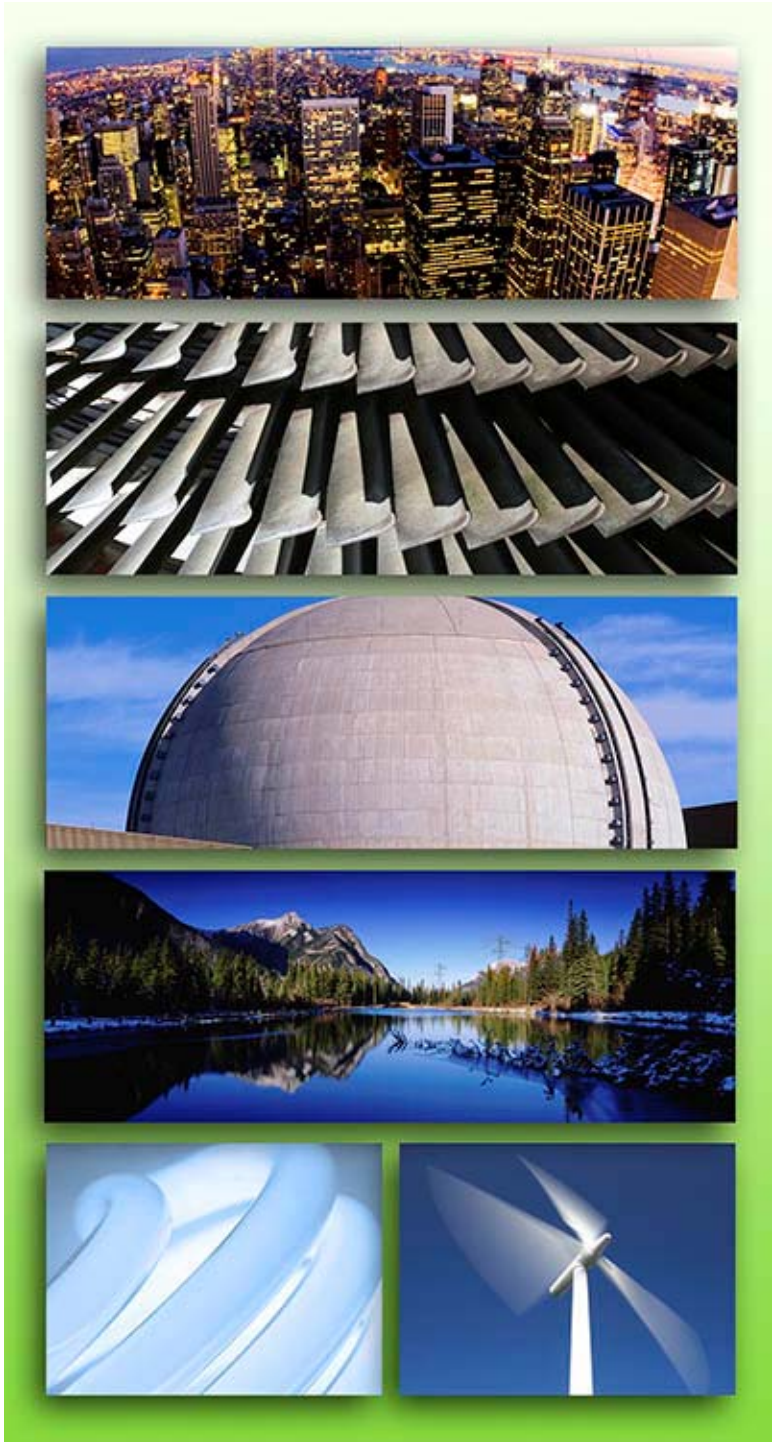


EPRI | ELECTRIC POWER RESEARCH INSTITUTE

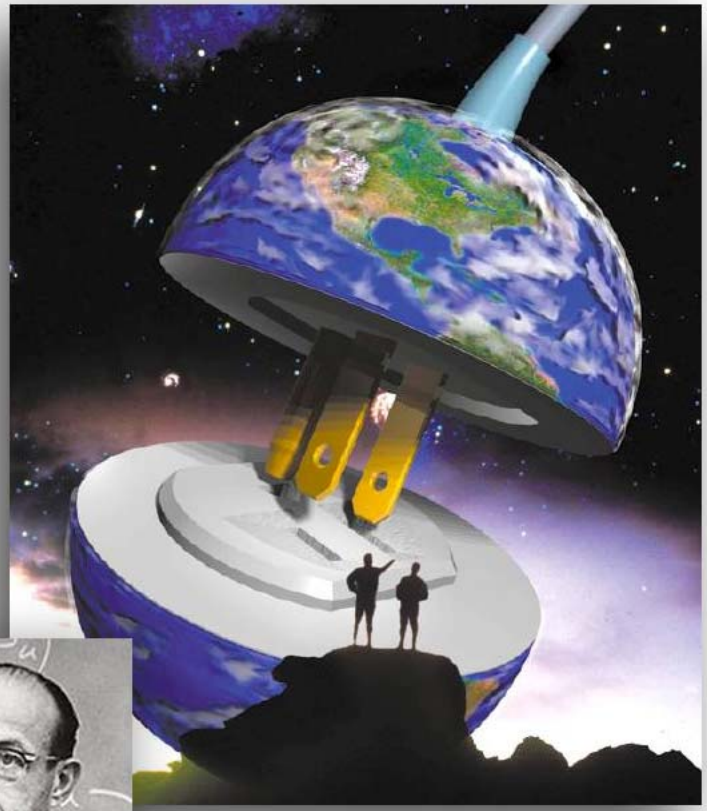
# Lithium Ion Batteries for Electric Transportation: Costs and Markets

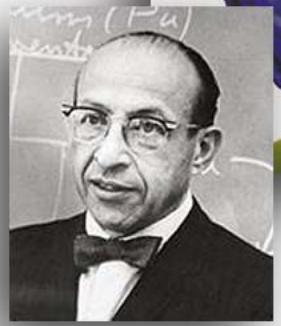
**Haresh Kamath**

September 22nd, 2009

# Our History…

- Founded by and for the electricity industry in 1973
- Independent, nonprofit center for public interest energy and environmental research
- **Collaborative** resource for the electricity sector
- Major offices in Palo Alto, CA; Charlotte, NC; Knoxville, TN
  - Laboratories in Knoxville, Charlotte and Lenox, MA





**Chauncey Starr**
EPRI Founder





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# Our Members…

- 450+ participants in more than 40 countries
- EPRI members generate more than 90% of the electricity in the United States
- International participation in more than 15% of EPRI's research, development and demonstrations
- Programs funded by more than 1,000 energy organizations





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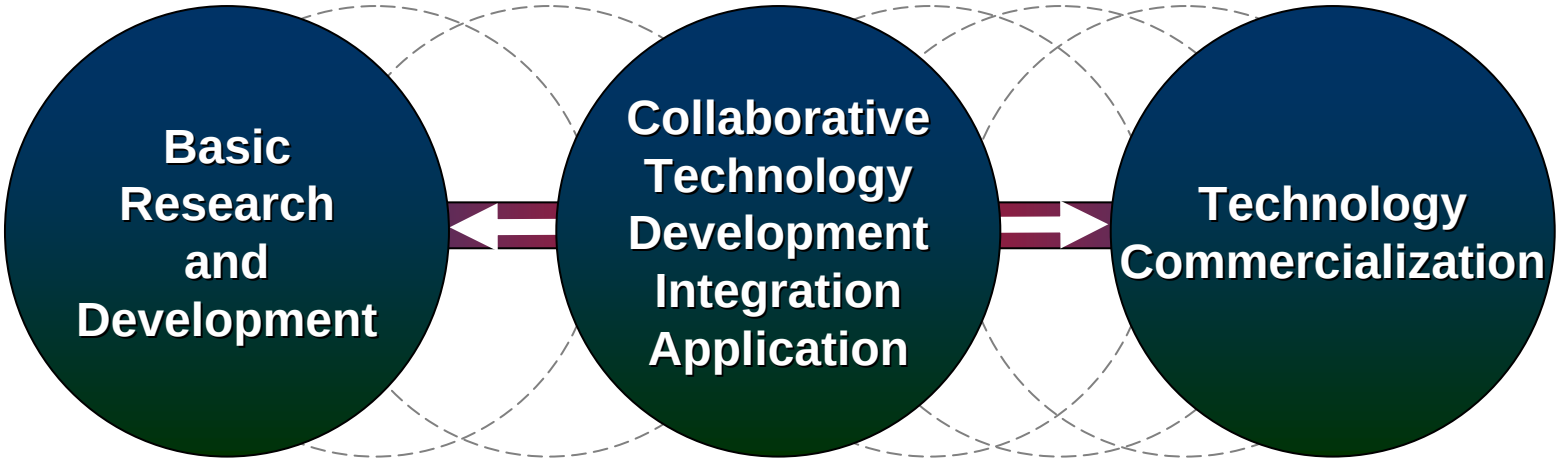
# Our Role…

## *Help Move Technologies to the Commercialization Stage…*




**National Laboratories**

**Universities**

**EPRI**

**Suppliers**

**Vendors**

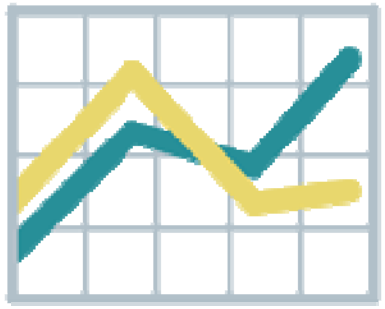
## *Technology Accelerator!*

# Electric Energy Storage:  Background

- Electric Energy Storage:  A critical technology
  - Portable electronics
  - Electric transportation
  - Stationary power
- Lithium Ion batteries – a very promising solution
  - High specific energy and energy density
  - High efficiency
  - Long life
  - Potentially low cost

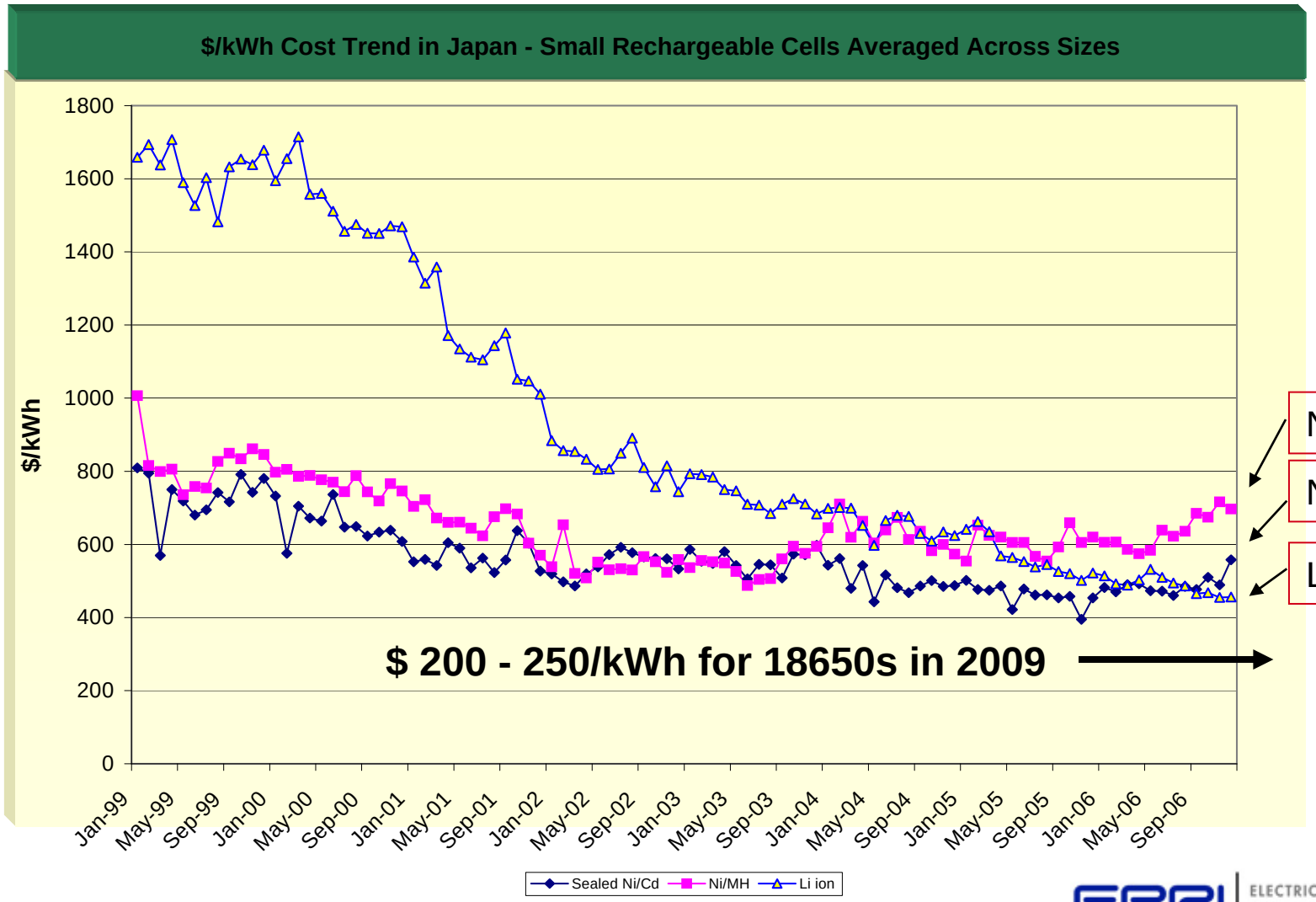
# Lithium Ion: Costs and Markets

- Cost of Lithium Ion Batteries
  - Understanding cost drivers
  - Projecting costs with volume



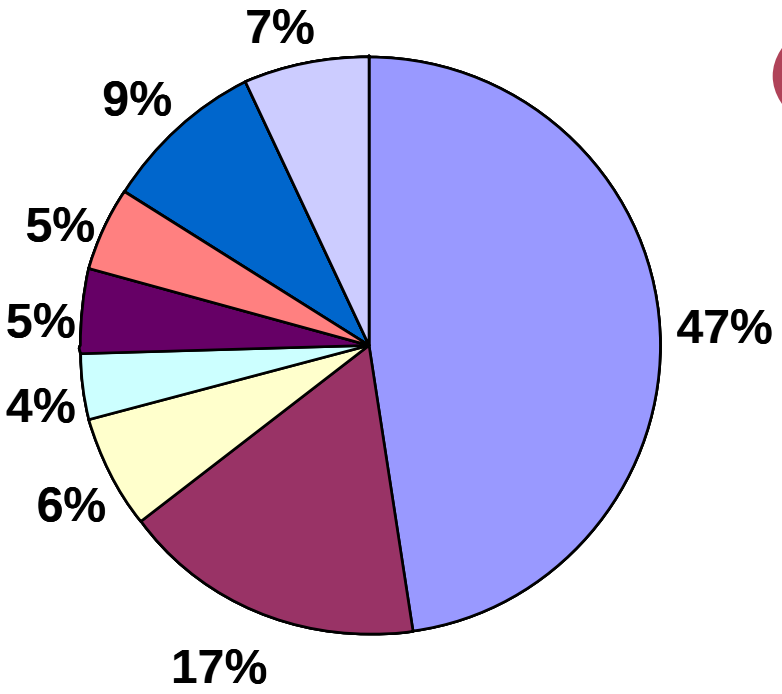
- Markets for Lithium Ion Batteries
  - How will we achieve volume?
  - Total applications

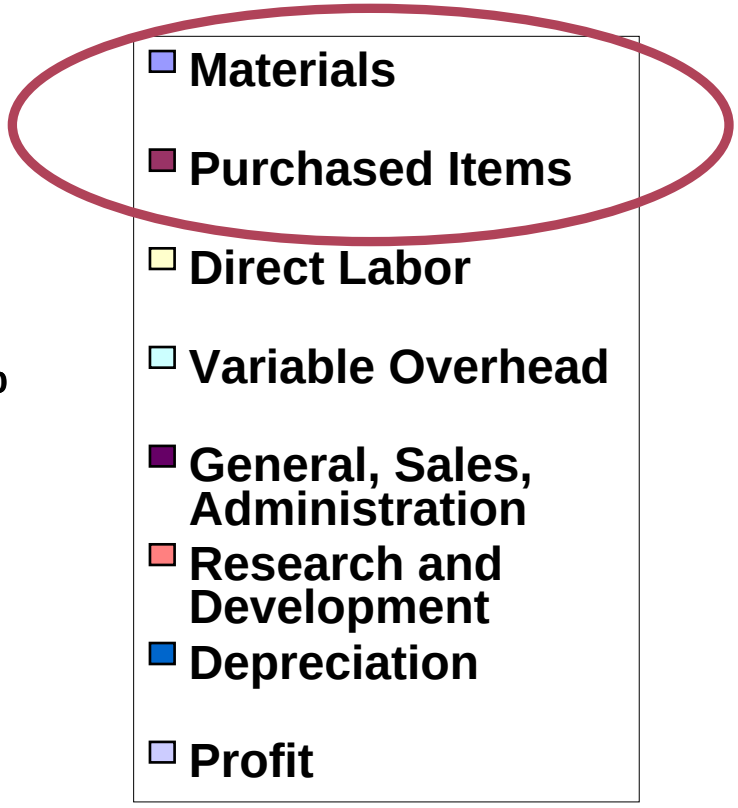
# Lithium Ion Battery Cost




Source: Created by TIAX based on METI data

# Investigations into Battery Cost Drivers

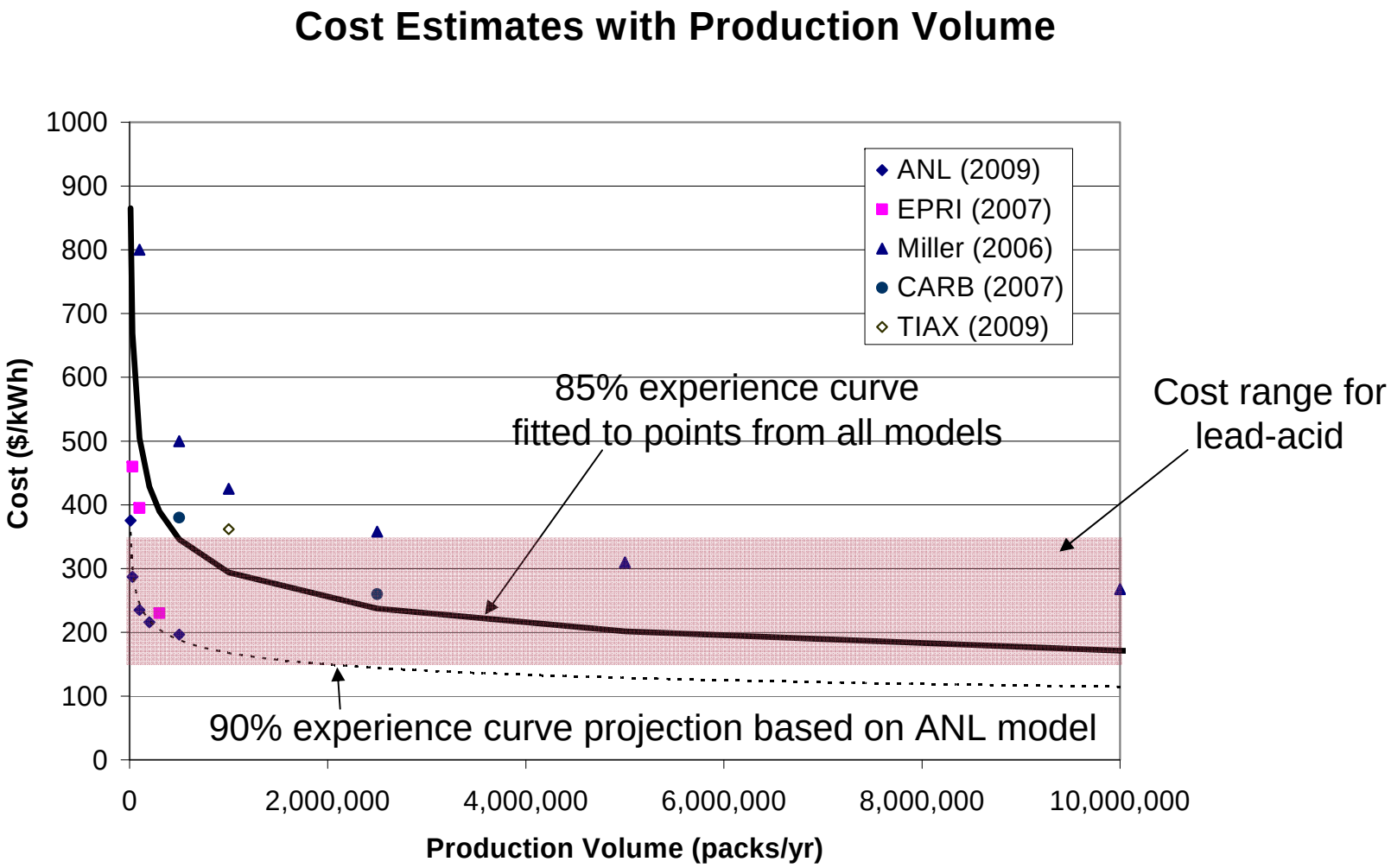



From: Nelson (ANL), 2009

**Sanity check: About 60% of 18650 cost comes from material costs and purchased items (Source: TIAX)**

# Where will battery costs go?



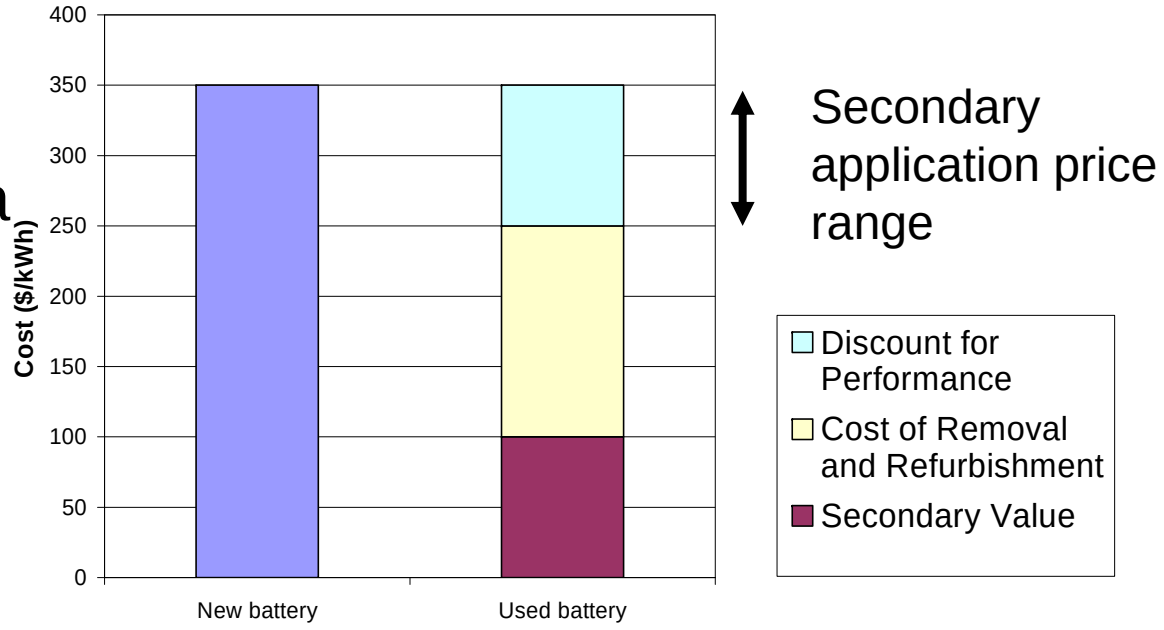
# Cost modeling: Next steps

- The ANL cost model requires verification
  - Close examination of material cost assumptions
    - Effects of volume production (positive and negative)
  - Examination of process cost assumptions
  - True costs at intermediate volumes
    - Critical for stationary applications
- Engage the vendor community
  - Keep expectations realistic
  - Focus vendors on *real* value

# PHEV Batteries in Secondary Use

Many questions about secondary use:

- What performance can we expect from a secondary use battery?
- What cost discount will there be?
- What will the cost be for refurbishment?



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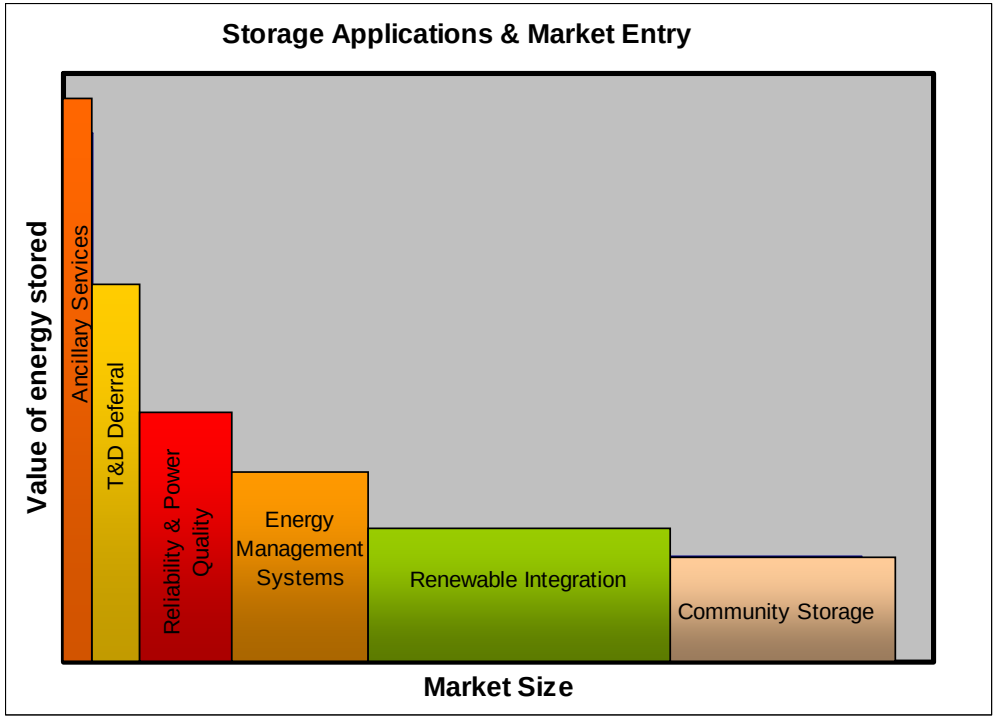
# Battery markets

- EPRI is now working to develop an understanding of the *total market* for automotive lithium ion batteries
  - Penetration into existing markets
  - Cost points at which new markets appear
  - Depth of new markets (i.e. market size)



# Understanding Stationary Applications

- Stationary storage applications come in many sizes:

Residential
(2 - 5 kW, 2 – 4 hours)


Community Energy Storage
(25 – 50 kW, 4 hours)

Commercial and Industrial
(100 kW to 1 MW, 2 – 4 hours)

Grid Support
(>1 MW, 4 – 5 hours)

# Battery Markets (Preliminary figures)

| Application | Estimated Market Size for Services (2012) | Estimated Total Market Size for Storage (MWh) | Suitability as Alternative Application: Technical Viability[1] | Suitability as Alternative Application: Cost Appropriateness[2] | Suitability as Alternative Application: Market Receptiveness[3] | Estimated Entrance Cost Point[4] ($/kWh) | Entrance MWh sales | Target Cost[5] ($/kWh) | Target MWh sales |
|---|---|---|---|---|---|---|---|---|---|
| **Existing Industrial Applications** | | | | | | | | | |
| Industrial truck | $ 935 M | 3,115 | Excellent | Good | Good | $600/kWh | 312 | $300/kWh | 1,558 |
| Telecom batteries | $ 463 M | 1,158 | Fair | Good | Fair | $600/kWh | 58 | $400/kWh | 116 |
| UPS/power quality batteries | $ 306 M | 766 | Fair | Good | Fair | $600/kWh | 38 | $400/kWh | 153 |
| **Utility Applications** | | | | | | | | | |
| Utility-owned residential load management | $ 9600 M | 64,000 | Fair | Fair | Fair | $150/kWh | 640 | $50/kWh | 12,800 |
| Utility-scale peak shaving | $ 5760 M | 4,267 | Fair | Fair | Good | $1,000/kWh | 427 | $450/kWh | 1,707 |
| Utility Regulation Services | $ 3000 M | 4,000 | Fair to Good | Good | Good | $450/kWh | 400 | $250/kWh | 1,600 |
| Utility-scale power quality | $ 1000 M | 741 | Good | Good | Good | $2,000/kWh | 74 | $450/kWh | 370 |
| Wind Integration (Leveling and Ramping) | $ 10000 M | 33,333 | Poor | Poor | Fair | $600/kWh | 333 | $100/kWh | 3,333 |
| Spinning reserve | $ 1000 M | 6,667 | Good | Fair | Fair | $100/kWh | 667 | $50/kWh | 2,667 |

1) Technical viability: How close is this application in technical specifications and operation to the PHEV application? How well can cells and/or batteries designed for a PHEV application be expected to operate in this application?

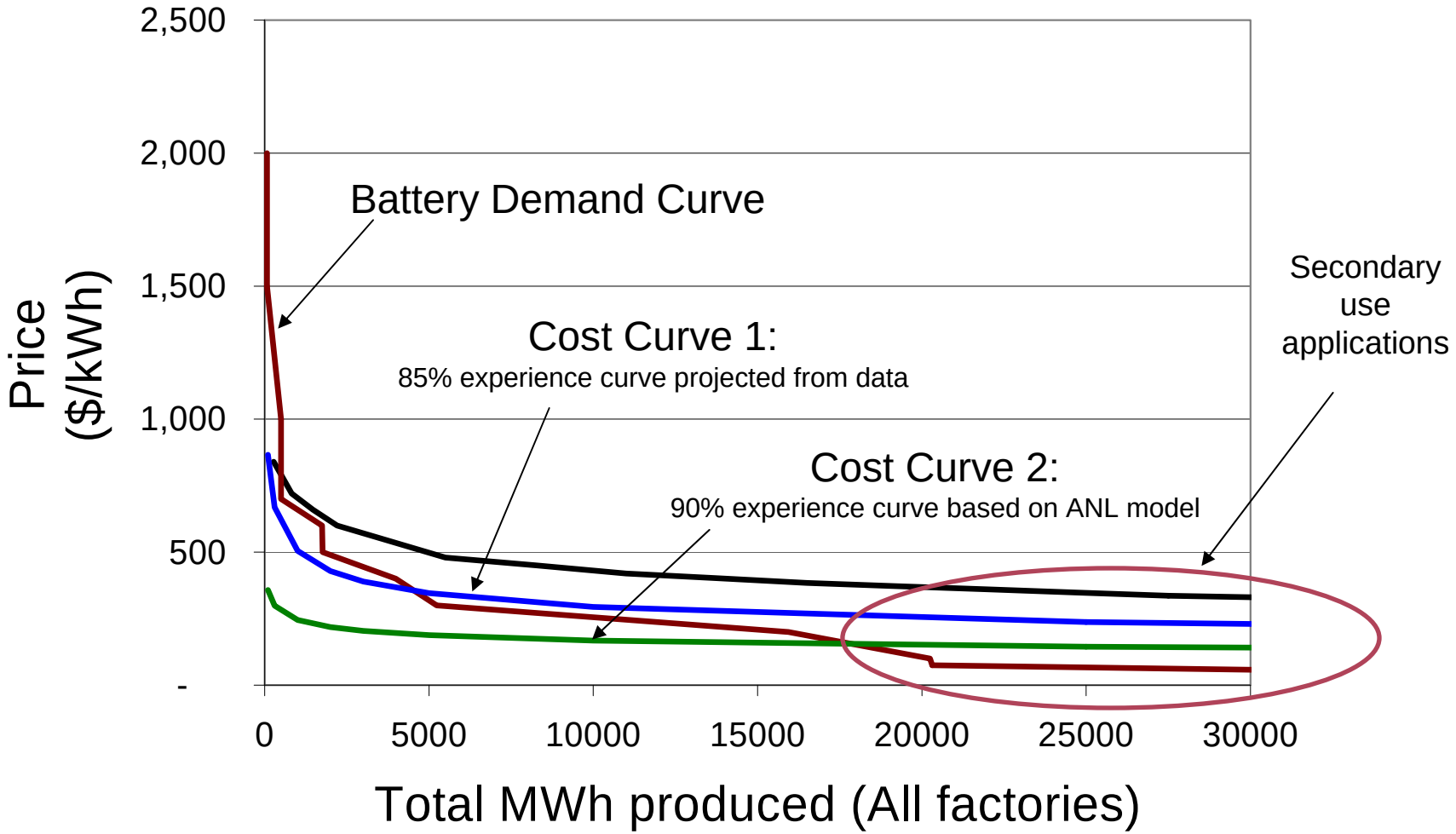
2) Cost sensitivity: How sensitive is this application to cost, and how likely is it that lithium ion will meet the cost point that satisfies the major clients in this market?

3) Market Obstacles: How conservative is the market, and how likely is it that lithium ion will achieve substantial penetration in this market?

4) Entrance cost point is the maximum cost *(for energy storage alone)* at which an alternative technology will first be considered on the basis of non-economic qualifiers

5) Target cost is the energy storage cost required for significant penetration (40%) in the near term

# Battery Market Demand with Cost



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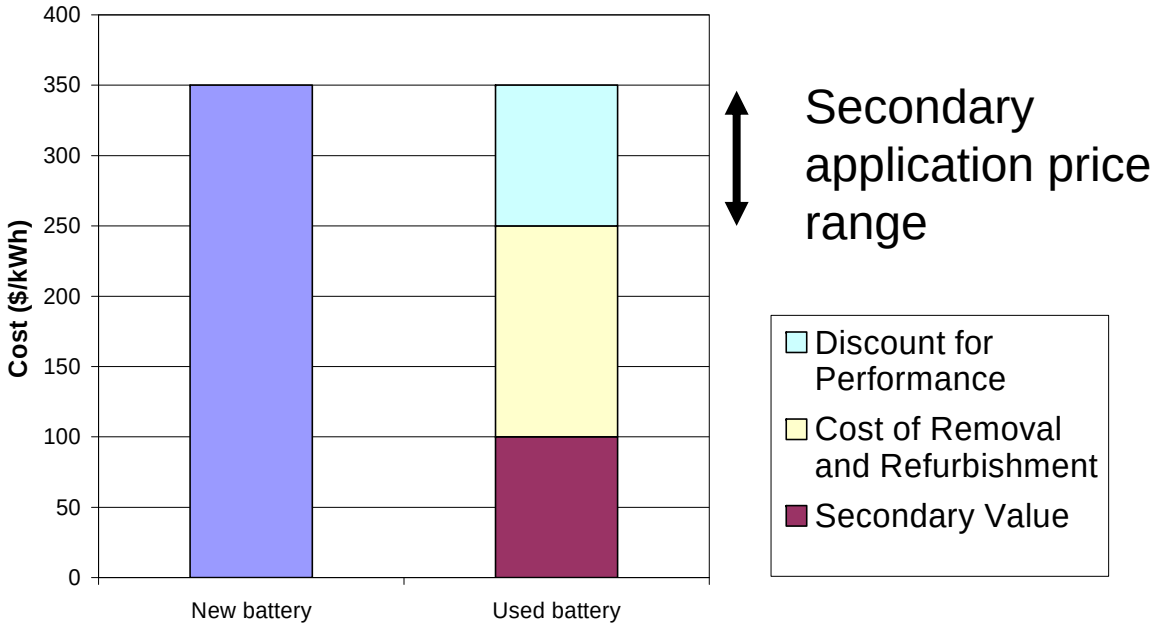

# Li Ion vs. Lead Acid and other technologies

- Will lithium ion batteries dominate the stationary market?
  - Most important factor in applications is cost
  - If lithium ion batteries are the most cost-effective solution, they will dominate *even if other technologies are better suited to the application*
- The real competition:  Lead-acid
  - Lead acid costs:  $250 – 350 / kWh in most stationary applications
  - Cost premium for lithium ion might be justified by longer life, less O&M costs, smaller footprint, ease of replacement

# Together...Shaping the Future of Electricity

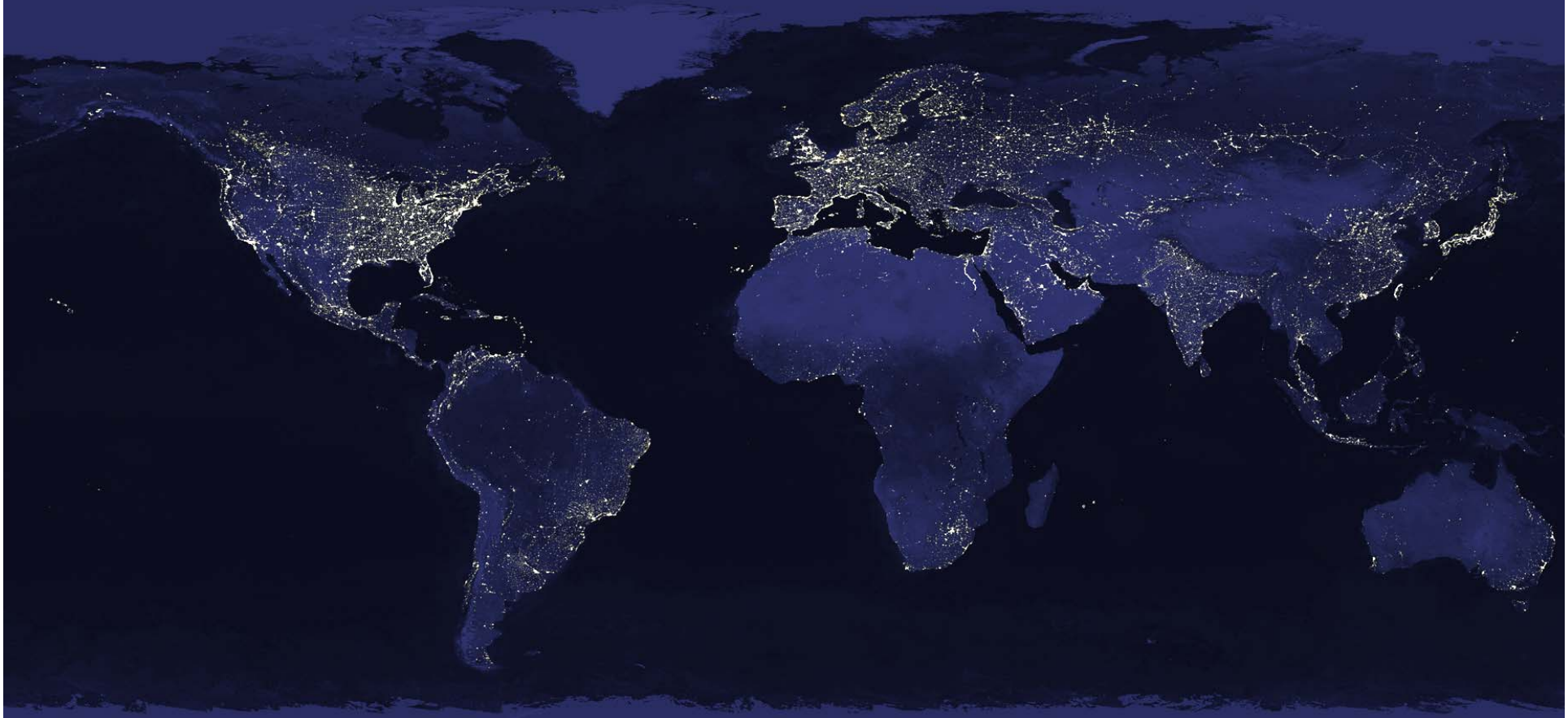

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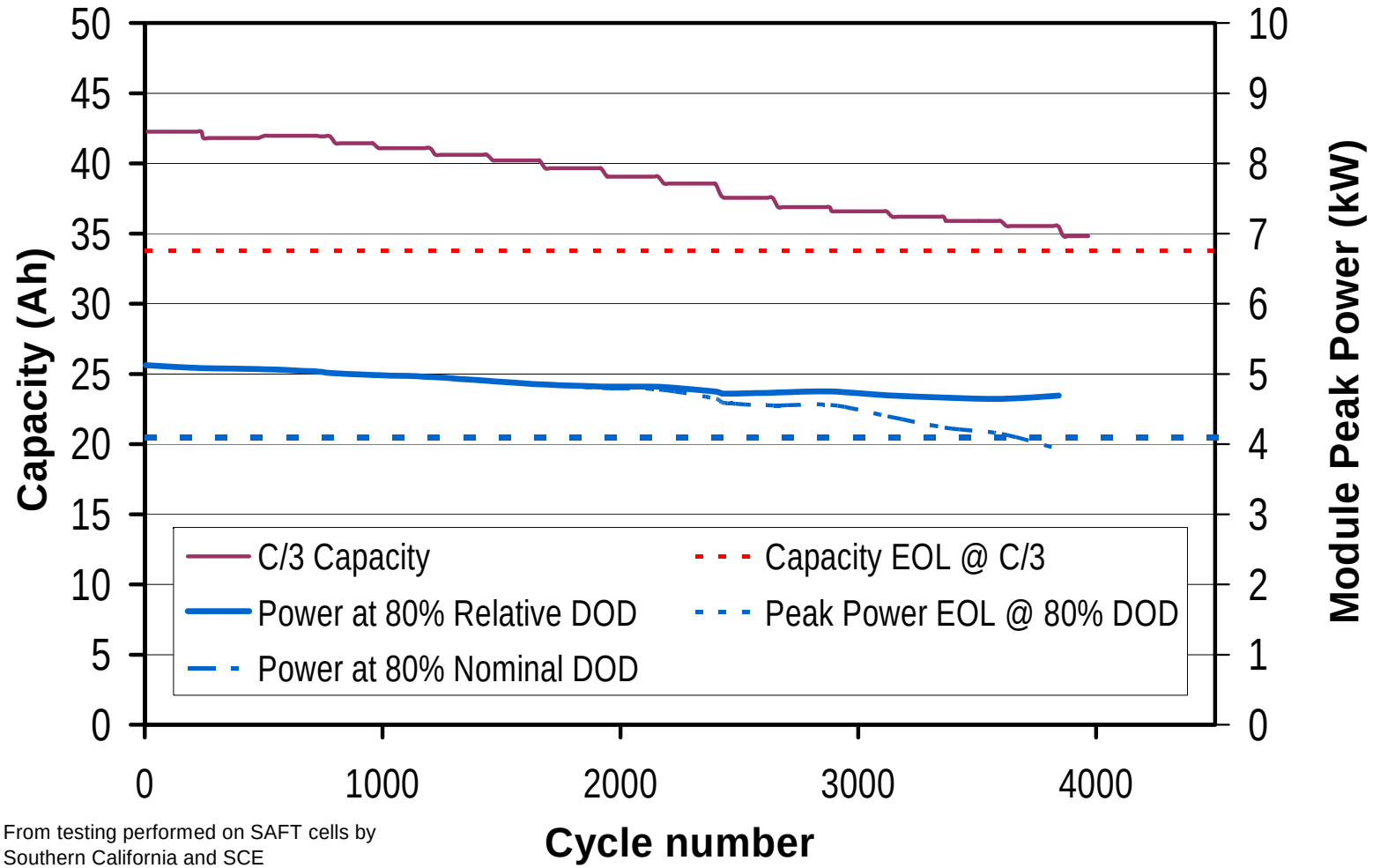
Image from *NASA Visible Earth*

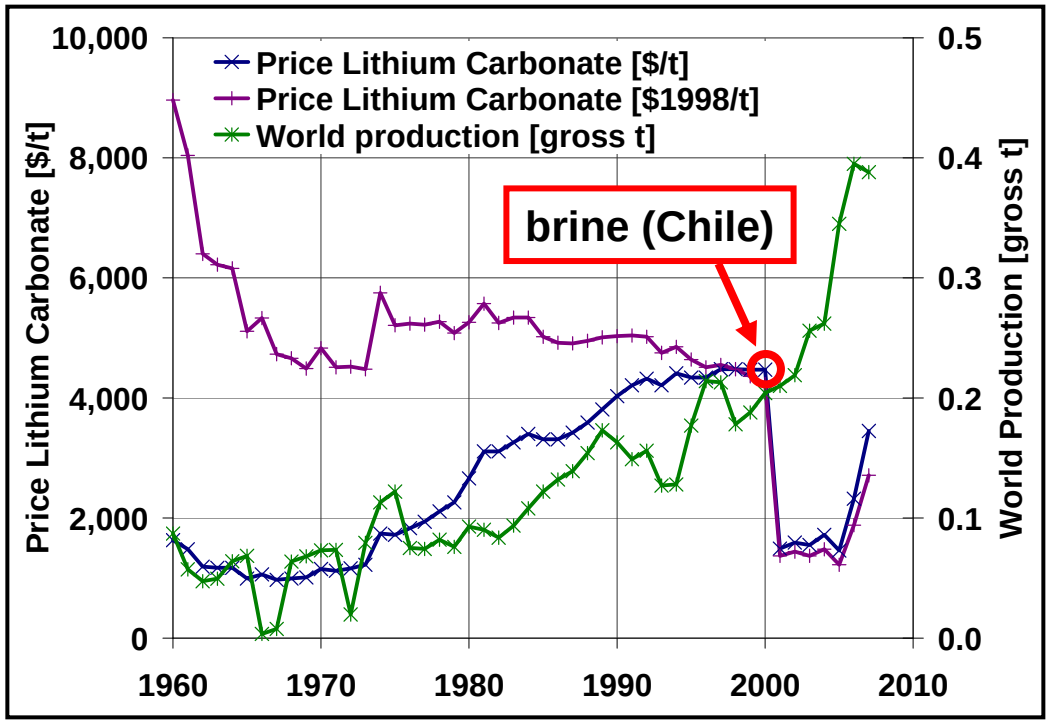
# Cycle Life



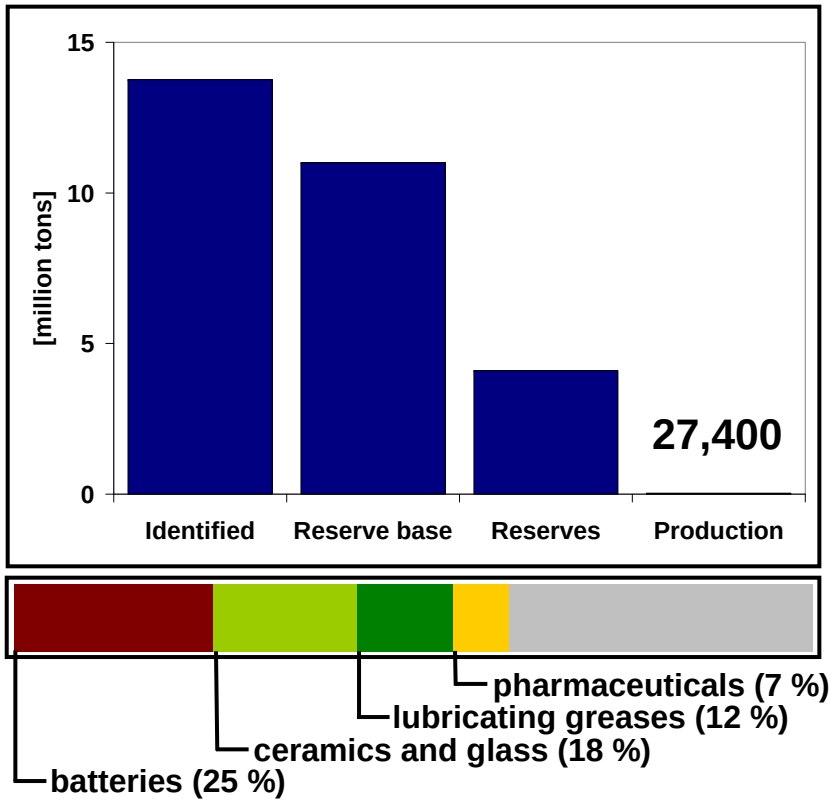

From testing performed on SAFT cells by Southern California and SCE

# Lithium Availability

## Market price & world production



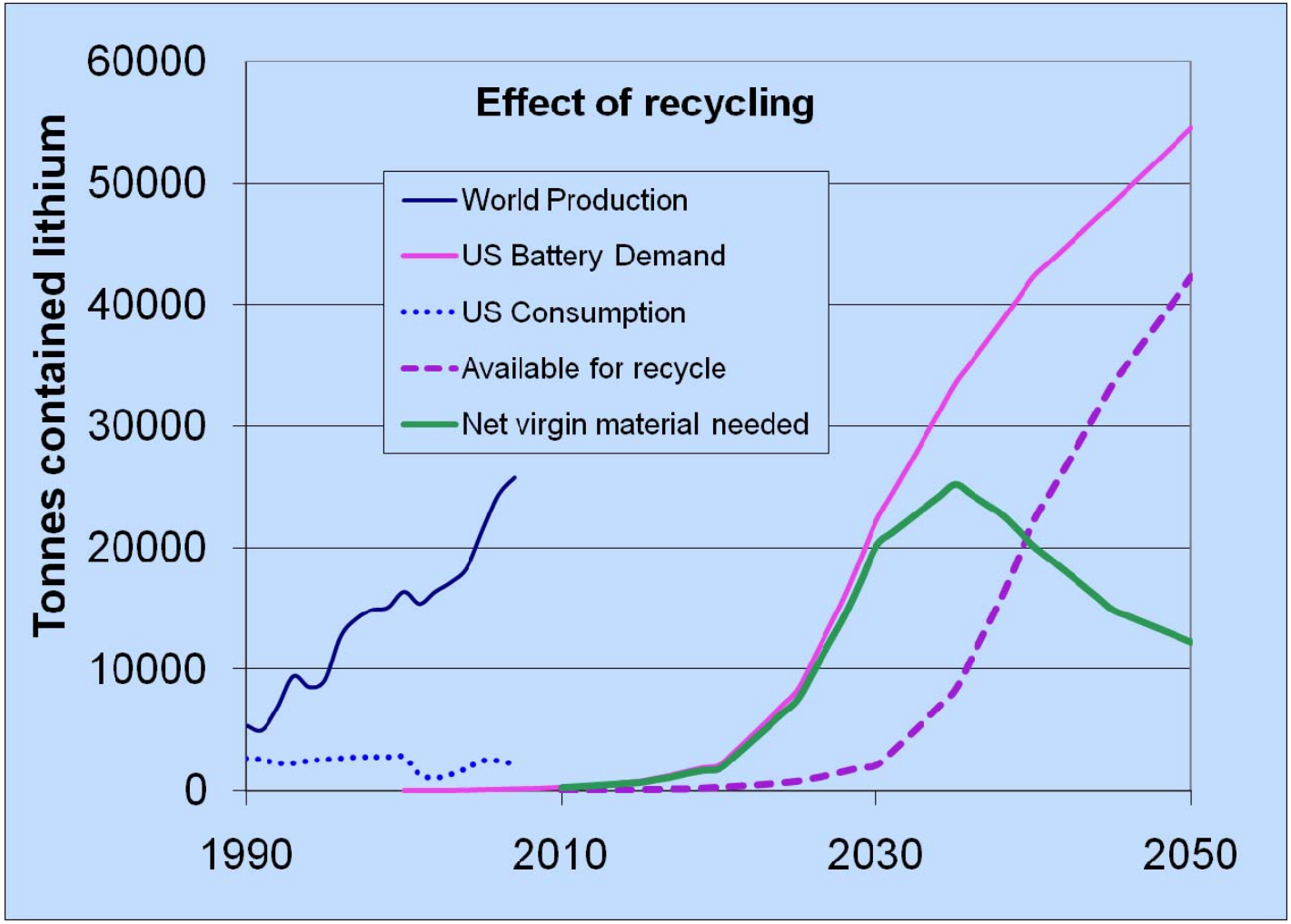

## Reserves & consumption




Data source: U.S. Geological Survey (USGS), Data Series 140
Price is for Lithium Carbonate, world production is for lithium minerals and brine
USGS Mineral Commodity Summaries, USGS Minerals Yearbook
Reserves & consumption is for lithium contained in minerals and compounds

**Peter Mock – German Aerospace Center (DLR) – Institute of Vehicle Concepts**

# Lithium Availability and Recycling




Source: Argonne National Laboratories