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# **ZEBRA Electric School Bus Project Review Presentation**

**ZEBRA Bus Seminar**

**CARB 7/27/04**

**William R. Warf**

**Sacramento Municipal Utility District**



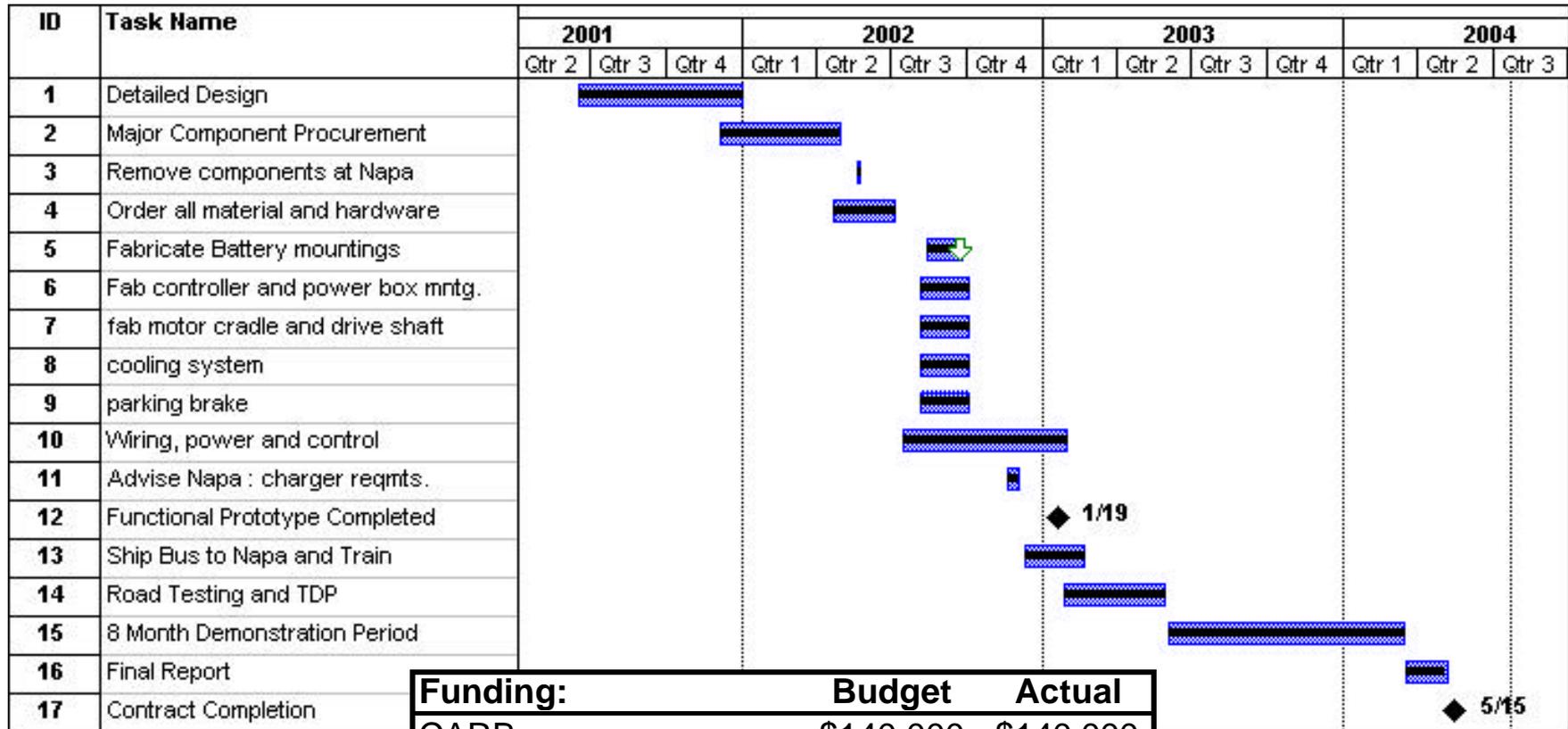
# Presentation Overview

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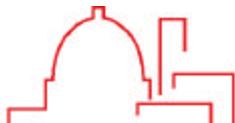
- This project addressed the barriers encountered by earlier electric busses:
- Reliability
- Performance
- Range
- Cost
- Technology
- *Results: electric school busses deserve additional deployment efforts*



# ZEBRA Bus Project: Schedule and Cost



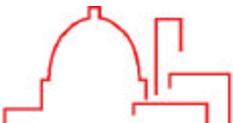
Funding:	Budget	Actual
CARB	\$140,000	\$140,000
DOT AVP	\$185,000	\$185,000
Santa Barbara EBW	\$35,648	\$103,606
SMUD	\$40,065	\$86,861
<b>Total</b>	<b>\$400,713</b>	<b>\$515,467</b>



# Reliability

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- Prototype Bus was in service 153 of 220 days in its first year: 70% availability (not 95%, but not bad for the first bus)
- Second Place in Bibendum on 5 of 6 battery modules
- High Reliability components from Automotive component suppliers Siemens and MES-DEA

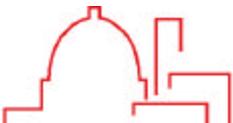


# Performance:

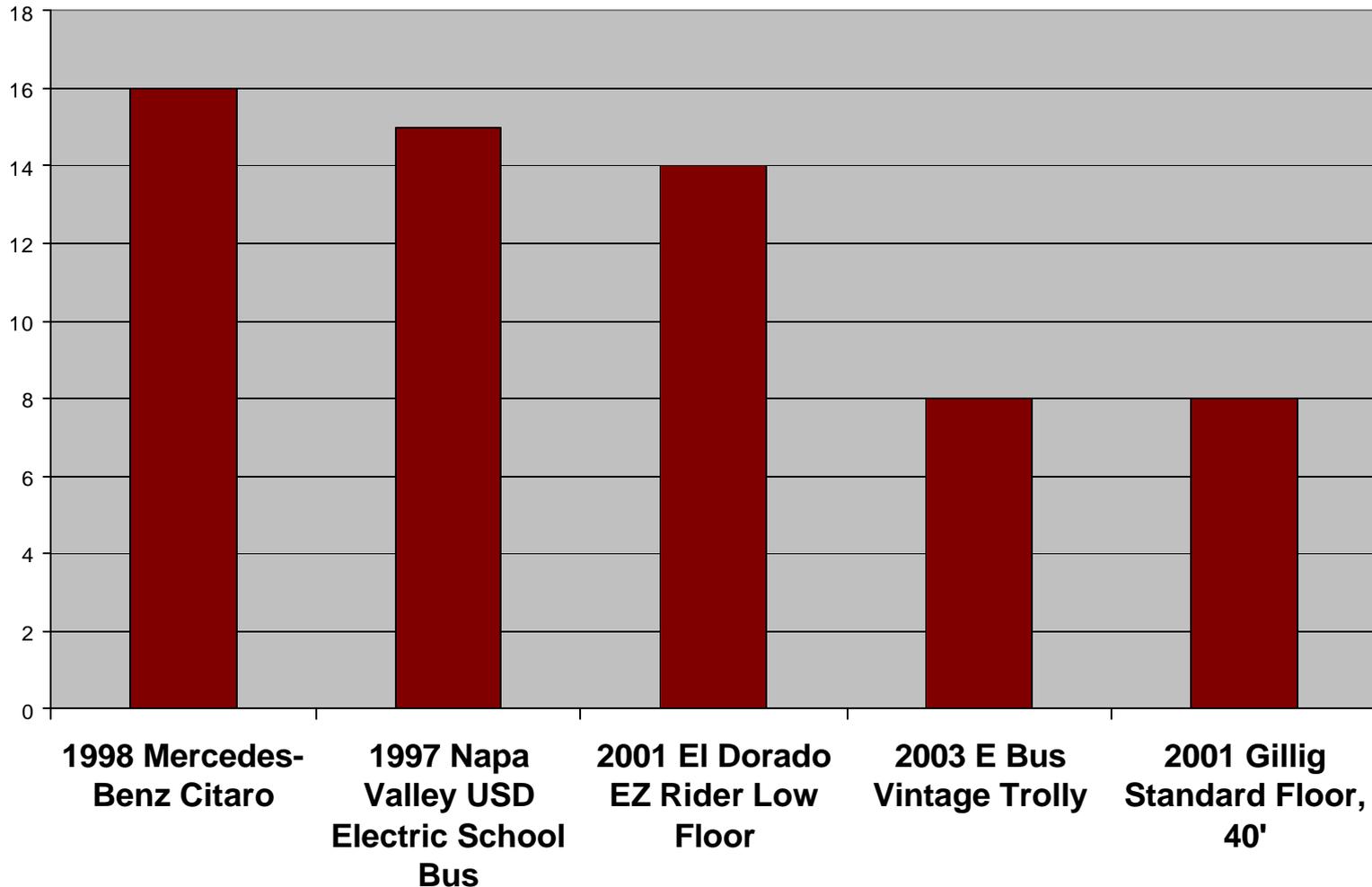


- Verified in Michelin Bibendum
- Top Speed 62 mph
- Drive Power: 170 kW
- Regenerative braking Power: 140 kW

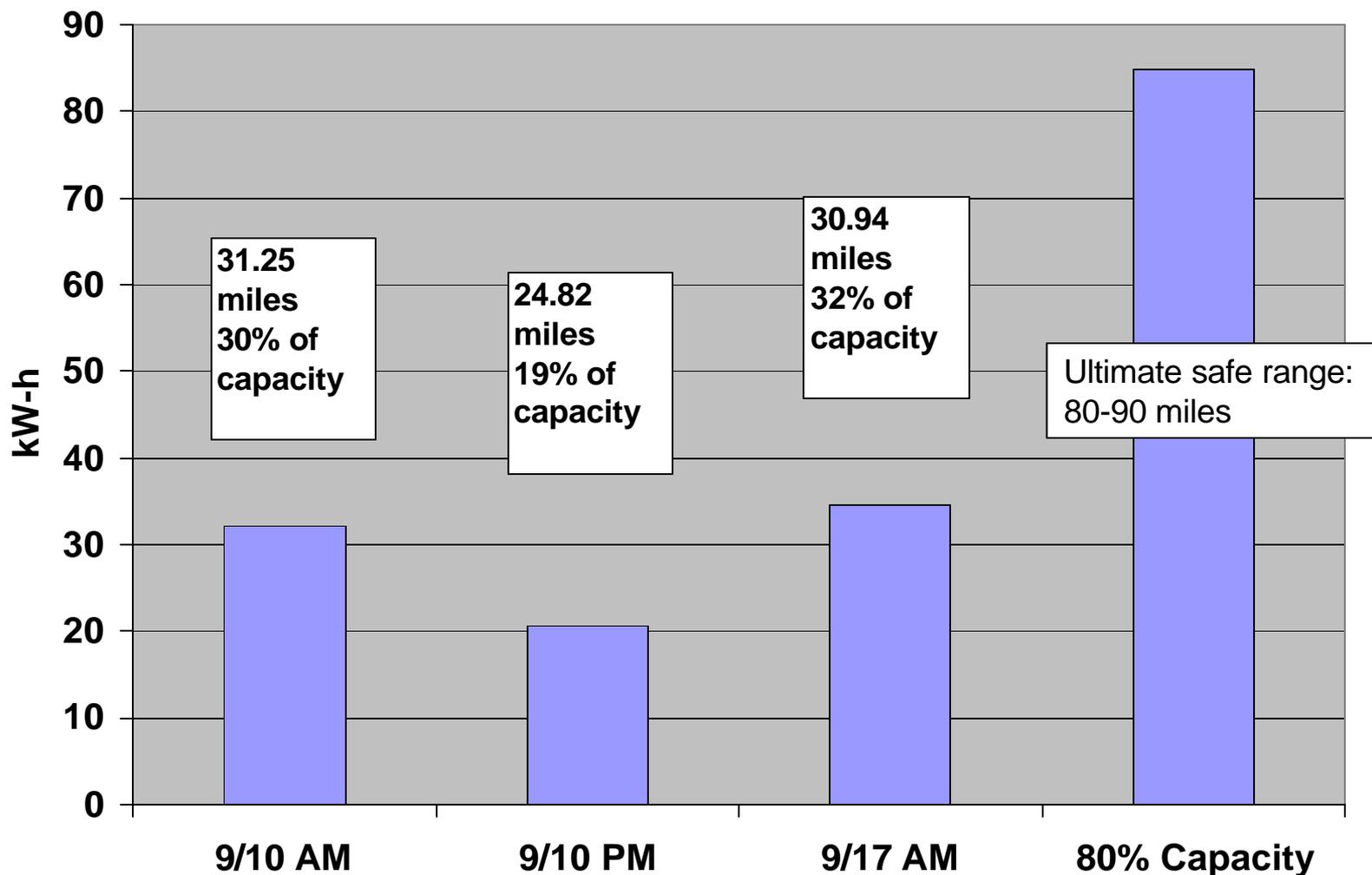
- Acceleration ¼ mile: 41.6 mph at 33,000 lbs GVWR
- Hill Climbing 24% with rolling start, 18% from stop
- Hold on Hills: motor holds bus from rolling back



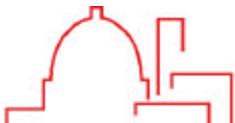
# Performance: The ZEBRA Bus finished second in the Michelin Bibendum



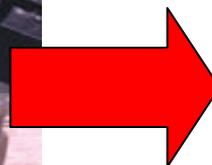
# Range: Zebra Bus Normal Duty Cycle uses less than 1/3 of battery capacity



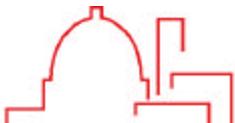
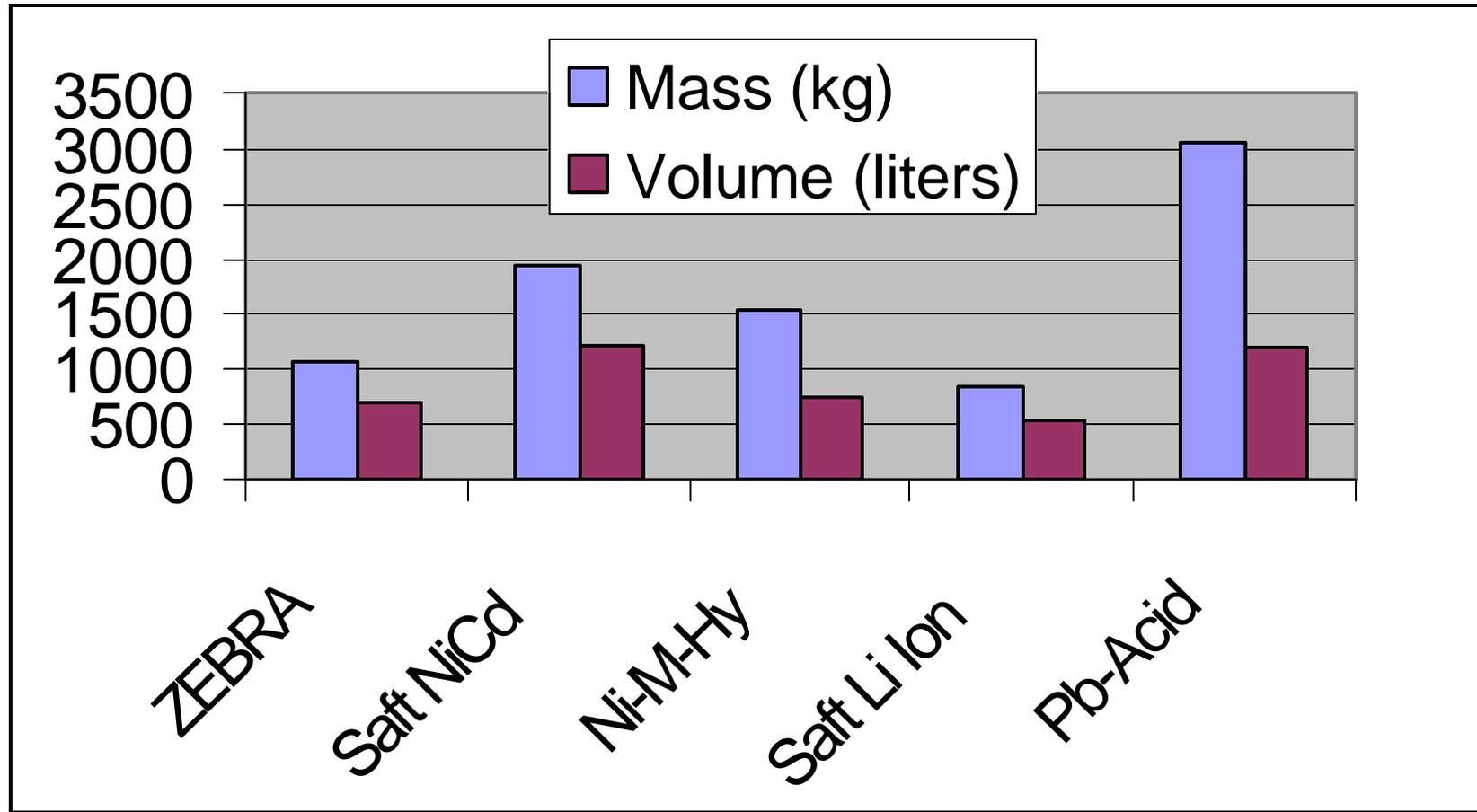
# ZEBRA Bus is recharged to ~80% from 30 mile trip in about an hour



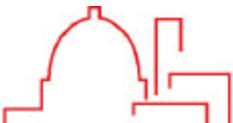
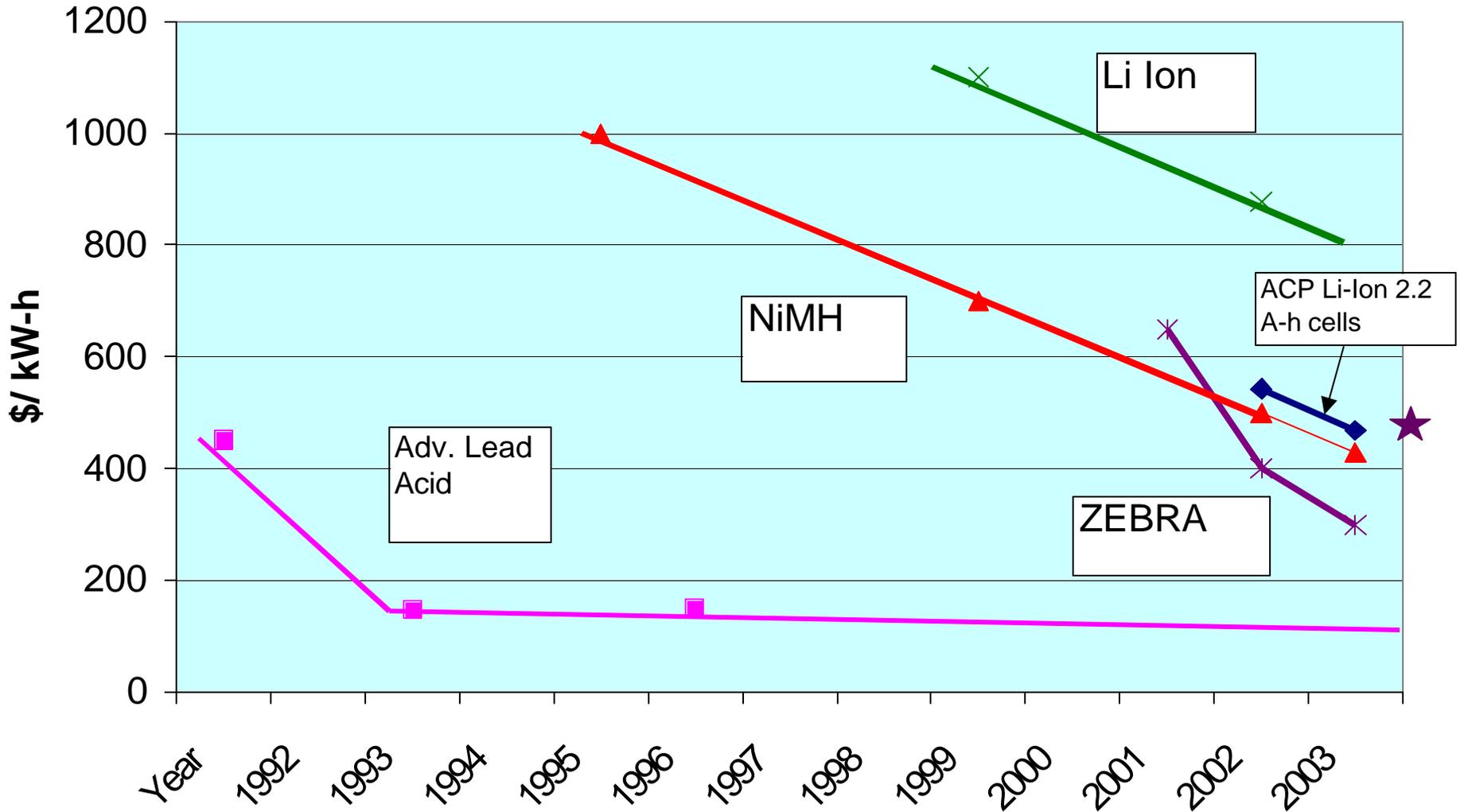
# ZEBRA Battery System Installation is a huge improvement



# School Bus Battery Mass Comparison

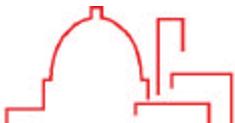
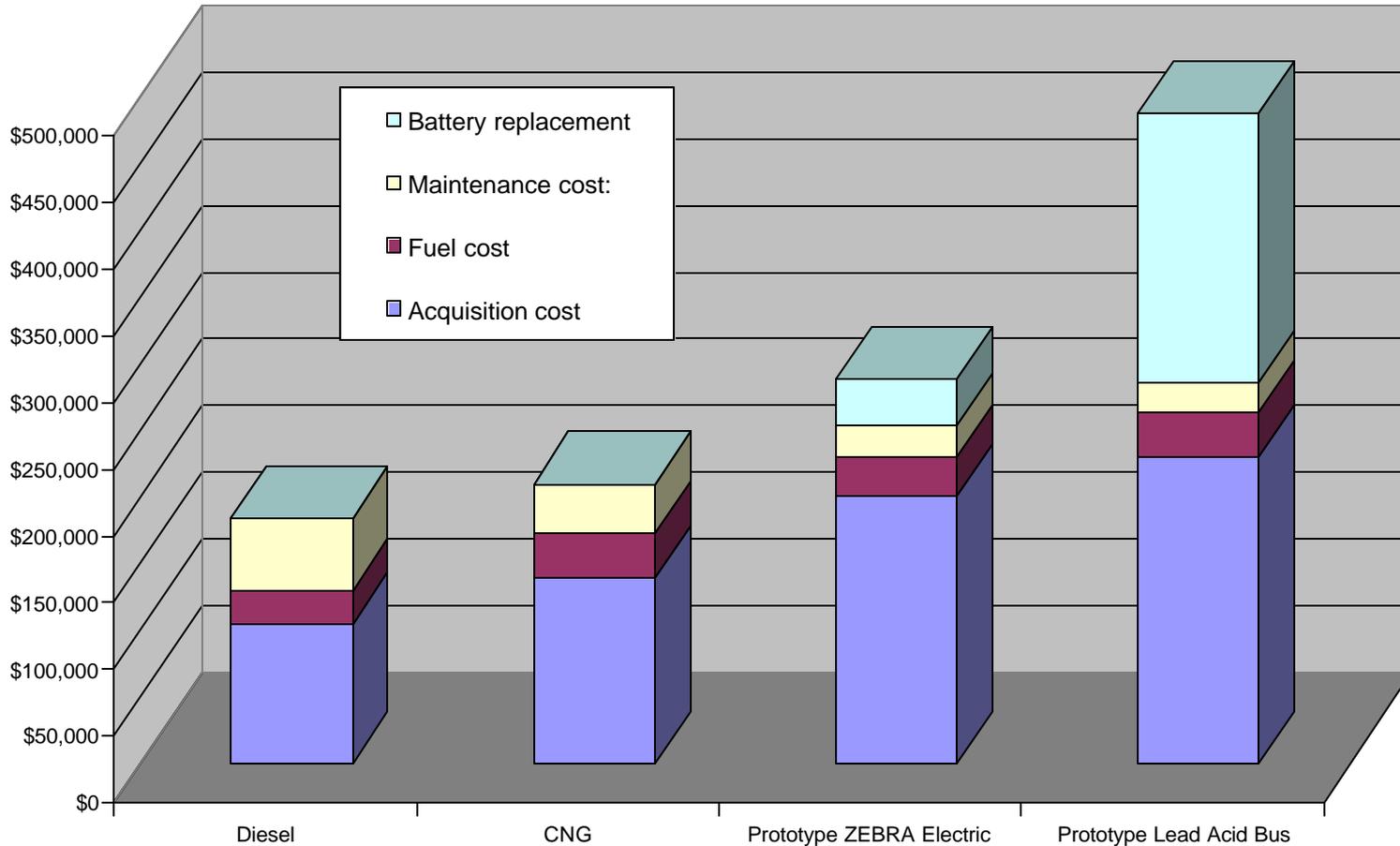


# Battery Cost Trends



# COST

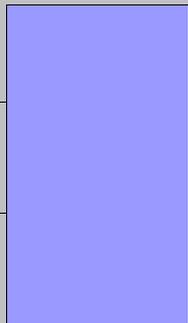
School Bus Life Cycle Cost Comparison



# Cost per mile is still higher than fossil fuel alternatives

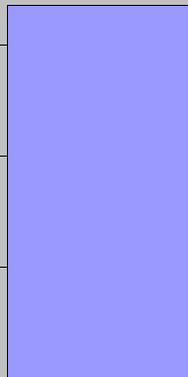
Calculation assumptions:  
15,000 miles/year  
5% discount rate  
ZEBRA battery life 6 years

\$1.44



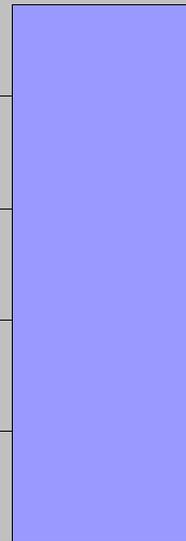
Diesel

\$1.67



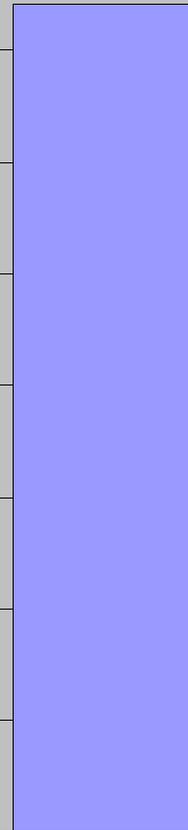
CNG

\$2.42

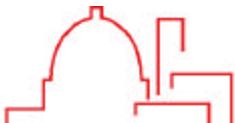


Prototype ZEBRA Electric

\$3.70



Orig. Lead Acid Bus



# Children's School Bus Exposure Study

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- Engine emissions are a significant source of exposure to Diesel Related Pollutants regardless of traffic
- Most Exposure occurs from commuting on the bus, not from loading and unloading

Recommendations:

- **Use Cleaner busses on longer routes**
- **Minimize Caravanning-stagger depart times**
- **Get kids to sit in the front of the bus**



<http://www.arb.ca.gov/research/schoolbus/schoolbus.htm>



**What is this cost?**

# Thanks to the Project Partners

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- California Air Resources Board – Innovative Clean Air Technology (ICAT) program
- Department of Transportation, Research and Special Projects Agency
- Napa Valley Unified School District
- Santa Barbara Electric Bus Works
- SMUD

