Second Use of Electric Vehicle Batteries in Stationary Applications

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Outline of Presentation

- 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

- **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

- **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.)

- **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

- **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

- **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**

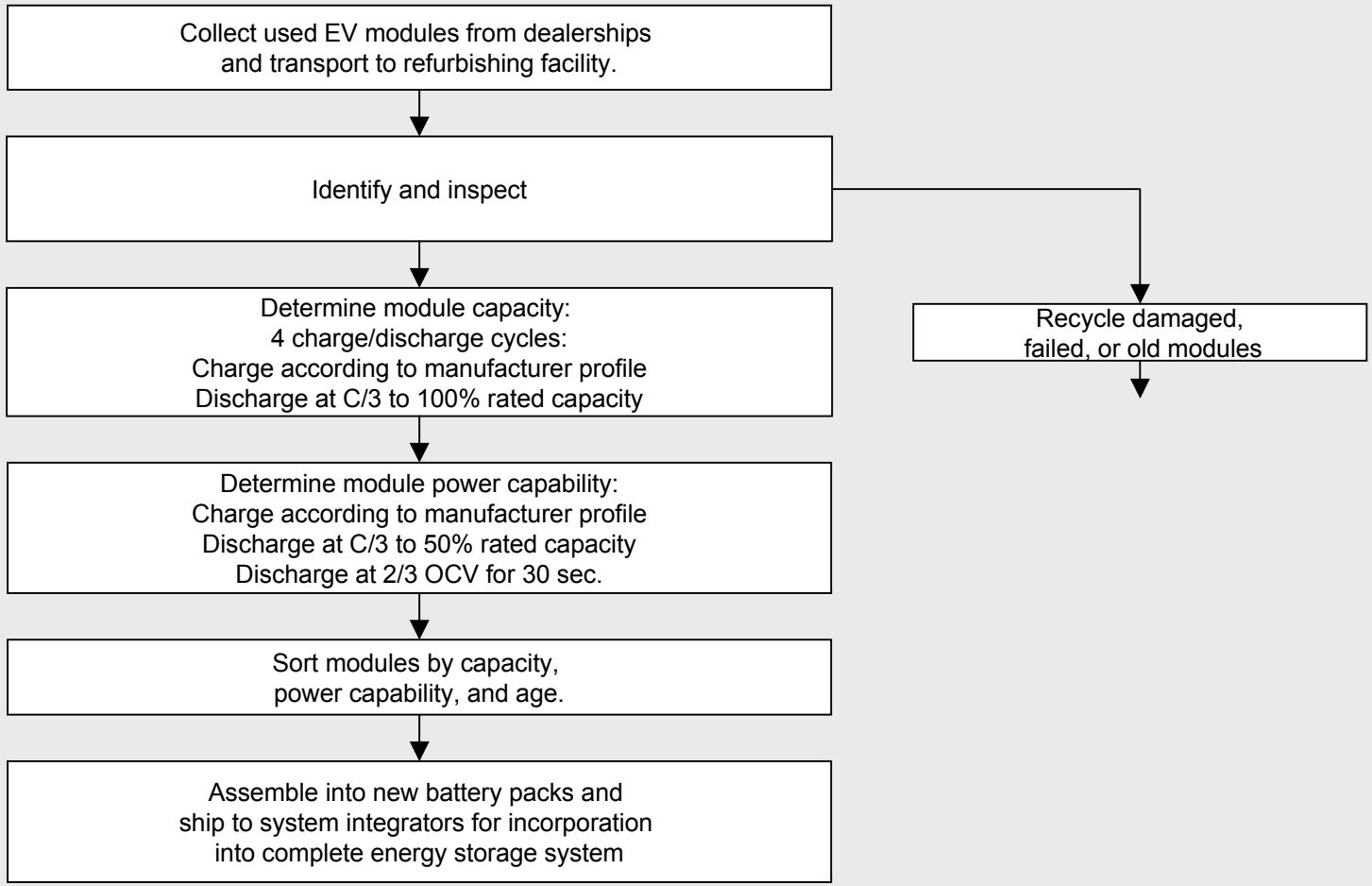
Economic Analysis

- **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

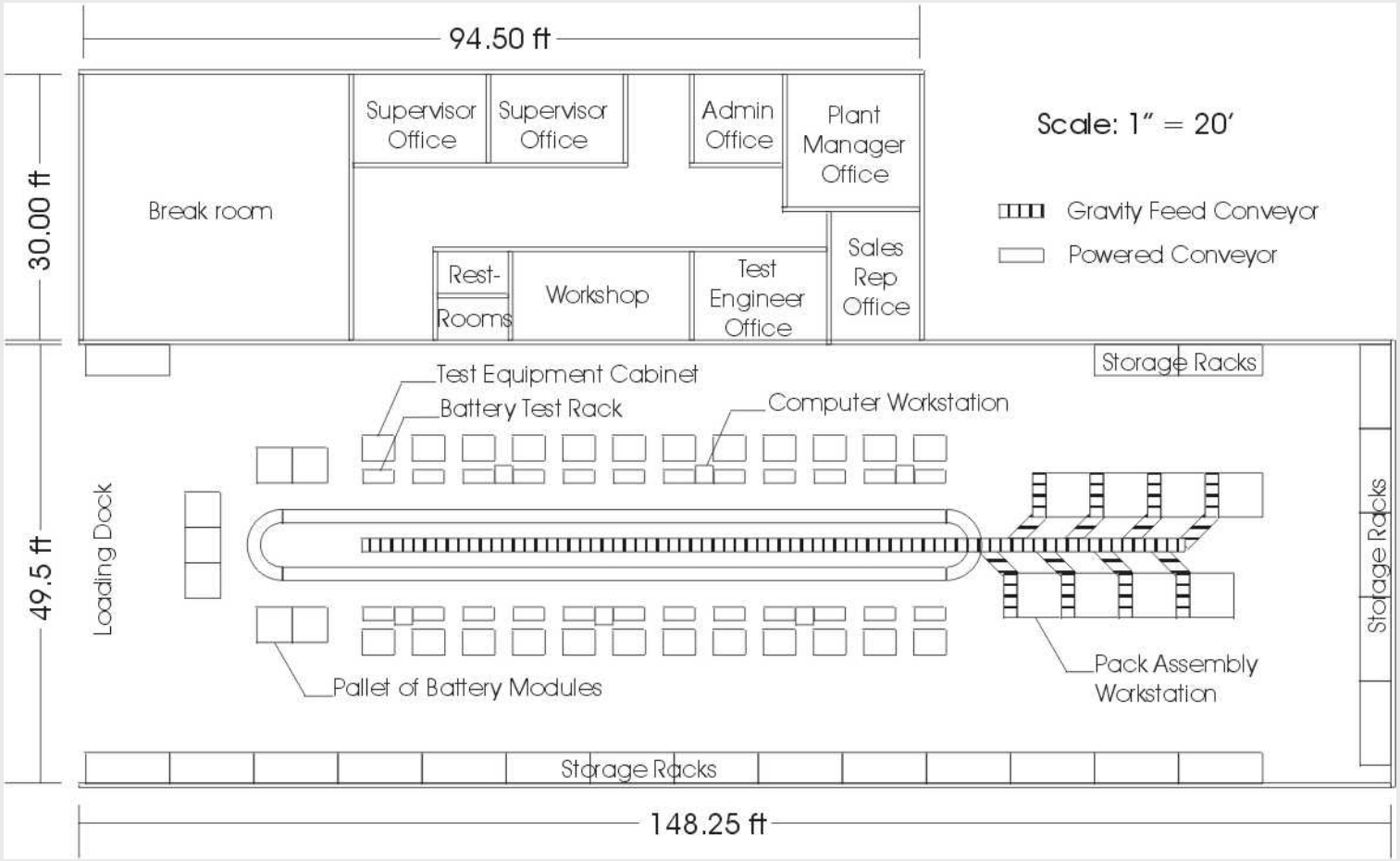
Assumptions in Economic Analysis

- **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

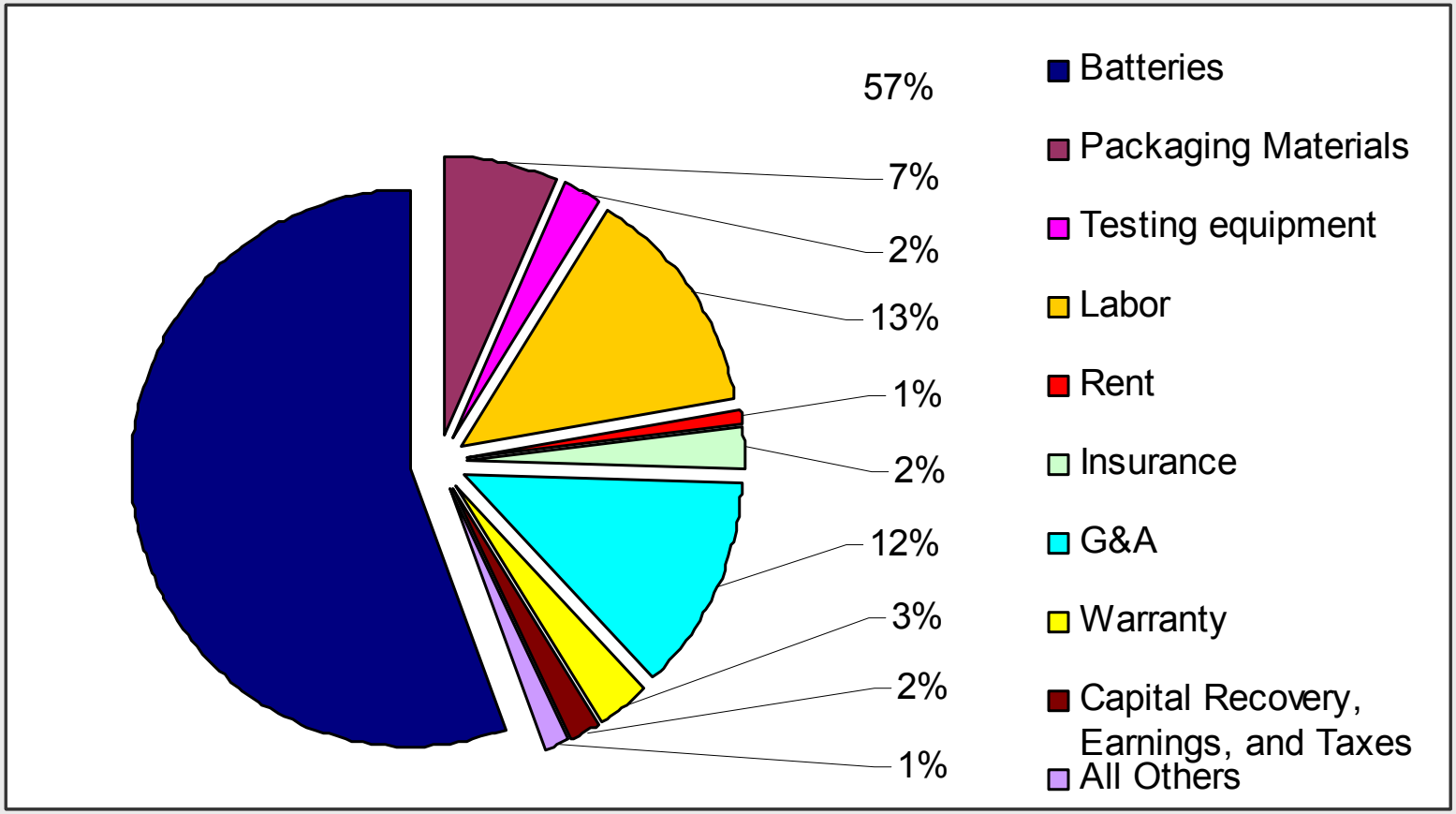
A Process for Applying Used EV batteries



A Facility for Refurbishing Used EV batteries

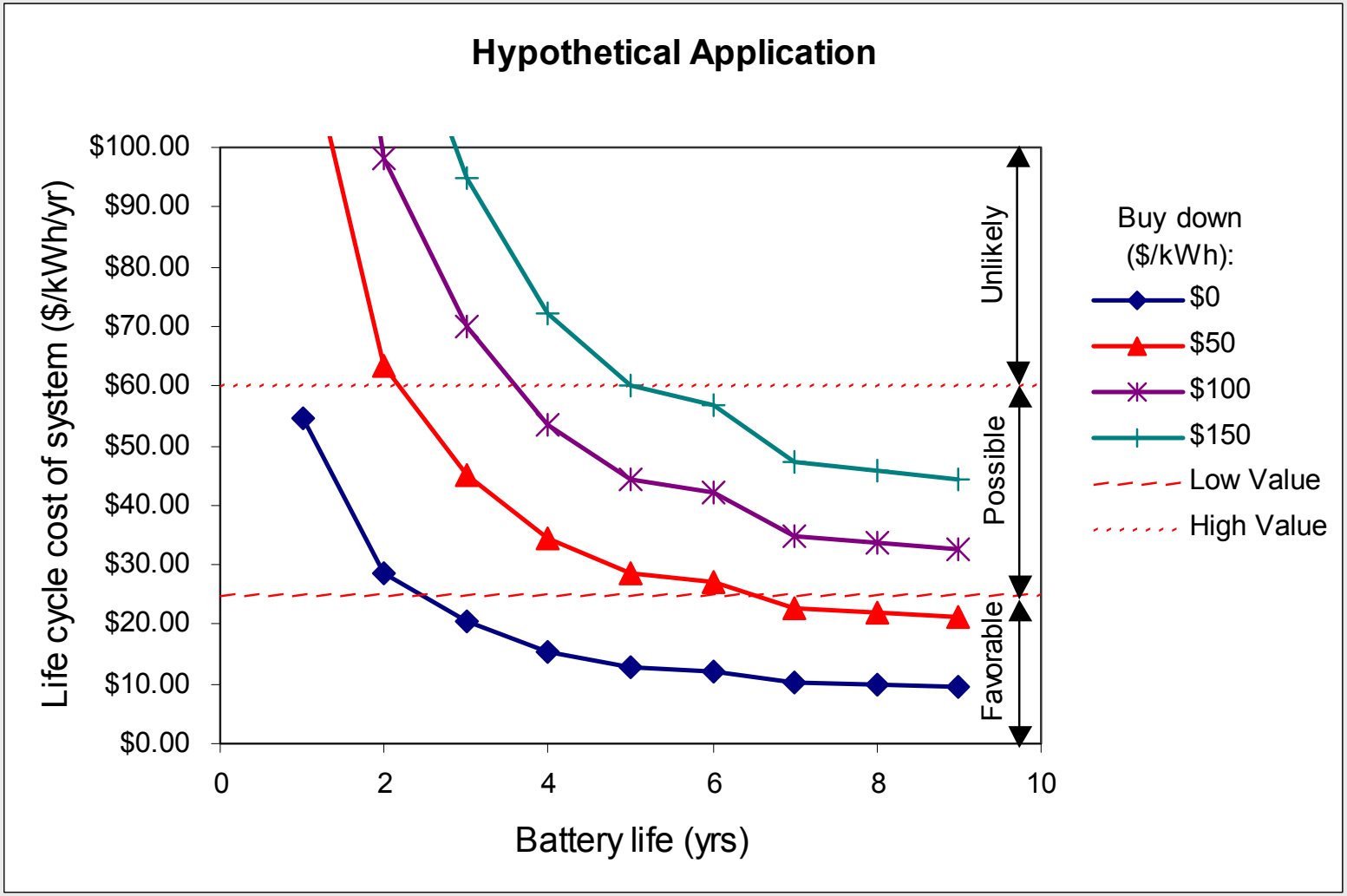


Cost of Reconfigured Batteries

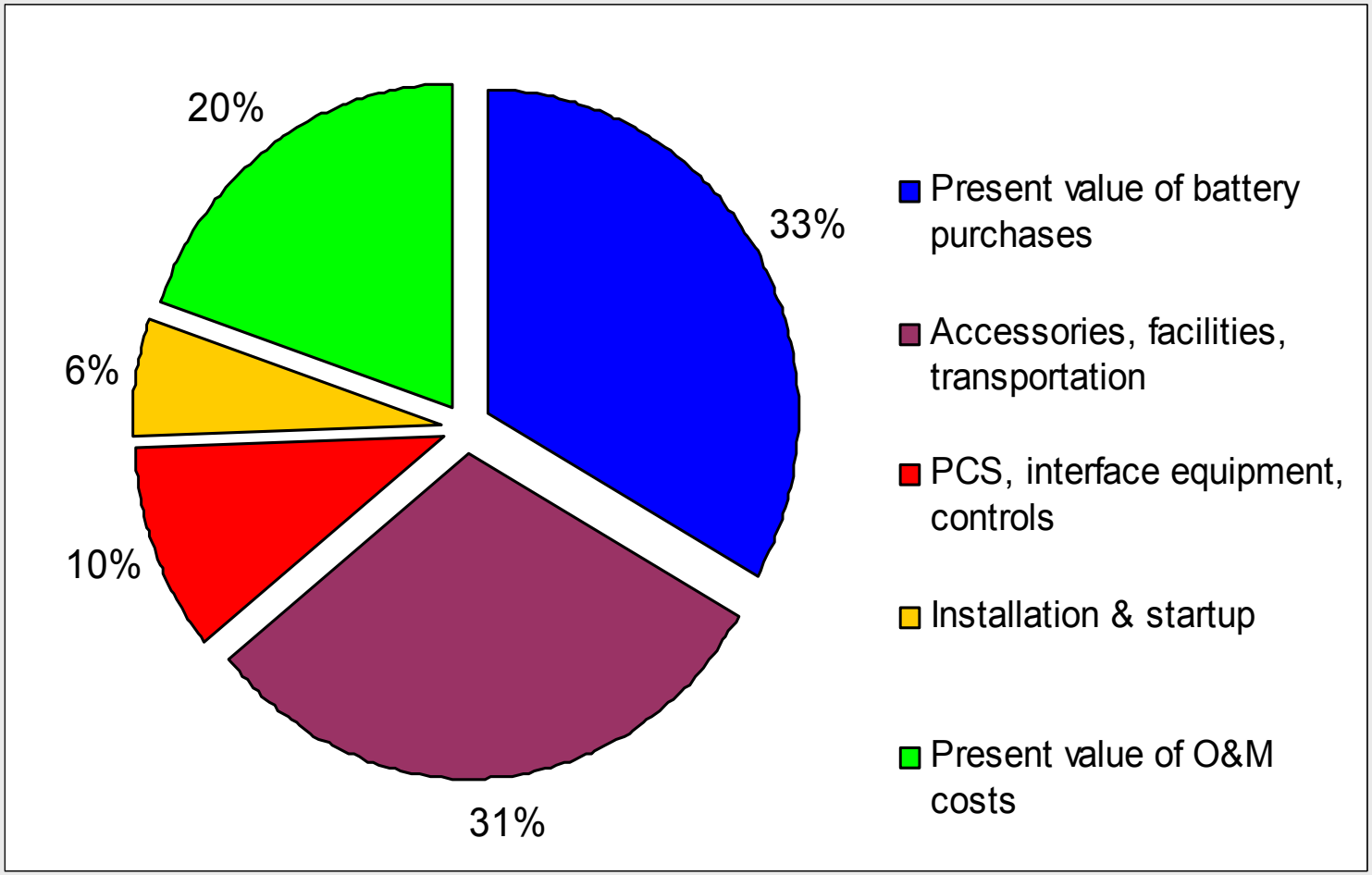


Total cost, assuming buy-down of $75/kWh = $147/kWh

Sample Life Cycle Cost Analysis



Sample of System Cost Drivers



Summary of Economic Analysis

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

Favorable Possible Unlikely

A Look at Other Battery Chemistries

Analyses based largely on NiMH.

- **Lead Acid**
  - Unlikely candidates for 2nd 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

- **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

- **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

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