling
- Manufacturing
  - electrode processing,
  - cell assembly
  - formation,
  - module & pack assembly
- Purchased items
  - cell terminals
  - packaging
  - module and pack jackets

EV Cost Estimates, $/kWh



- Estimates from ANL's BatPaC model.
- Based on 2020 production year & annual production of 100k packs
- Chemistry
  - graphite anode
  - NMC441 cathode
  - EC-EMC-$LiPF_6$ electrolyte
- Liquid cooling
- Manufacturing
  - electrode processing,
  - cell assembly
  - formation,
  - module & pack assembly
- Purchased items
  - cell terminals
  - packaging
  - module and pack jackets

Cost of Key Materials, $/kWh

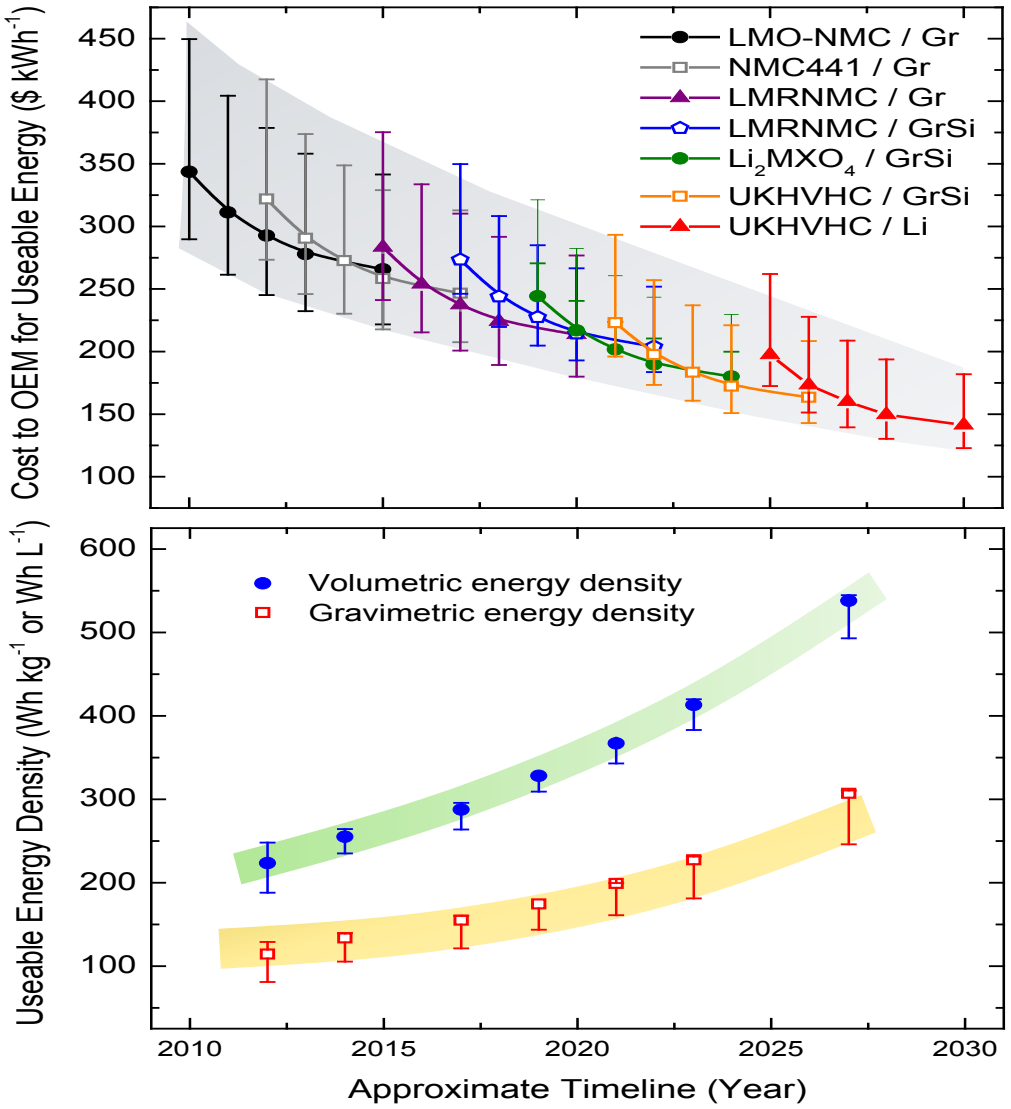


Non-active materials costs are higher for higher power systems. Material costs for other systems are similar, non-active material costs decrease on a relative basis with increasing AER.

Path Forward for Lithium-Based Batteries

Battery Cost Model Calculations (BatPaC v1.0) **for a 100 mile range Electric Vehicle (EV100)**

- Battery Specs: 30 kWh, 80 kW, 360V
- Total cost to OEM includes purchased battery, battery management system, and liquid thermal management (w/o electric compressor).
- **If high-risk research is successful,** material advances may lead to a 60% reduction in cost and 250% increase in energy density
- Larger batteries (EV200+) will have higher energy densities and lower costs for energy.



Source: Argonne National Laboratory

Current & Future Technologies

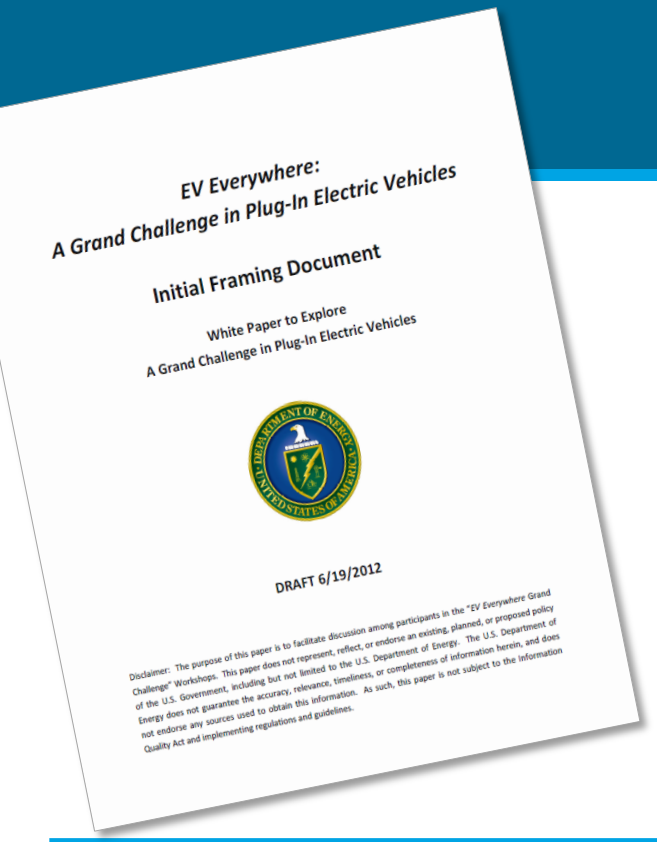
Attributes of Battery Technologies (Battery Pack level)

	Specific Energy (Wh/kg)	Energy Density (Wh/l)	Power (W/kg)	Life (cycles)	Safety
Lithium-ion (current status)	50-80	100-150	500-1000	>3,000	Meets SAE J2929
Lithium-ion (future generations)	150-200	**250+**	**2,000**	**>3,000**	Meet SAE J2929
Lithium metal polymer	150-200	**250-300**	500	~1000	**+++++**
Lithium metal / Sulfur	**250-400**	180-250	750	~100	Concern
Lithium metal / Air	**400-800**	180-250	Poor	~10	Concern

Current Status – Charge Times* Versus Method

	Plug-in Prius	Volt	Leaf
			
AC Level 1 **RESIDENTIAL** *5 mi/hour @ 1.7 kW*	**2.6 hrs**	**10.5 hrs**	**20 hrs**
AC Level 2 **RESIDENTIAL** *10 mi/hour @ 3.3 kW* **COMMERCIAL** *20 mi/hour @ 6.6 kW*	**1.3 hrs**	**4.25 hrs**	**10 hrs**
DC Level 2 **(Fast Charging)** **COMMERCIAL** *165 mi/hour @ 50 kW*	**Not applicable**	**Not applicable**	**36 min**

* Approximations using the charge rate (mi/hour) and nominal electric range (13, 40 and 100 mi, respectively);
The AC Level 1 charge time for the Volt (10 hrs) is the GM estimate based on the 120v 1.2 kW charger provided as standard equipment with the vehicle


EV Everywhere:
A Grand Challenge in Plug-In Electric Vehicles

Initial Framing Document

White Paper to Explore
A Grand Challenge in Plug-In Electric Vehicles

DRAFT 6/19/2012

Disclaimer: The purpose of this paper is to facilitate discussion among participants in the "EV Everywhere Grand Challenge" Workshops. This paper does not represent, reflect, or endorse an existing, planned, or proposed policy of the U.S. Government, including but not limited to the U.S. Department of Energy. The U.S. Department of Energy does not guarantee the accuracy, relevance, timeliness, or completeness of information herein, and does not endorse any sources used to obtain this information. As such, this paper is not subject to the Information Quality Act and implementing regulations and guidelines.

- 5 workshops this summer
- Framing document
  - Draft: Facilitate discussion among participants
- Recruit the best and brightest American scientists, engineers, and businesses to tackle this electric vehicle challenge
- Re-evaluate and refine the existing technical goals for increasing performance and cutting costs

Topic	Date	Location
Kick-Off Framing Workshop	June 21	Dearborn, MI
Electric Drive Components	July 24-25	Chicago, IL
Advanced Batteries	July 26	Chicago, IL
Consumer Behavior and Charging Infrastructure	July 31 – Aug 1	Los Angeles, CA
Vehicle Design and Lightweight Structures	Sep 13	Washington DC