Craig E. Irwin, Vice President – Equity Research
Energy Storage & Efficiency

Advanced Battery Technologies

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The Broad Questions

- **How does Merriman look at Energy Storage?**
- **What are the broader opportunities?**
- **What early stage technologies hold promise?**

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An Ideal Energy Storage Market

It runs on its conventional gasoline-powered engine until it senses guilt, then it switches over to battery power.

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Major Types of Energy Storage

- **Battery technologies include both disposable (primary) and rechargeable (secondary) chemistries**
- **Emerging energy storage technologies include mechanical or flywheel technology, hydrogen and thermal storage**
- **Theoretical comparisons are often made to distillate fuels and pumped hydroelectric storage used by utilities**

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Today's Storage Market

- **$14B Lead Acid for Industrial and Automotive**
- **$5B Lithium Ion for Consumer and Portables**
- **$1B Nickel Metal Hydride for Consumer and Hybrids**
- **Military Aerospace and Niche or Emerging Markets**

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Growth Potential In Storage Markets

	Market in 2007	Market in 2017
Consumer	$6B	$12B
Hybrids	$900m	$15B
Large Format	$50m	$5B

Source: Merriman Curhan Ford Estimates and Industry Sources

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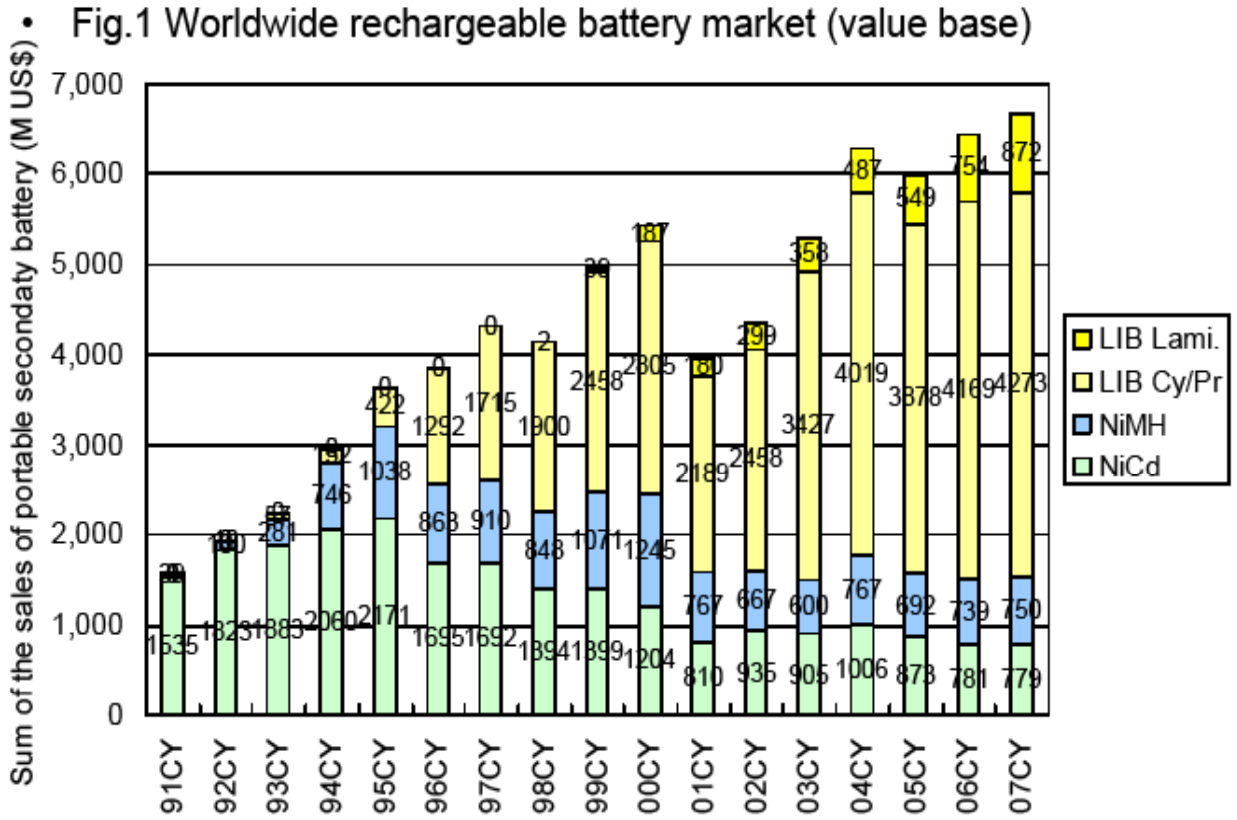
Rechargeable Battery Market

1-1 Almost 10B US$ market with HEV and packs



Source: Institute of Information Technology, Ltd

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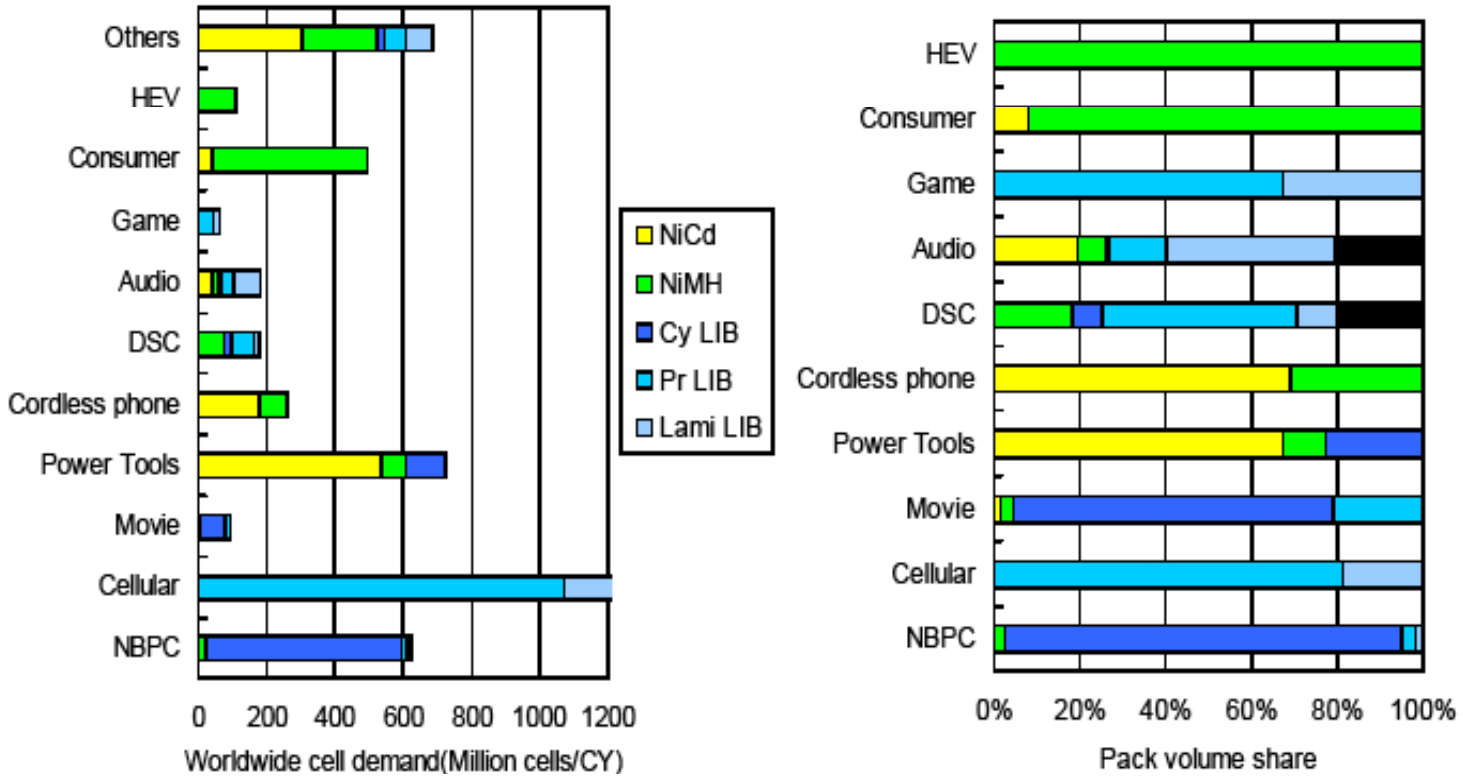
Energy Storage Markets by Application



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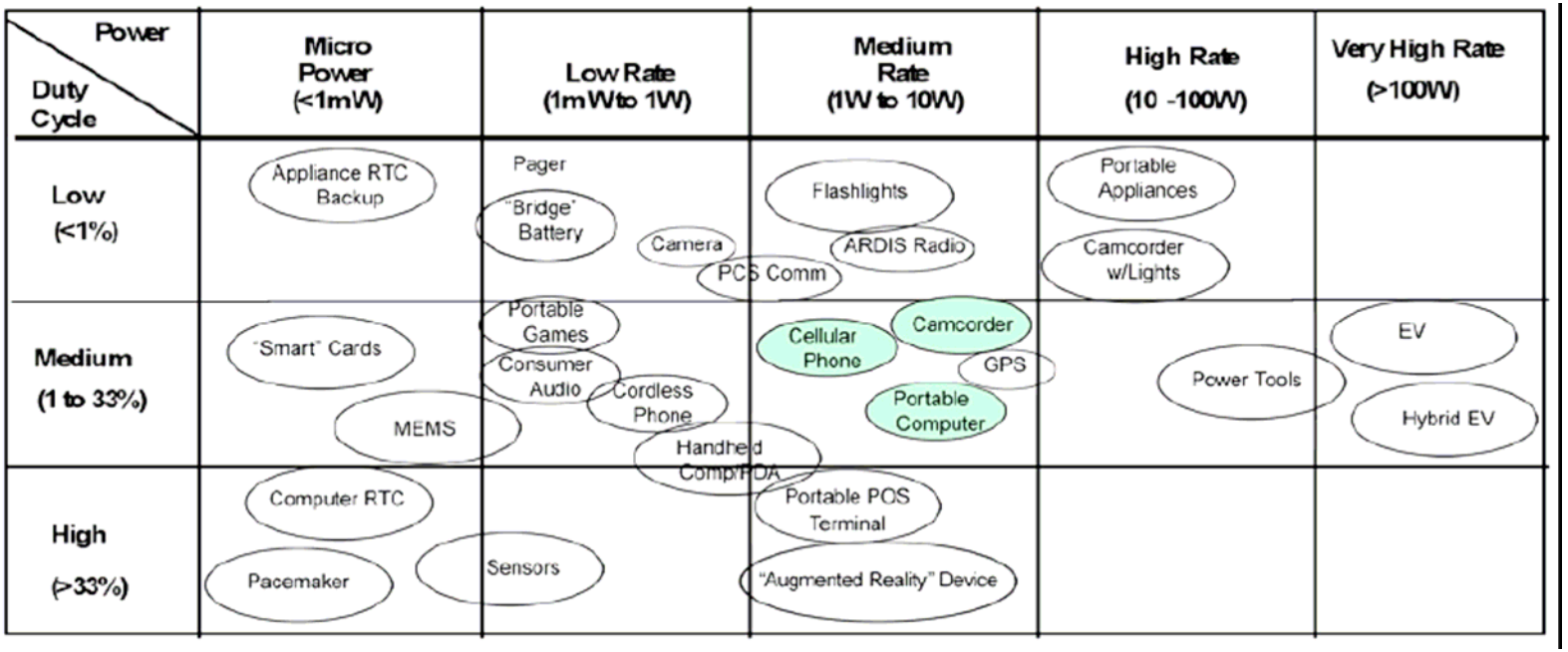
Application Map



Source: U.S. Department of Energy

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Battery Performance Metrics

Performance Metrics of Common Rechargeable Battery Chemistries

Chemistry	Sp. Energy (Wh/kg)	Energy Density (Wh/L)	Life Cycles	Operating Temp. °C	Electrolyte	Losses (%/Mo)	Comments	Primary Markets	Cost ($/kWh)
Lead Acid - SLI	35	70	200-700	-40 to 55	Aqueous	20-30	low cost, high rate	Automotive	$50
Lead Acid - Motive	25	80	1,500	-20 to 40	Aqueous	4-6	~9h cycling discharge	Lift Trucks	
Lead Acid - Standby	10-20	50-70	--	-10 to 40	Aqueous	--	Long life	UPS/Telecom	$35 - $500
Lead Acid - Portable	30	90	250-500	-40 to 60	Aqueous	4-8	low cost	Portable Tools	
Nickel-Cadmium	30-40	40-80	500-2,000	-40 to 45	Aqueous	10-20	Memory effect	Consumer to HEV	$300
Nickel-Iron	30	55	2,000-4,000	-10 to 45	Aqueous	20-40	Extremely rugged	Railroad	
Nickel-Zinc	50-60	80-120	500	-10 to 50	Aqueous	<20	Extended cycle life	Scooters	$250
Silver-Zinc	105	180	50-100	-20 to 60	Aqueous	5	Best High rate capacity	Military/Aerospace	
Silver-Cadmium	70	120	300-800	-25 to 70	Aqueous	5	Low temp sensitive	Aerospace	
Nickel-Hydrogen	64	105	1,500-6,000	0 to 50	Aqueous	very high	Discharge | H2 P&T	Aerospace	
Nickel-Metal-Hydride	75	240	300-600	-20 to 50	Aqueous	15-25	Capacity > NiCd	Consumer to HEV	$500
Lithium-Ion	150	400	1,000+	-20 to 50	Organic	2	High Energy Density	Consumer	$800
Lithium Polymer	500	600	2,000+	-20 to 60	Organic	<1	Penetrating Market	Portable Electronics	

Source: Handbook of Batteries, Company Datasheets and Merriman Curhan Ford.

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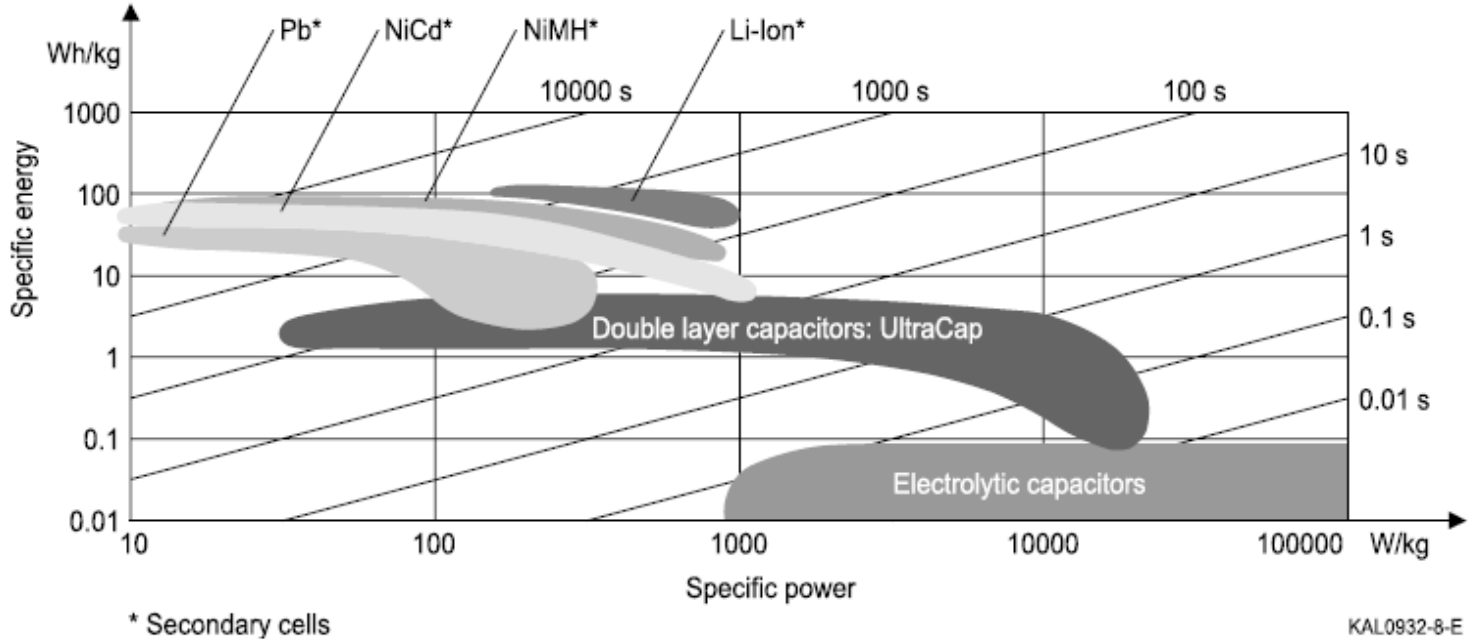
Energy Versus Power Comparisons



Source: EPCOS

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Consumer Markets Offer Abundant Diversity

- **There is tremendous diversity of end applications with each application having unique design requirements**
- **Individual applications even have diversity of chemistry**
- **Batteries are good at storing lots of energy, capacitors are better at storing power, and ultracaps are in between**
- **Individual chemistries can be tweaked to operate across broad performance ranges; chemistry and manufacturing**

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Evolution of Lithium Ion Batteries

	1991 - 1995	1996 - 2000	2001 - 2005	2006 - 2010
New Cathode	$LiCoO_2$	$LiMn_2O_4$		$LiFePO_4$
New Anode	Amorphous Carbon (Graphite)	Graphite Capacity Enhancement	Sn Type Anodes	Si Anodes
Supporting Material		Functional Electrolyte Gel Polymer and Laminate		Functional Separator
Structure	Cylindrical	Prismatic	Laminate / Stack	Thin / Large for HEV
Key Players	Sony and ATB	Sanyo, MBI, NEC, Maxell	Sanyo for High Speed BYD, LGC, SDI	A123, Phostech
Key Users	Sony, Dell, Toshiba	Motorola, IBM, NTT	Nokia for low cost Bosch, Makita for p tools	Dewalt, GM and BAE

Source: Institute of Information Technology, Ltd and Merriman Curhan Ford

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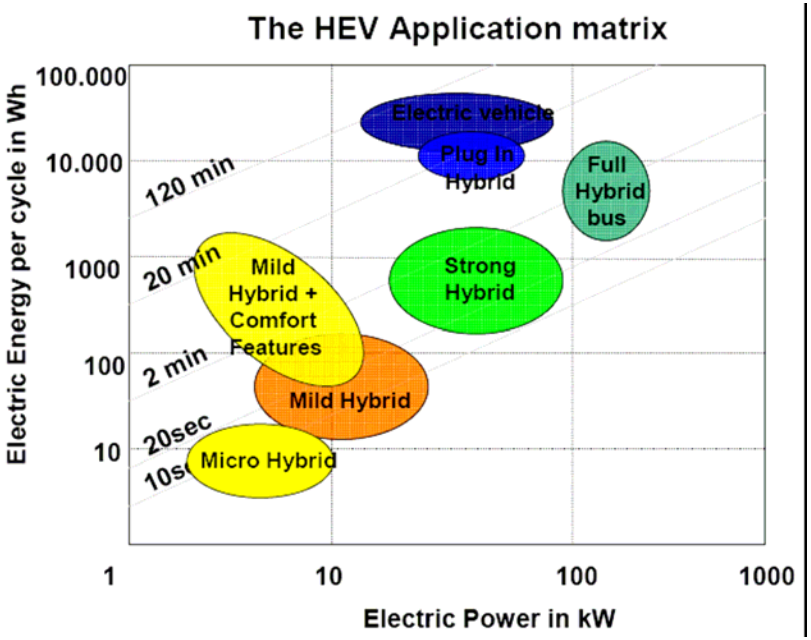
The Evolving Hybrid and Plug in Markets

- **Over 1m hybrids are on the road with over 400k sold globally in 2007**
- **$900m battery mkt in 2007 served mostly by Panasonic, Sanyo and Cobasys**
- **Hybrids premium priced for $5-6k extra battery drivetrain and electronics content**
- **Battery is the largest piece of increased vehicle content**
- **All degrees of hybridization are being actively pursued with full hybrids comprising the most vehicles sold**



Source: U.S. Department of Energy

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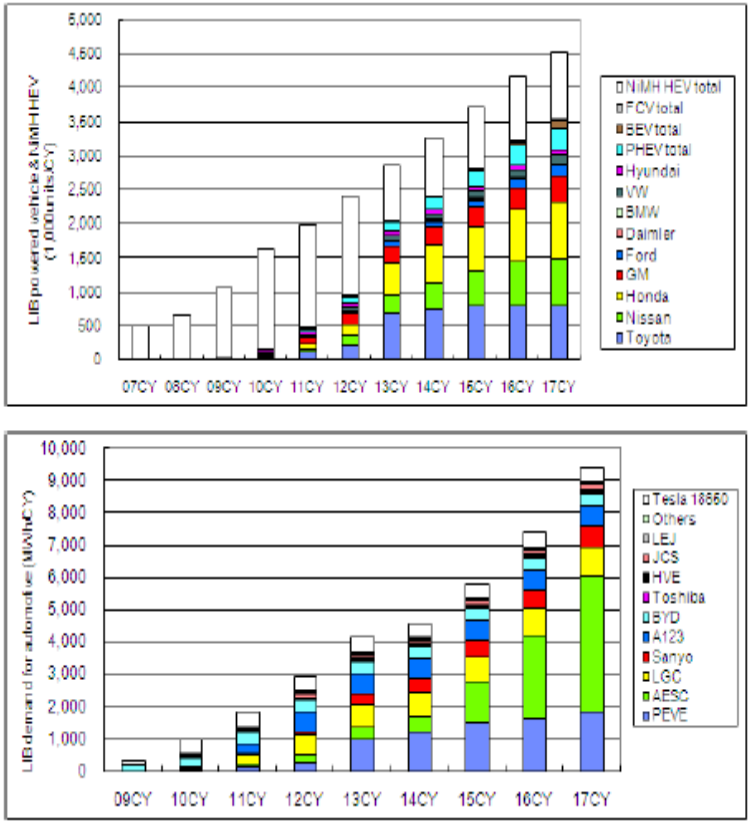
Hybrid Battery Market Forecasts

- 5% penetration of Li-Ion hybrid batteries into fleet sales results in a $6B market
- All major auto OEMs are working on new hybrid vehicle platforms
- Most OEMs are focused on NiMH batteries for near-term and Li-Ion for longer-term
- Many emerging auto OEMs are aggressively adopting Li-Ion technology
- IIT forecasts NiMH hybrid batteries will grow and stay a large piece of the market

Battery Demand by OEM and Supplier



Source: Institute of Information Technology, Ltd

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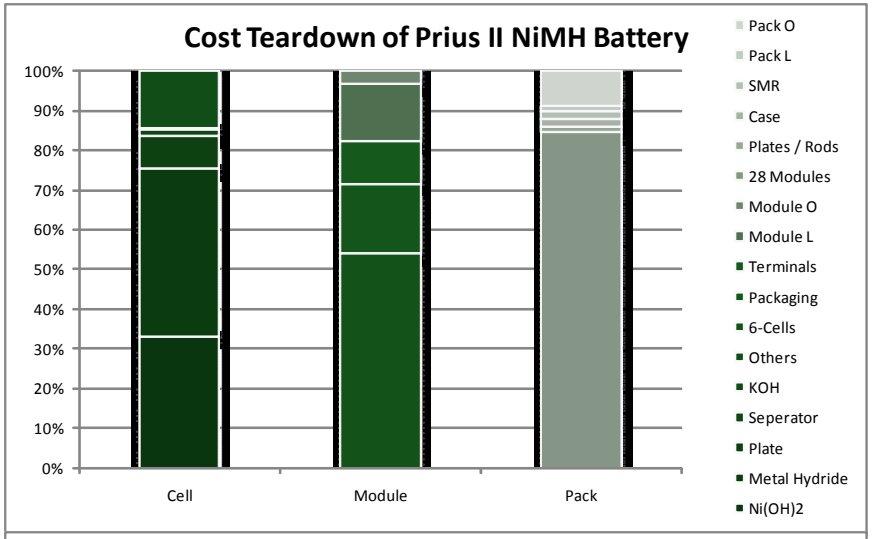
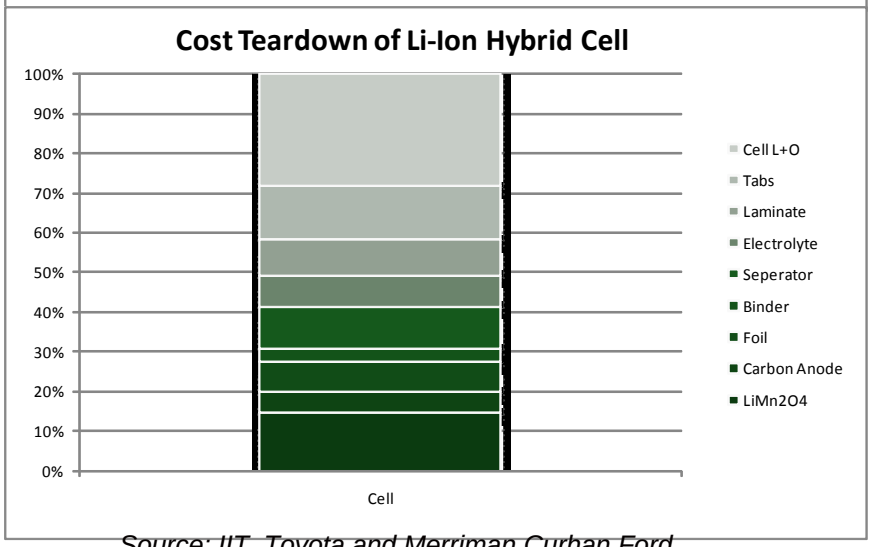
Cost Structure of Hybrid Batteries

- **Nickel content makes up almost 35% the cost of a NiMH hybrid battery pack**
- **Cost leverage for NiMH has been already achieved due to existing consumer NiMH demand, and cell similarities**
- **Lithium Ion hybrid batteries are widely expected to have long-term cost benefits due to low commodity content**
- **Separator represents ~1% of a NiMH hybrid cell, but ~10% for lithium ion cells**
- **Li-Ion has weight, energy and efficiency advantages**





Source: IIT, Toyota and Merriman Curhan Ford

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Large Format Storage Technologies

- **Major large format chemistries include sodium sulfur, zinc bromide, and vanadium redox.**
- **Solar and wind are major PULLERS as generation is not coincident with demand**
- **Utilities say they have significant demand; batteries can allow peak shaving, load shifting and deferred maintenance of switchyards or transmission lines**
- **Practical economics largely analogous to standby power used in utility switch stations and central telecom plants, and most of the current market activity focuses on proof of concept or advanced demonstration projects**
- **Demonstration projects with lead acid, nickel metal hydride, and lithium ion have shown these chemistries work but have significant cost and other limitations**

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Standby Power Market Potential

Storage Parameter	Power Quality	Power Backup for Outages	Regulation	Grid Stability & Reliability	Load Shifting & Leveling
Capital Cost ($/kW)	400		700	300 - 1000	300 load leveling 400-100 peak shaving 650 renewables
US Market (GW)			30-40	70-100	80 (cost sensitive)
Storage Power Level	Up to 100 kW	1 to 50 MW	Up to 200 MW	10MW to 1 GW	1MW to 1GW
Discharge at Rated Power	0 to 5 sec	Minutes to Days	Seconds	20 min to 2 hours	1 to 8 hours
Capacity	Up to 1 min	Months to years	Seconds	Weeks	Hours to Days
Lifetime (yrs)	5	20	20	40	7-10
Other			Long Cycle Length		

Source: U.S. Department of Energy and Merriman Curhan Ford

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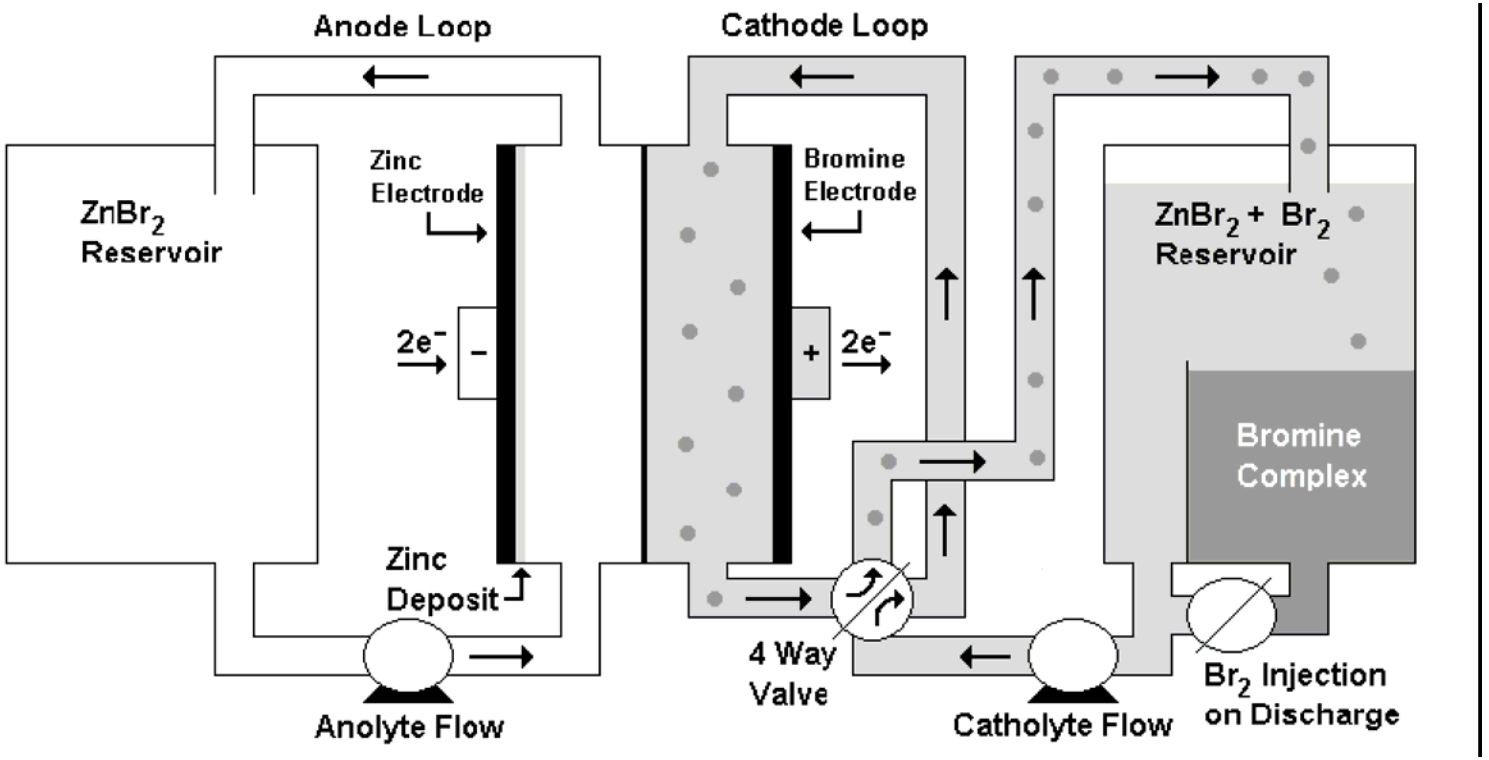
Flow Battery Illustration



Source: ZBB Energy

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