

PHEV Prius Test Program by Sacramento Municipal Utility District



**CARB
2006 ZEV
Technology
Review**

9/27/06



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PHEV Prius Conversion

- **SMUD provided standard 2005 MY Prius to EnergyCS in Dec. 2005 to be converted to PHEV**
- **Car received at SMUD April 19, 2006**
- **“Break-in” runs were conducted for two months**



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PHEV Technology Changes

- Replaced 1.3 kWh NiMH battery with Lithium FePO₄ (cathode) 8.5 kWh pack from Valence Technologies
- Usable energy went from 0.4 kWh to 6.5 kWh
- Installed 1.1 kW Delta Q charger & 110 volt plug
- Proprietary Energy CS software manages the 2,376 Li cells (18650's)



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The Nature of Prototypes

- **Delta Q prototype charger failed in early May**
- **Delta Q prototype charger failed again in mid-June, causing cell/group low voltage problem**
- **Replaced one group of cells**
- **Vi (voltage/current) contactor malfunctioned in Sept. – disabled Delta Q charge function.**



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PHEV Prius Test Program

- **Purpose:** Measure PHEV fuel economy of “enhanced boost mode”
- **The larger battery pack provides “enhanced electric boost” for up to 44 miles.**
- **All of the PHEV data is for trips made while in enhanced boost mode.**
- **Methodology:** Side by side testing with converted and non-converted Prius vehicles, both 2005 MY



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PHEV Prius Test Program Methodology

- **Test trips ranged from 3 miles to 45 miles**
- **3 test regimes:**
 - **City (all city streets) -- 15 runs**
 - **Urban (combined city/highway) – 3 runs**
 - **Freeway (95% freeway) – 10 runs**
- **28 side-by-side test runs between June 9, 2006 and Sept. 7, 2006**



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PHEV Prius Test Program Methodology

- **15 cold start & 13 warm start trips (out & back)**
- **Six different drivers**
- **Switched driver at midpoint in order to neutralize driving styles**
- **A/C and accessories running at similar level on all trips**



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PHEV Prius Test Program Methodology

- **Manual data collected from the Control/Display Unit (CDU):**
 - **Date, time, temp, type of driving, trip speed, distance, fuel use, mpg**
- **Manual data collected from Prius display:**
 - **mpg, distance, odometer reading**
- **Electronic data from vehicle CDU emailed to EnergyCS weekly**

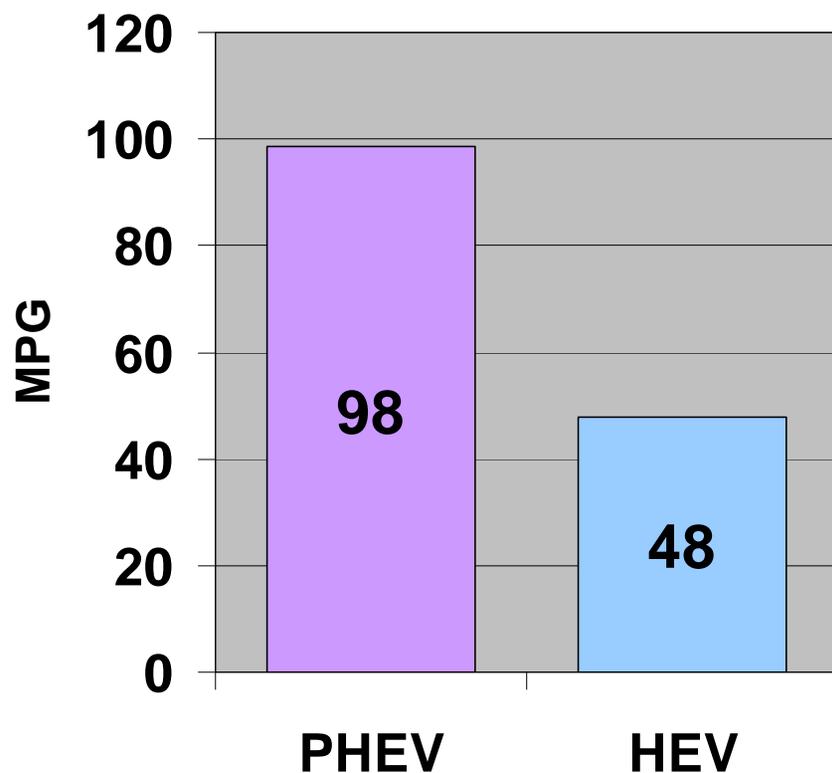


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Overall MPG



- **PHEV MPG is 2.0x more than HEV**
- **28 trips, 373 miles**
- **Avg. 14.8 miles/trip**
- **Combined City, Highway and Urban**

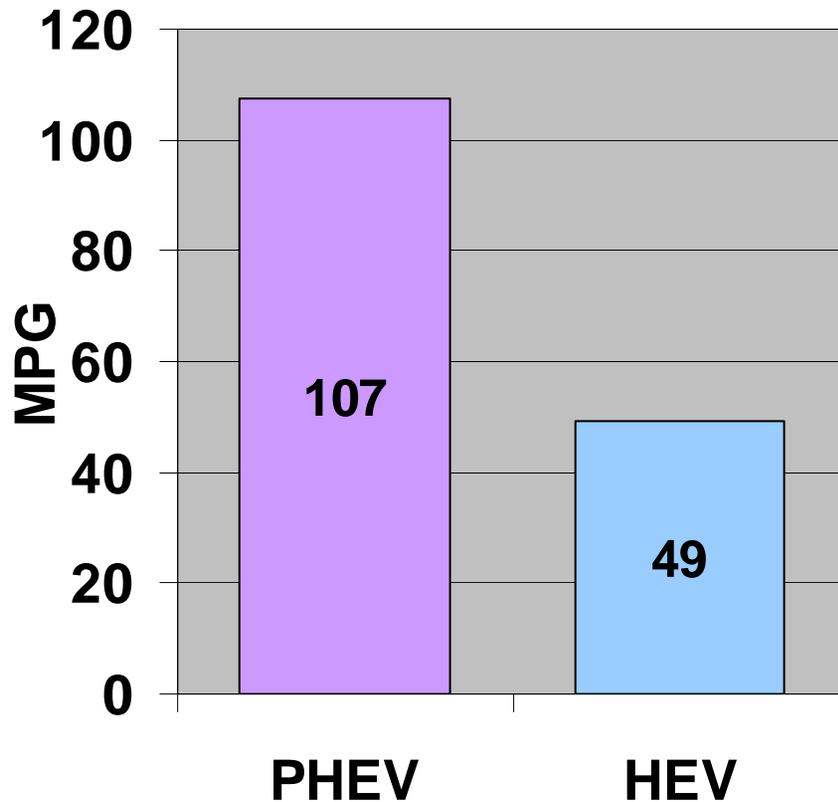


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Freeway MPG



- PHEV mpg = 2.2x HEV
- 10 trips
- Avg. 19.3 miles per trip
- EPA rating of 51 mpg for HEV
- Achieved 49 mpg

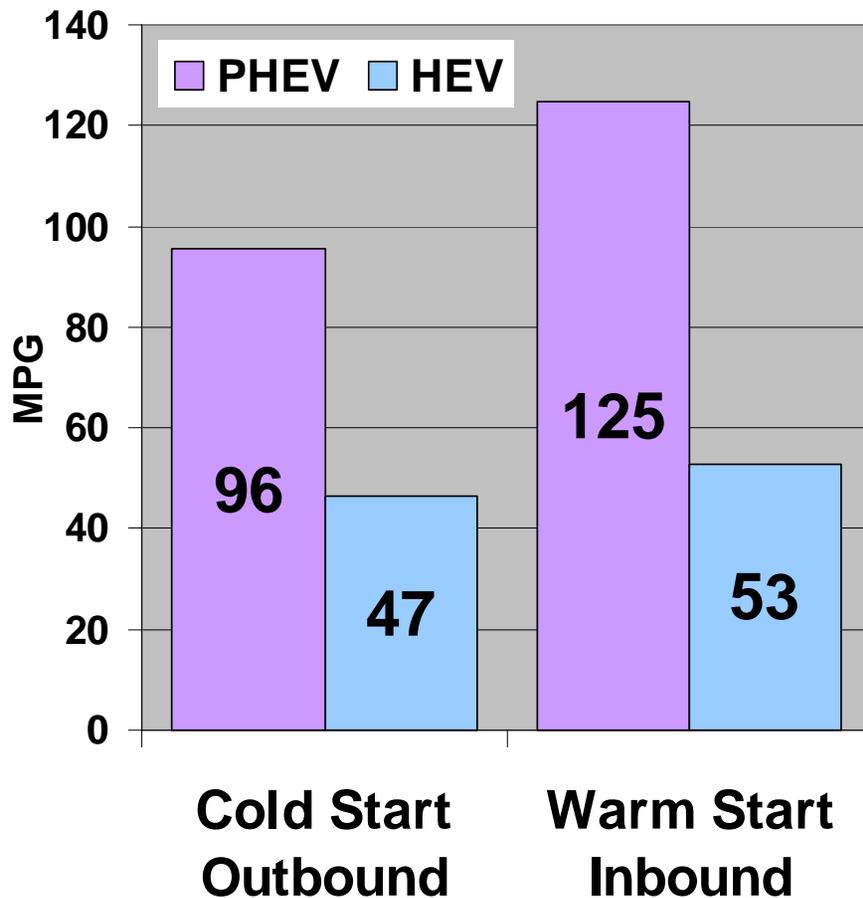


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Freeway MPG: Cold Start vs. Warm Start



6 cold start trips

- Engine/catalyst warm up time

4 warm start trips

- PHEV MPG 30% better w/ warm start
- 12% better HEV MPG w/ warm start

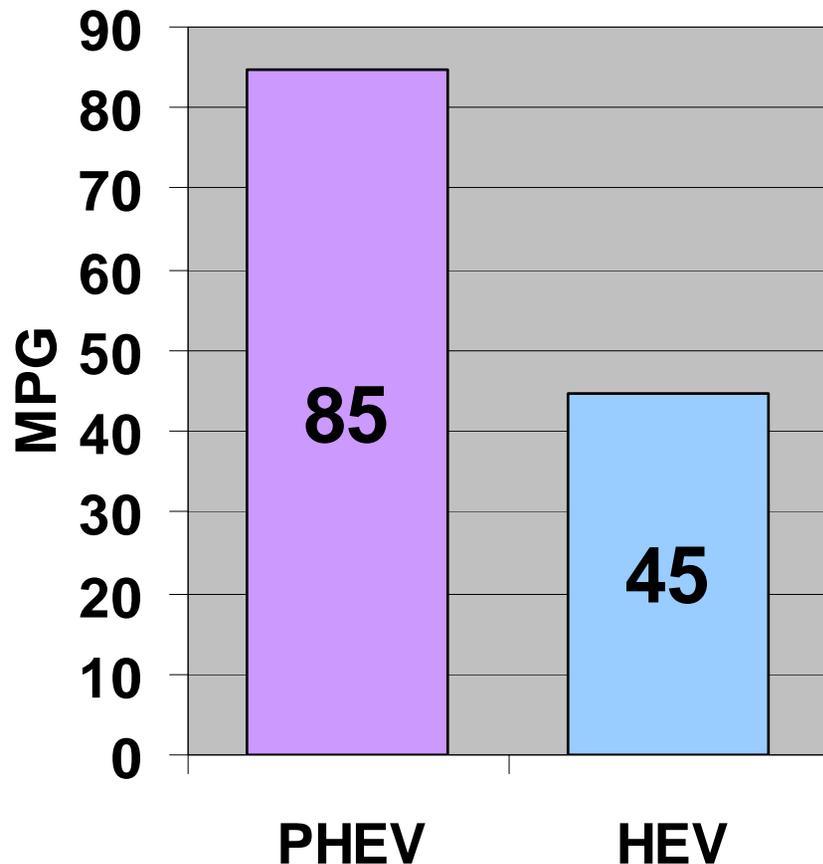


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City MPG



- 15 city trips
- Avg. length ~ 7.9 miles
- PHEV mpg 1.9x standard Prius
- HEV results lower than EPA rating of 60 mpg due to several short trips

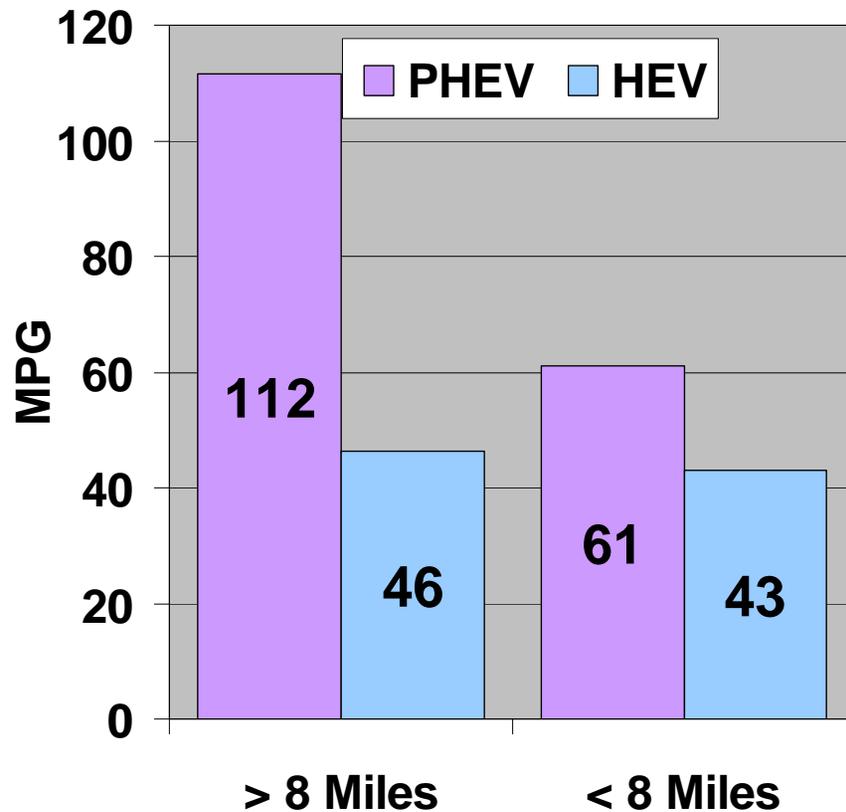


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City MPG: Distance Matters



7 city trips > 8 miles

- avg. trip ~ 12.2 miles
- PHEV mpg 2.4x HEV

8 city trips < 8 miles

- Avg. trip ~ 4.3 miles
- PHEV mpg 1.4x HEV



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Cost of 50 Mile Trip

- **Electricity use during enhanced boost mode = 154 whrs/mile est. for daily use (AC from grid)**
- **Calculated cost for 50 mile trip**
 - Assume gasoline at \$2.75/gal.
 - Assume electricity at \$0.102 / kW
- **CAFE vehicle (27.5 mpg) = \$5.00**
- **Standard Prius (50 mpg) = \$2.75**
- **PHEV Prius “blended” (100 mpg + kWh) = \$2.17**
- **PHEV Prius all electric mode (kWh) = \$1.48**



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Conclusions

- **Converted PHEV Prius provides 40% to 140% better fuel economy than standard non-converted Prius during the enhanced boost mode -- up to 44 miles**
- **PHEV achieved best fuel economy for trips > 8 miles -- 110 mpg**
- **PHEV fuel economy was 45% less for trips < 8 miles -- 61 mpg**



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Conclusions

- **Continue testing and data collection over next year to confirm preliminary findings, particularly:**
 - **City trips of greater length**
 - **Trips that fully deplete pack**
 - **Winter time, colder weather trips**
 - **Track gasoline usage (1,200 mile tank a challenge to track)**



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Conclusions

- **PHEVs have significant potential for improved fuel economy, especially for the commuter with round trips between 10 and 40 miles**



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