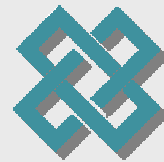


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# Second Use of Electric Vehicle Batteries in Stationary Applications

*Presented at*  
**DOE Energy Storage Systems Program Review**  
**Washington, DC**  
**November 19, 2002**

*Presented by*  
**Irwin B. Weinstock**  
**SENTECH, INC.**



# Outline of Presentation

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- **Background**
- **Review of battery-related information**
- **Applications for battery energy storage**
- **A process for re-applying used EV batteries**
- **Basis for economic analysis**
- **Results of economic analysis**
- **Demonstrations**
- **Acknowledgements**



# Background

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- **Objectives of this Phase I Study**
  - Evaluate feasibility of using “spent” EV/HEV batteries in stationary applications
  - Identify criteria and possible partners for a demonstration project
- **Objectives of future phases**
  - Additional laboratory testing
  - Field trial/demonstration
- **Ultimate goals**
  - Reduce net cost of batteries to EV owner
  - Make advanced batteries available for stationary applications



# Literature Review Findings

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- **There is an active market for used batteries**
  - A variety of battery chemistries
    - Lead acid to Lithium ion
  - Wide range of applications
    - Renewable energy systems to laptop computers
- **Battery testing & condition of batteries at EOL**
  - Little published data on behavior of batteries after EOL
  - Cycling could give data for predicting future life



# Literature Review Findings (cont.)

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- **ANL/USABC study (1996-1997)**
  - Ni-MH batteries from EV test program were evaluated for stationary applications
    - Accumulated over 500 DST cycles to 80% DOD, simulating EV use
  - Evaluated for stationary applications
    - Utility load management and uninterruptible power systems
  - Performance, after de-rating, was competitive with new lead acid batteries



# Applications for Used EV Batteries

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- **Looked at three size categories**
  - Utility/industrial (up to 50 MWh)
  - Commercial (25 kWh to 4 MWh)
  - Residential (3 to 4 kWh)
- **Determined energy storage requirements**
  - Load characteristics
    - Energy
    - Power
    - Duty cycle
- **Determined value of energy storage**
  - \$/kW/yr or \$/kWh/yr



# Candidate Applications

APPLICATION	POWER Peak/Average	ENERGY	DUTY CYCLE	VALUE, \$/kW/yr	
				High	Low
Transmission Support	100 MW	140 kWh	1/mo	\$50	\$100
Area Regulation and Spinning Reserve	∞20 MW/ ∞10 MW 20 MW/20 MW	∞2 MWh 7.5 MWh	1/15 min 1/mo	\$35	\$75
Load Leveling/Energy Arbitrage	15 MW	50 MWh	100-200/yr	\$50	\$150
Renewables Firming	5 MW/1 MW	10 MWh	10-20/mo	\$50	\$75
Power Reliability and Peak Shaving	2 MW/1 MW	3-4 MWh	6/year 1/day	\$120	\$250
Light Commercial Load Following	200 kW/25 kW	75-100 kWh	1/day	\$120	\$240
Residential Load Following	10 kW/1 kW	3-4 kWh	1/day	\$60	\$120
Distributed Node Telecom	5 kW	25-50 kWh	2/yr	\$31	\$52



# Barriers to Second Use

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- **Non-standardized EV battery modules**  
*and*
- **Non-standard history of used EV batteries**
  - Limits availability of matched modules for assembly of large batteries
- **Chain of custody & warranty issues**
  - How does the “buy down” benefit the EV buyer?
  - Who provides warranty and on what?
- **Perceived value of used vs. new battery**





# Economic Analysis

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- **Compare life-cycle cost of the energy storage system in the stationary application with its value.**
- **Life-cycle cost of the energy storage system**
  - Cost of batteries (including replacements required over system lifetime)
    - Cost of used EV batteries
    - Testing
    - Refurbishing
  - Balance of system cost
    - Power conversion system
    - Battery accessories (racking, interconnects, etc.)
  - Operating and maintenance costs



# Assumptions in Economic Analysis

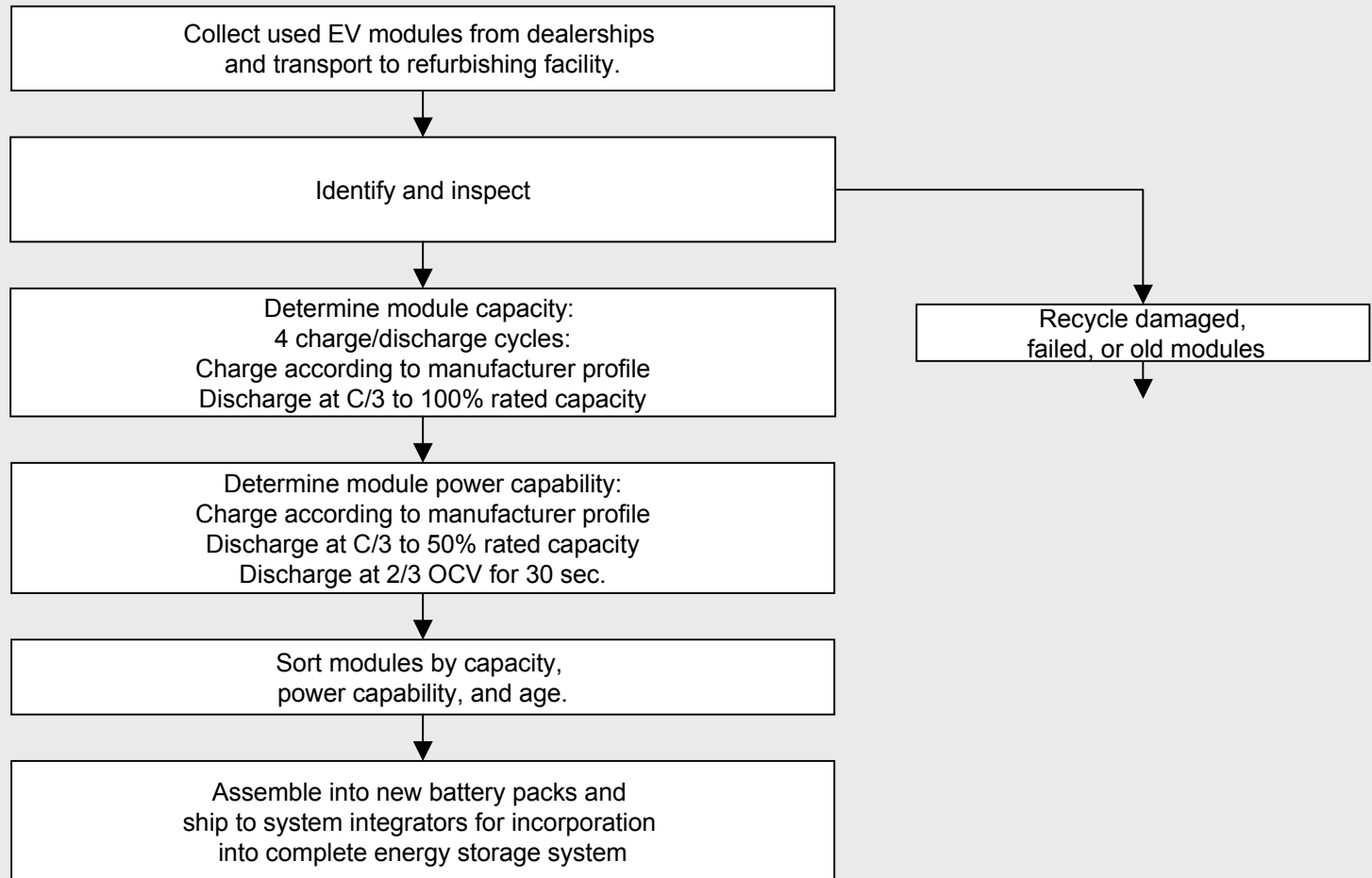
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- **Availability of used EV batteries**
  - Significant sales of full-function ZEVs (battery EVs) in California
    - CARB mandate: 10,000 ZEVs in 2006
  - 250,000 – 300,000 battery modules/year by ~2010
- **Production costs vs. goals**
  - Battery cost estimates from \$225/kWh to \$300/kWh
    - NiMH and Li-ion technologies
  - USABC cost goals are \$150/kWh
  - Buy-down of up to \$150/kWh needed

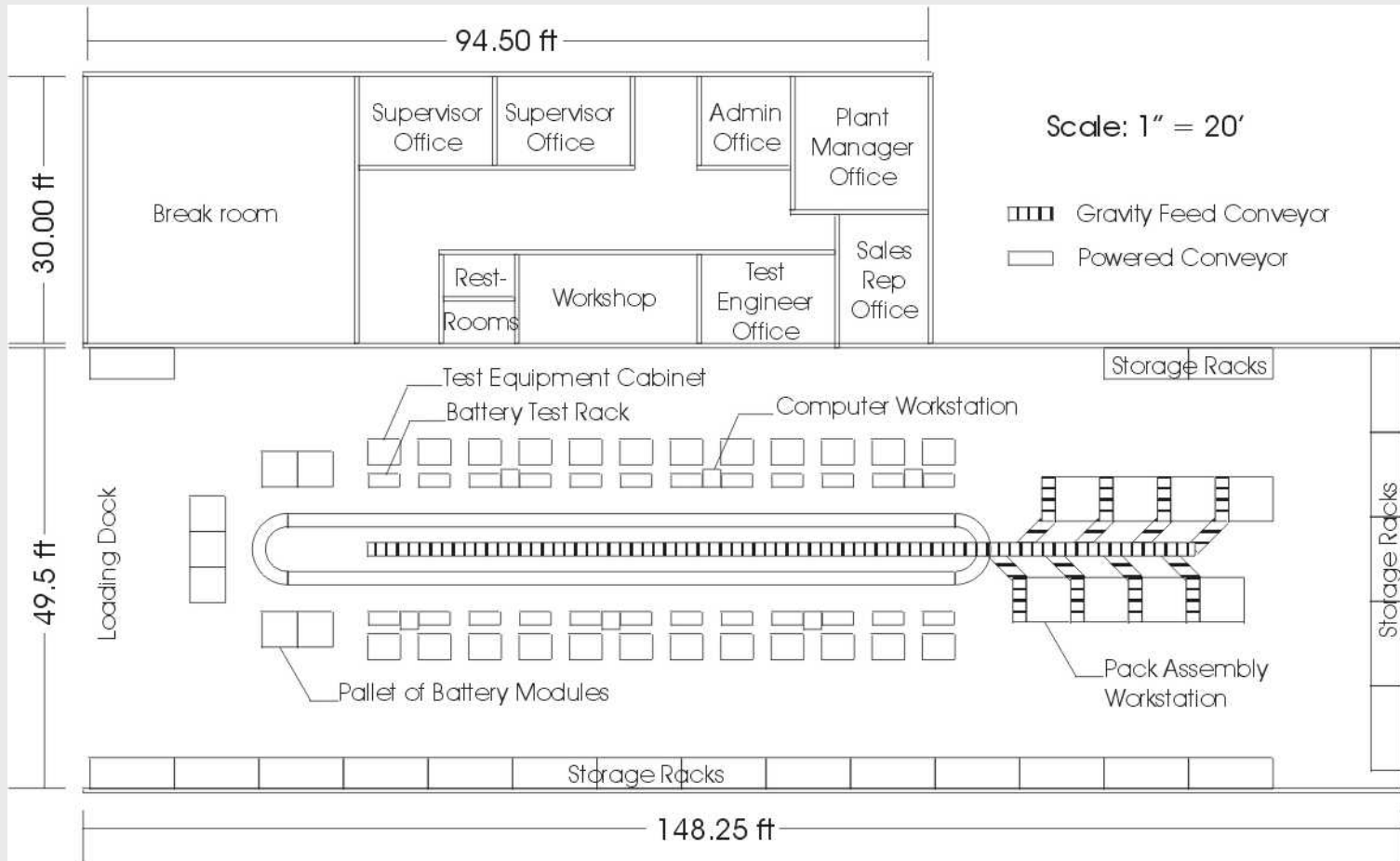


# A Process for Applying Used EV batteries

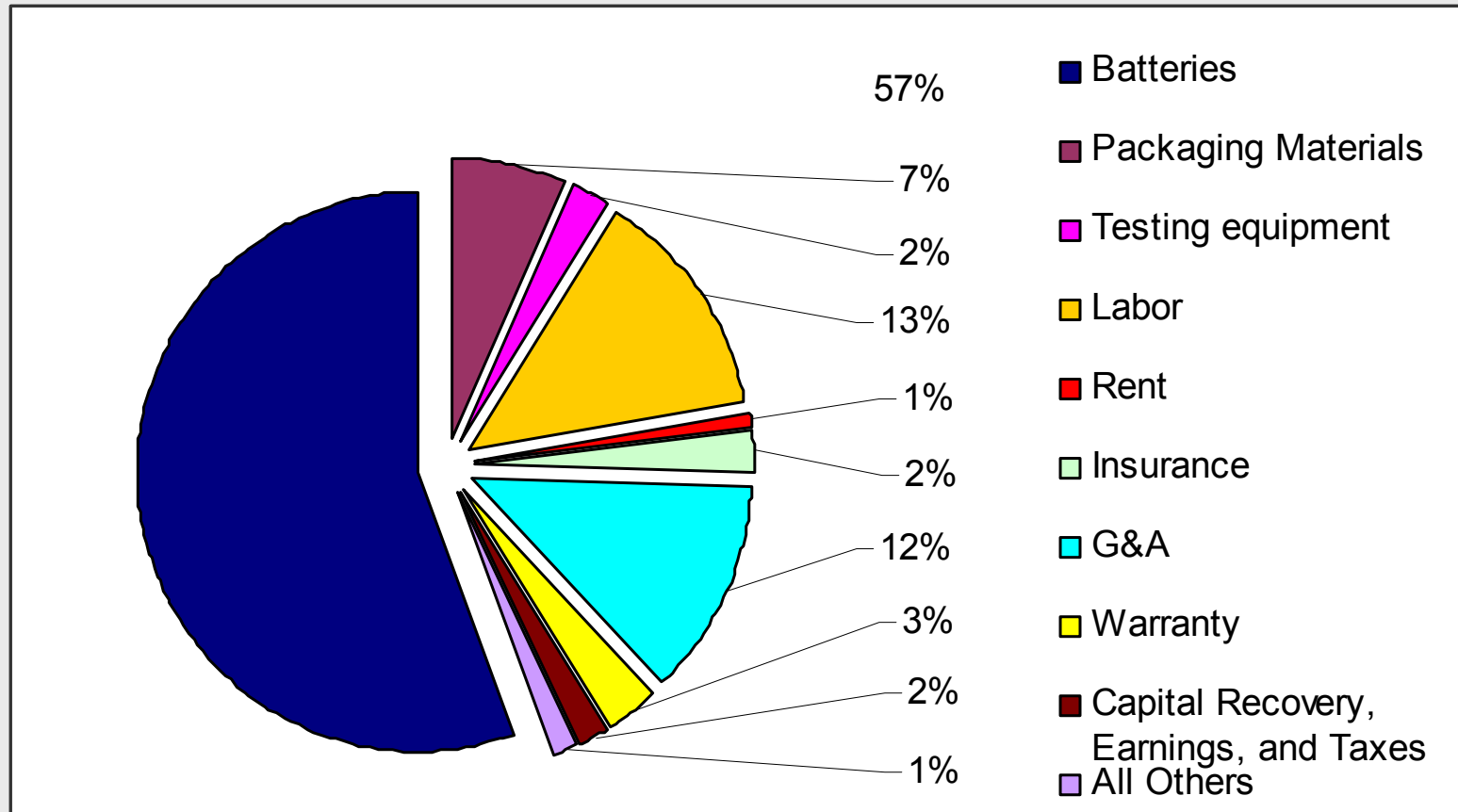
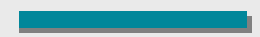
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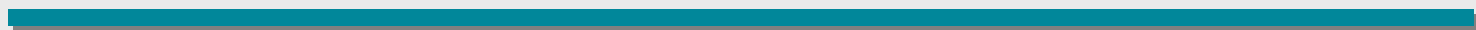
# A Facility for Refurbishing Used EV batteries



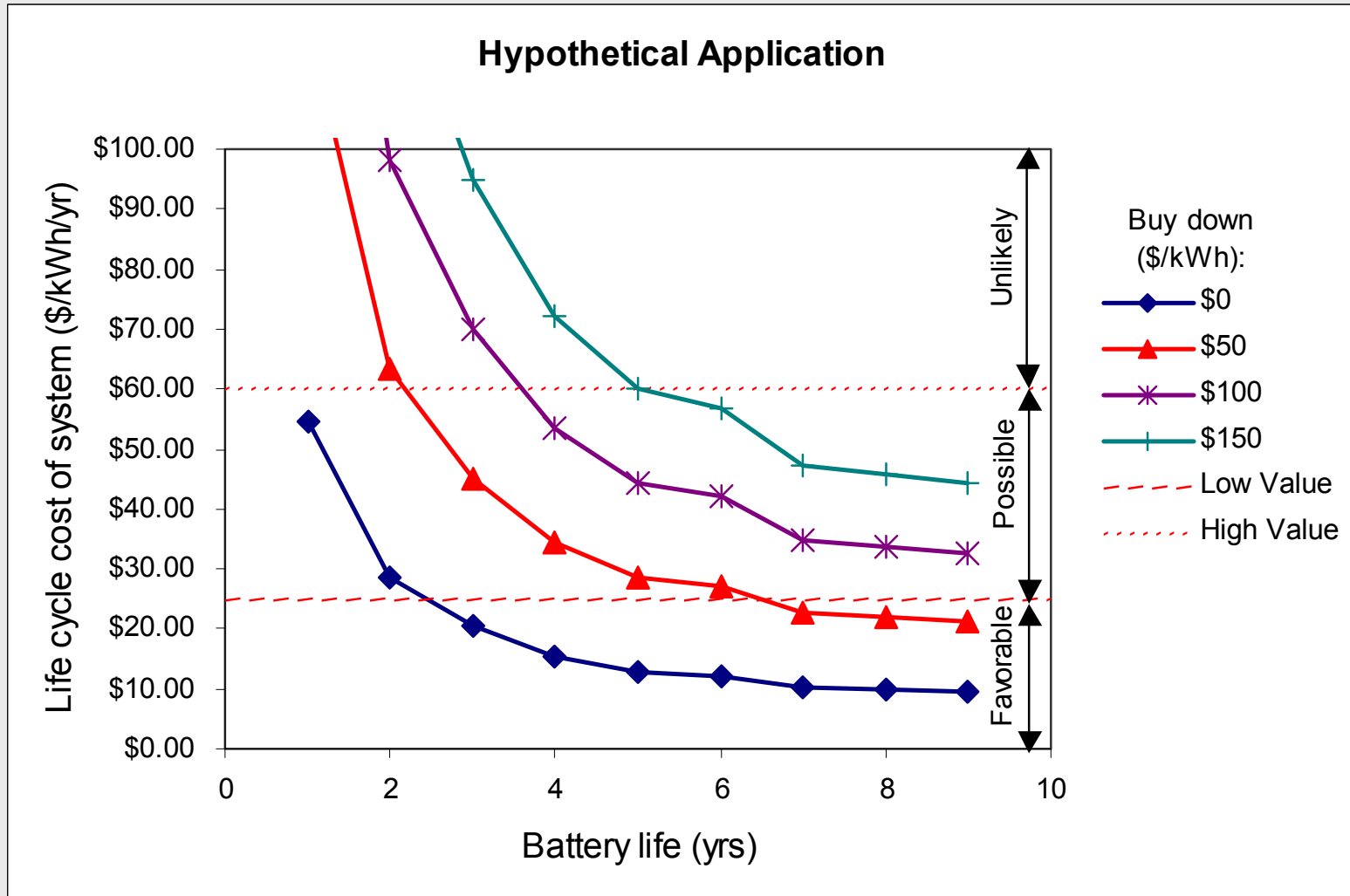
# Cost of Reconfigured Batteries



**Total cost, assuming buy-down of \$75/kWh = \$147/kWh**

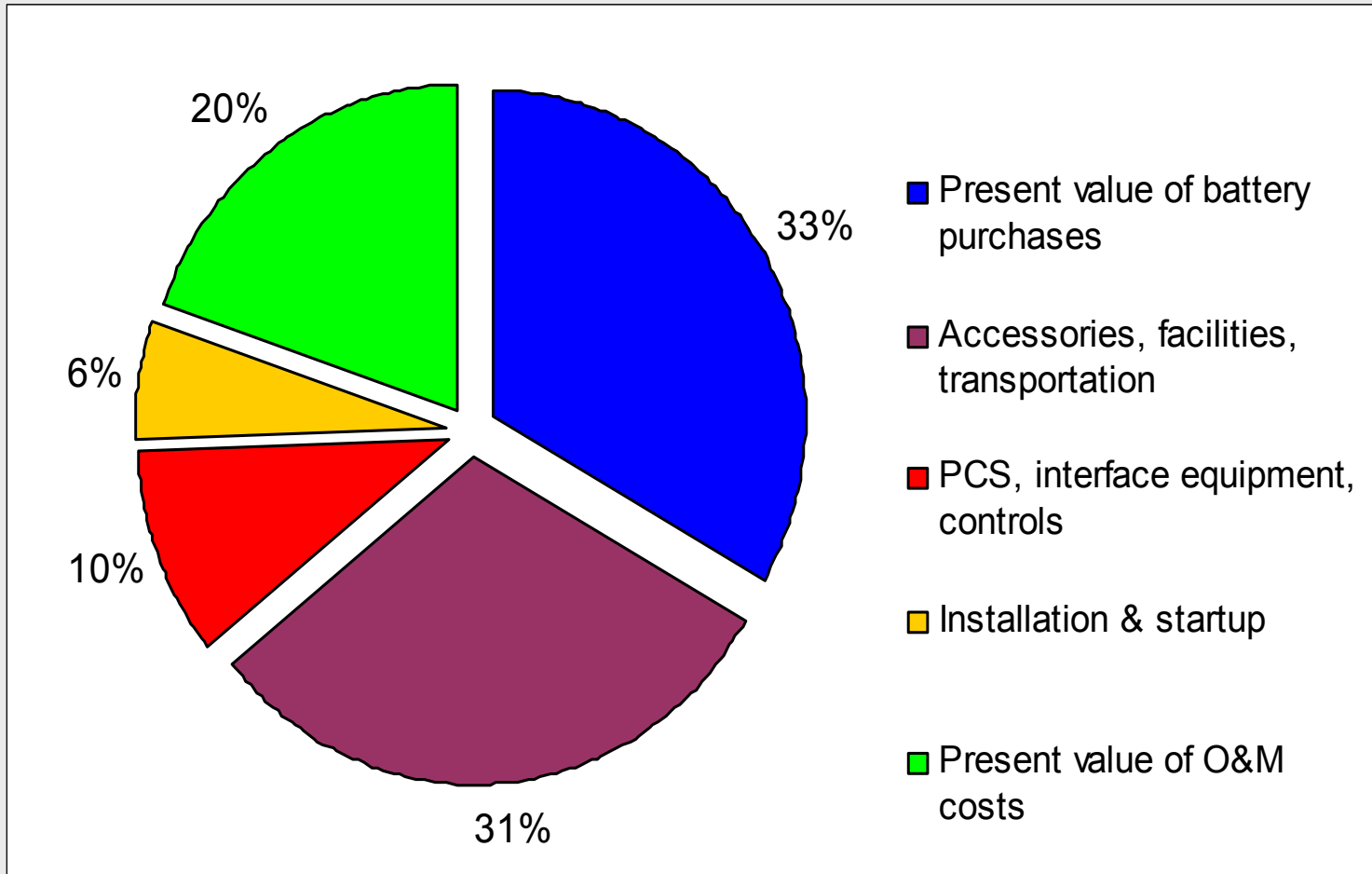


# Sample Life Cycle Cost Analysis



# Sample of System Cost Drivers

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# Summary of Economic Analysis

APPLICATION	BUY-DOWN, \$/kWh			
	0	50	100	150
Transmission Support	●	●	●	●
Area Regulation & Spinning Reserve	●	●	●	●
Load Leveling/Energy Arbitrage	●	●	●	●
Renewables Firming	●	●	●	●
Power Reliability	●	●	●	●
Light Commercial Load Following	●	●	●	●
Distributed Node Telecom	●	●	●	●
Residential Load Following	●	●	●	●

● Favorable

● Possible

● Unlikely





# A Look at Other Battery Chemistries

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## Analyses based largely on NiMH.

- **Lead Acid**

- Unlikely candidates for 2<sup>nd</sup> use
  - Used/refurbished batteries may cost more than new batteries

- **Nickel Cadmium**

- Environmental concerns limit EV use

- **Lithium Ion/Lithium Polymer**

- Batteries in development
- Have not yet met EV cycle/calendar life goals



# A Look at Other Battery Chemistries —

- **Economic feasibility largely independent of battery chemistry**
  - Refurbishing costs largely independent of battery type
    - Impact of electronics associated with Li systems unknown
  - Transportation, installation, BOS independent of battery type
  - Life cycle cost of the various applications only significantly affected when battery life is very short
    - a year or less



# Recommended Demonstrations

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- **Transmission support**
  - One system
  - 600 EV modules
    - 650 kWh, 3.2MW
  - \$4,000,000
- **Light commercial load following**
  - Five systems
  - 100 EV battery modules/system
    - 110 kWh, 200 kW
  - \$485,000/system



# Recommended Demonstrations

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- **Distributed node telecom**
  - Two phases
    - 1 system in Phase 1, 9 systems in Phase 2
  - 43 EV modules/system
    - 52 kWh, 5 kW
  - \$37,000/system
- **Residential load following**
  - Ten systems
  - Five EV battery modules/system
    - 5 kWh, 10 kW
  - \$83,000/system



# Acknowledgements

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  - Phil Symons, EECl
  - Irwin Weinstock

