Idaho National Laboratory
International Nuclear Leadership for the 21st Century

Battery Technology for Vehicles

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Cascadia, Transforming Transportation
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INL Focus

EERE -Vehicle Technologies Program

Support U.S. Department of Energy's effort to reduce national dependence on foreign oil through:

Vehicle Systems and Energy Storage

- Technology and Infrastructure Development
- Vehicle and component testing, demonstrations

Introduction

- Electrochemical Energy Storage is the most efficient way to push cars around.

  - Highest potential payoff for the $$.

    - Assuming cleaner production of electricity that includes renewables and nuclear.

  - Achievable infrastructure improvements.

    - Expansion of smart grid systems to access clean energy and accommodate vehicle charging at home and public facilities.

Introduction

- Advanced batteries are improving

  - Consumer acceptance of HEVs today is due to the durability of the NiMH batteries.

  - Gradual displacement of NiMH batteries is expected as Lithium ion promises increased performance and longer life.

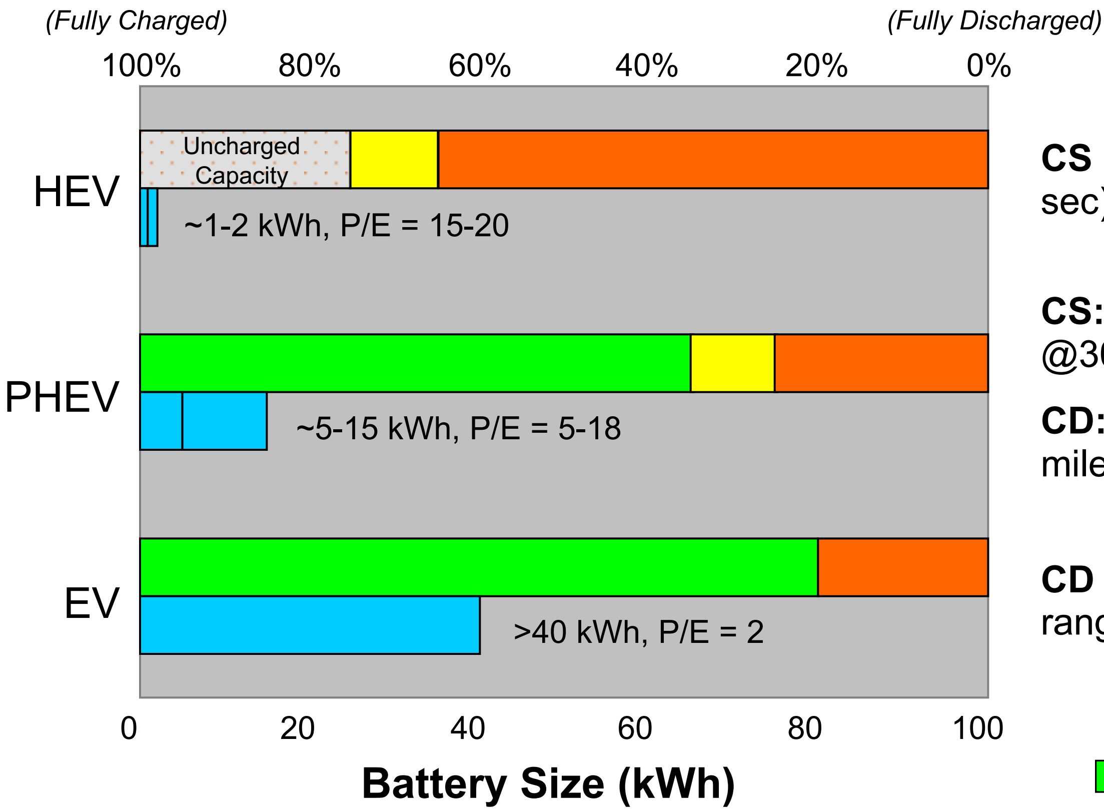
  - Cost of lithium ion batteries for consumer electronics is now below that of NiCd and NiMH batteries (<$500/kWh).

  - Lithium ion is viewed as the most commercially viable energy storage option for PHEVs due to its potential for much higher energy and power densities.

  - Further improvements are needed for high energy lithium ion before a large penetration of PHEVs and transition to EV’s can take place.

Vehicle Battery Operation

Battery State of Charge (SOC)



CS only: 300-500 Wh, 25-40 kW (10 sec) @70% SOC, 300,000 cycles

CS: 300-500 Wh, 25-40 kW (10 sec) @30% SOC, 300,000 cycles

CD: Energy scaled for range (10-40 miles), 5,000 deep discharge cycles

CD only: Energy scaled for 100+ mile range, 1,000+ deep discharge cycles

- Charge Depleting (CD)
- Charge Sustaining (CS)
- Unused Energy
- Battery Size (kWh)

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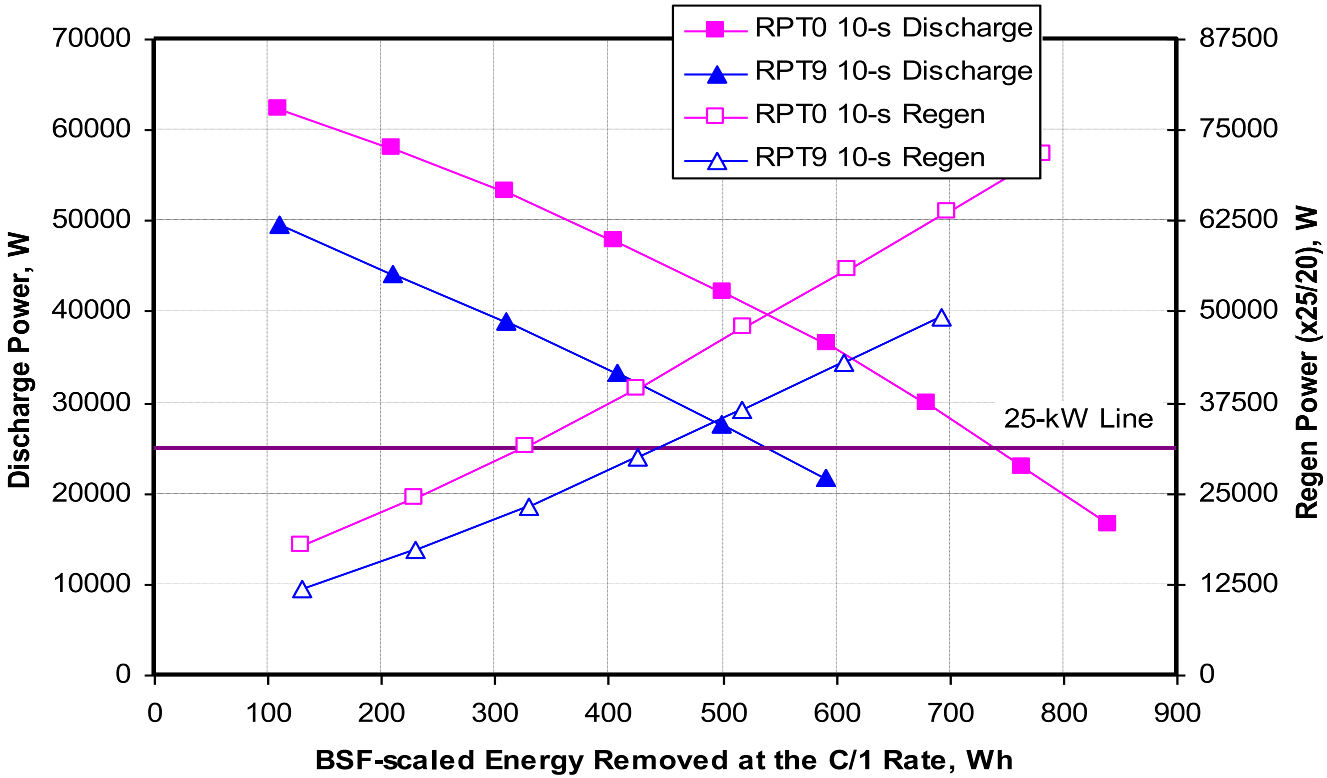
Source: Duong, BES Workshop, Apr. 2, 2007

Battery Issues

- High energy battery issues (PHEV, EV)
  - Limited availability and U.S. production capacity
  - Cost: current batteries are 8X the DOE PHEV goal ($2000/kWh today vs. $250/kWh goal in 2015)
  - Life: projections of 10-15 years are based on limited data
  - Abuse tolerance
  - Low-temperature performance
- Emerging technologies – Improved chemistry, stability
  - $Li_4Ti_5O_{12}$ and alloy composite negatives
  - $LiFePO_4$, $LiMnPO_4$, and other layered-spinel electrodes
  - Advanced Pb Acid for light HEVs (Ultrabattery)

HEV Batteries - power and energy fade

Power level decreases with time
Energy window at constant power decreases with time



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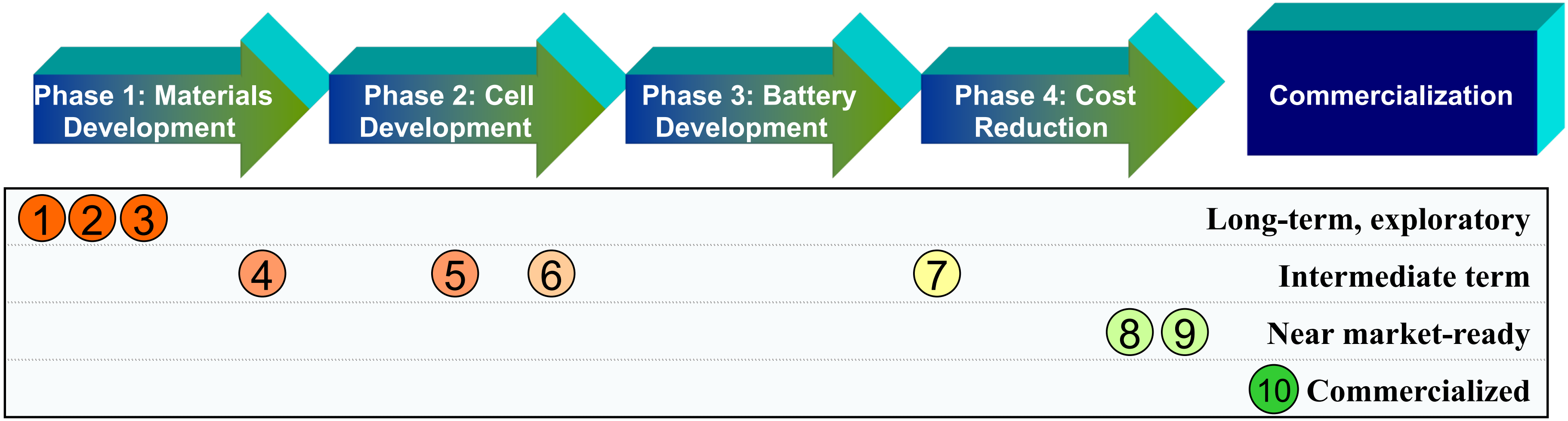
DOE Technology Development Roadmap
HEV to PHEV to EV

Research Goals

Specific Energy: 100 Wh/kg (by 2010)
150 Wh/kg (by 2015)

Cost Goals

HEV: $20/kWh (by 2010)
PHEV: $250/kWh (by 2015)



1. Li Metal Polymer
2. Li/Sulfur system
3. Li alloy/high V TMO system
4. Li titanate/Mn spinel
5. Graphite/Mn spinel
6. Graphite/Iron phosphate
7. Graphite/Nickelate
8. Ultracapacitors
9. Low cost separators
10. NiMH

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Source: Duong, BES Workshop Apr. 2, 2007

USABC Goals for PHEV Batteries

Power requirements are set to allow an all-electric operation under Urban Dynamometer Driving Schedule (UDDS) in charge-depleting mode

•Characteristics at EOL (End of Life)		High Power/ Energy Ratio Battery	•High Energy/ Power Ratio Battery
Reference Equivalent Electric Range	miles	10	40
Peak Pulse Discharge Power - 2 Sec / 10 Sec	kW	50 / 45	46 / 38
Peak Regen Pulse Power (10 sec)	**kW**	**30**	**25**
Available Energy for CD (Charge Depleting) Mode, 10 kW Rate	kWh	3.4	11.6
Available Energy for CS (Charge Sustaining) Mode	kWh	0.5	0.3
Minimum Round-trip Energy Efficiency (USABC HEV Cycle)	**%**	**90**	**90**
Cold cranking power at -30°C, 2 sec - 3 Pulses	**kW**	**7**	**7**
CD Life / Discharge Throughput	Cycles/MWh	5,000 / 17	5,000 / 58
CS HEV Cycle Life, 50 Wh Profile	Cycles	300,000	300,000
Calendar Life, 35°C	**year**	**15**	**15**
Maximum System Weight	**kg**	**60**	**120**
Maximum System Volume	**Liter**	**40**	**80**

DOE PHEV Battery Activities

- DOE PHEV R&D Plan
- 5 new lithium ion PHEV battery projects
  - JCS, CPI, Enerdel, A123, 3M
- Evaluated at ANL and INL
- PHEV Battery Test Procedures Manual published
- Testing batteries in vehicle conversions
  - Lithium ion (PHEVs), advanced Pb acid (HEVs)
- Battery to grid charging/power flow studies
- Transition to EV battery systems

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