



# **U.S. Department of Energy - Vehicle Technologies Program 2008 Annual Merit Review**

## **Advanced Vehicle Testing Activity (AVTA) – Non-PHEV Evaluations and Data Collection**

**Vehicle Systems Merit Review**

**Jim Francfort – INL AVTA Principle Investigator**

**Lee Slezak – DOE Sponsor**

**February 2008, Bethesda, Maryland**

# Vehicle Testing Objectives

- Overall vehicle testing objectives
  - Benchmark and reduce operational uncertainties of emerging vehicle technologies
  - Provide testing results to vehicle modelers and technology target setters in support of DOE technology development efforts, and to early adaptor fleet managers
  - Continue to utilize Phoenix area test tracks and fleet testing arrangements



# Vehicle Testing Objectives – cont'd

- Hybrid Electric Vehicles (HEVs)
  - Reduce HEV battery and vehicle uncertainties and document life-cycle costs
- Hydrogen Internal Combustion Engine (HICE) Vehicles
  - Assess the safety, reliability and operating characteristics of 100% HICE vehicles
  - Identify any engine or vehicle system degradations when operating on hydrogen



# Vehicle Testing Objectives – cont'd

- **Neighborhood Electric Vehicles (NEVs)**
  - Support the California Air Resource Board's (CARB) decision to require all NEV models sold in California be tested by the AVTA in order to be eligible for CARB incremental funding and credits
- **Electric Ground Support Equipment (eGSE)**
  - Support the development, understanding and deployment of eGSE at domestic airports



# FY07 Testing Accomplishments

- **Hybrid Electric Vehicles (HEVs)**
  - **Completed baseline performance testing on 12 HEV models to date (five models during FY07)**
  - **As of September 2007, 3.2 million test miles have been accumulated (987,380 miles during FY07) on 19 HEVs in JPMorgan fleet (160,000 miles per vehicle in 3 years, minimum 2 vehicles per model)**
  - **Initiated end of life (EoL) battery testing on two Gen II Prius and two Escape HEVs, having previously completed EoL battery testing on two Gen I Prius, two Gen I Civic, and two Honda Insight HEVs**
  - **Collected fuel economy, maintenance, depreciation, operations (insurance and registration), and other life-cycle related vehicle costs in fleet missions to determine life-cycle costs**

# **FY07 Testing Accomplishments – cont'd**

- **Hydrogen Internal Combustion Engine (HICE) Vehicles**
  - **Eight 100% HICE pickups (Roush CNG conversions) being fueled at the Integrated Waste Hydrogen Utilization Project (IWHUP) in Vancouver, BC**
    - **16,000 total test miles and 20.1 miles per GGE with no safety problems**
    - **Faster exhaust gas oxygen sensor degradation**
    - **Increased presence of water in the engine oils due to lower combustion temperatures during lean-burn operations**
    - **Increased exhaust manifold corrosion**
  - **Roush 100% HICE pickup baseline performance tested in FY07 (total of 4 HICE and HCNG models tested to date)**

# FY07 Testing Accomplishments – cont'd

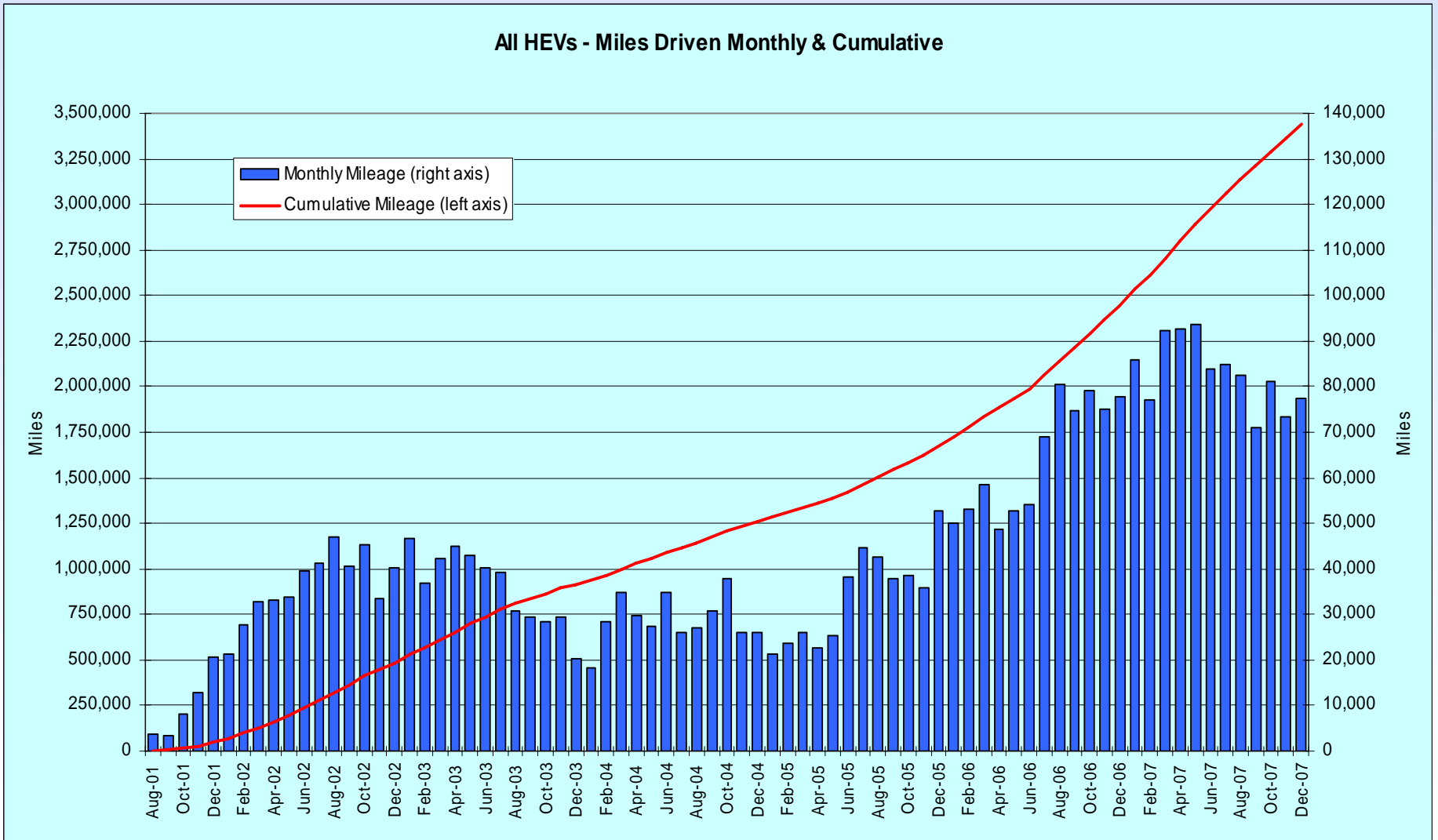
- **Neighborhood Electric Vehicles (NEVs)**
  - CARB and Wisconsin required all NEV models be tested to the AVTA's NEVAmerica testing procedures
  - Initiated the testing of a new NEV from Global Electric Motors (GEM), a Chrysler subsidiary
- **Electric Ground Support Equipment (eGSE)**
  - Completed baseline performance testing on electric pushback tractor
  - Developed economic payback model for baggage tractors, belt loaders, and pushback tractors propelled by electric motors or petroleum engines (including fueling infrastructure). Based on operations of two airlines at four airports. Partners: EPRI, SCE, SMUD, Georgia Power, Southwest and Delta Airlines

# HEVs in Testing

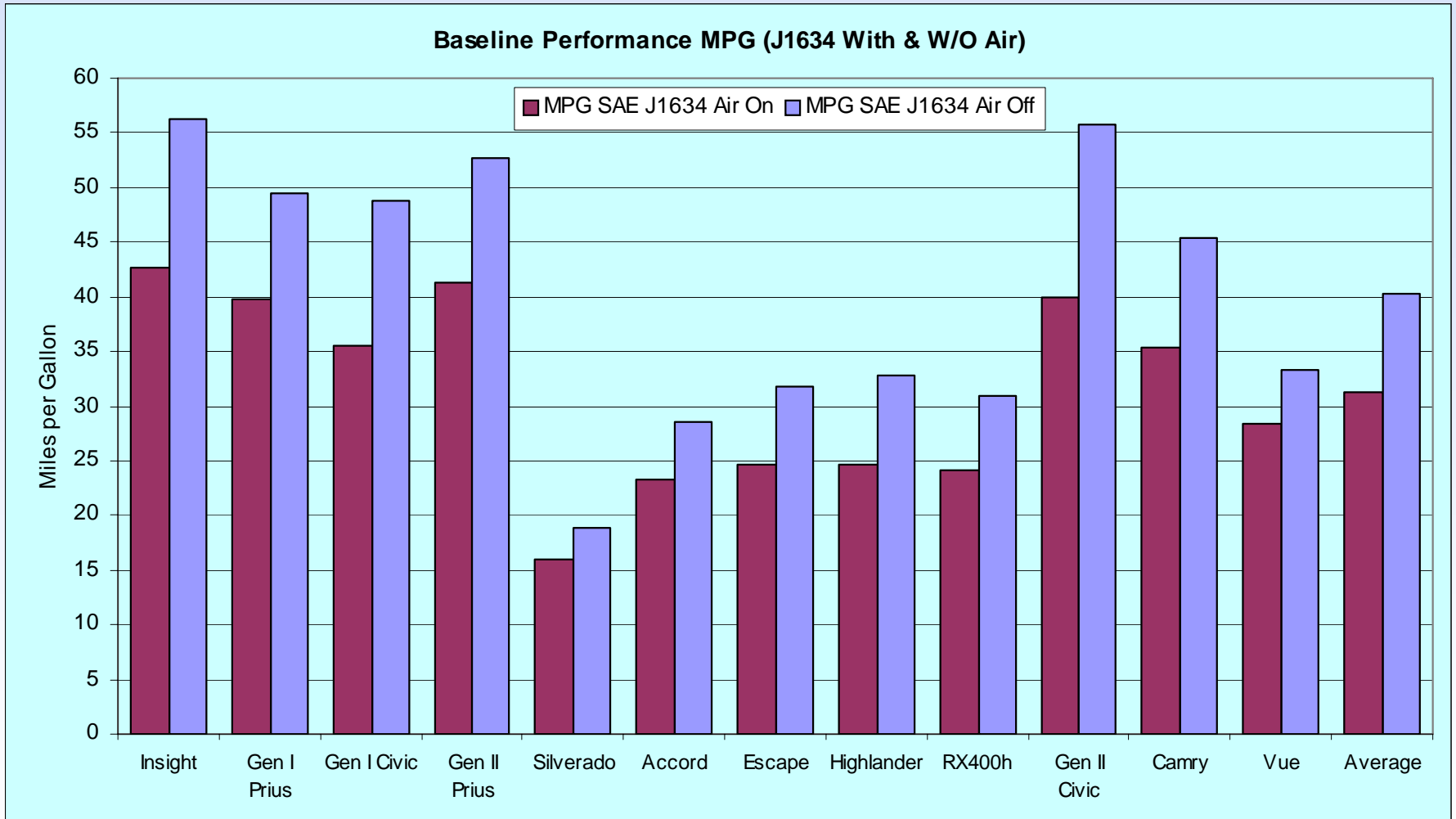
<b>2001 Honda Insight</b>	<b>6</b>	<b>Completed</b>
<b>2002 Gen I Toyota Prius</b>	<b>6</b>	<b>Completed</b>
<b>2003 Gen I Honda Civic</b>	<b>4</b>	<b>Completed</b>
<b>2004 Chevrolet Silverado (2- &amp; 4-WD)</b>	<b>2</b>	<b>Ongoing</b>
<b>2004 Gen II Toyota Prius</b>	<b>2</b>	<b>Completing</b>
<b>2005 Ford Escape (front &amp; 4-WD)</b>	<b>2</b>	<b>Completing</b>
<b>2005 Honda Accord</b>	<b>2</b>	<b>Ongoing</b>
<b>2006 Lexus RX 400h (front &amp; 2 AWD)</b>	<b>3</b>	<b>Ongoing</b>
<b>2006 Toyota Highlander (AWD)</b>	<b>2</b>	<b>Ongoing</b>
<b>2006 Gen II Honda Civic</b>	<b>2</b>	<b>Ongoing</b>
<b>2007 Saturn Vue</b>	<b>2</b>	<b>Ongoing</b>
<b>2007 Toyota Camry</b>	<b>2</b>	<b>Ongoing</b>
<b>2008 Nissan Altima</b>	<b>2</b>	<b>Ongoing</b>
<b>2008 GM 2-mode Tahoes</b>	<b>2</b>	<b>Starting</b>
<b>Total test or in testing</b>	<b>39 to date</b>	



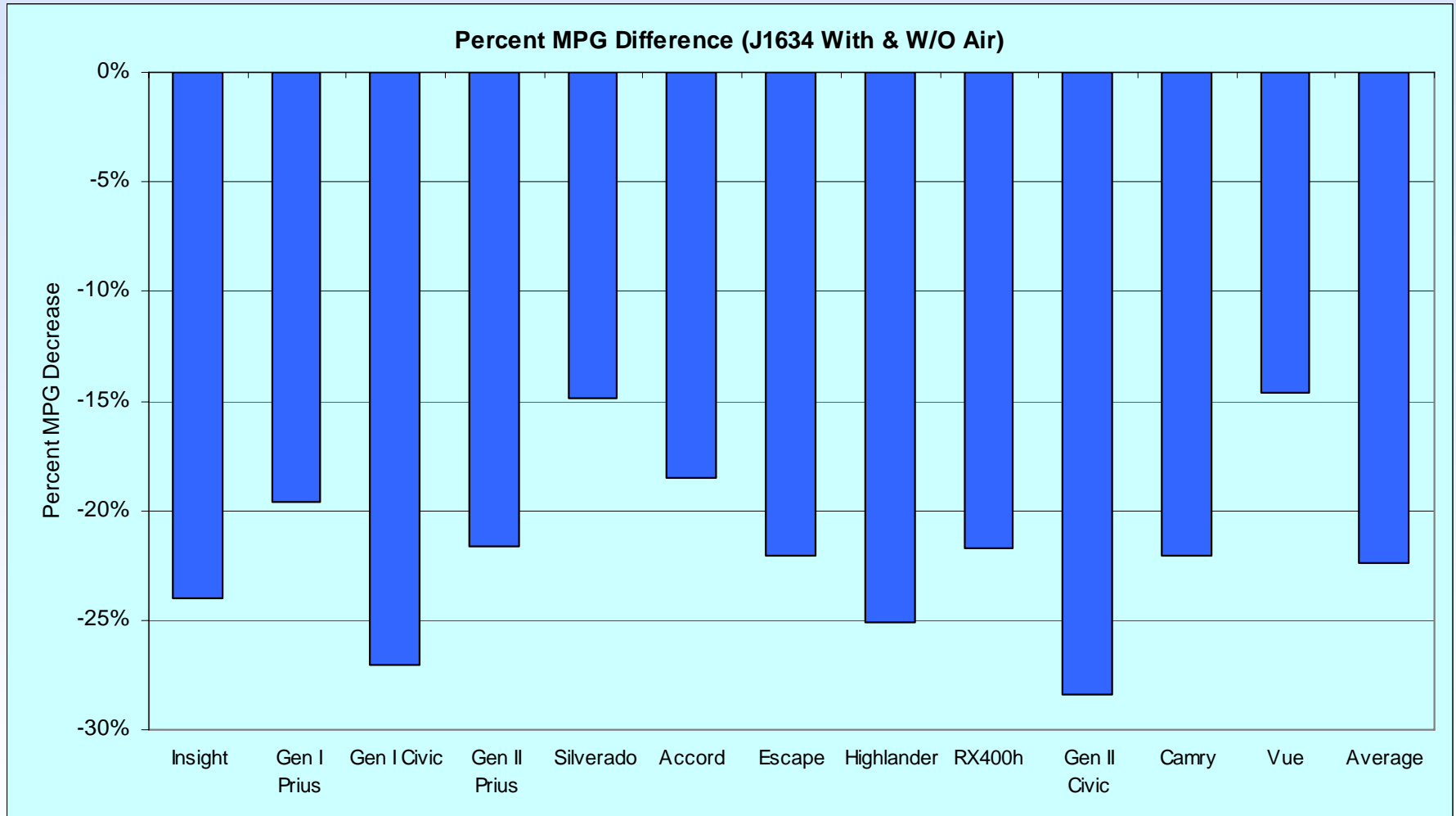
# 3.4 Million HEV Onroad Test Miles



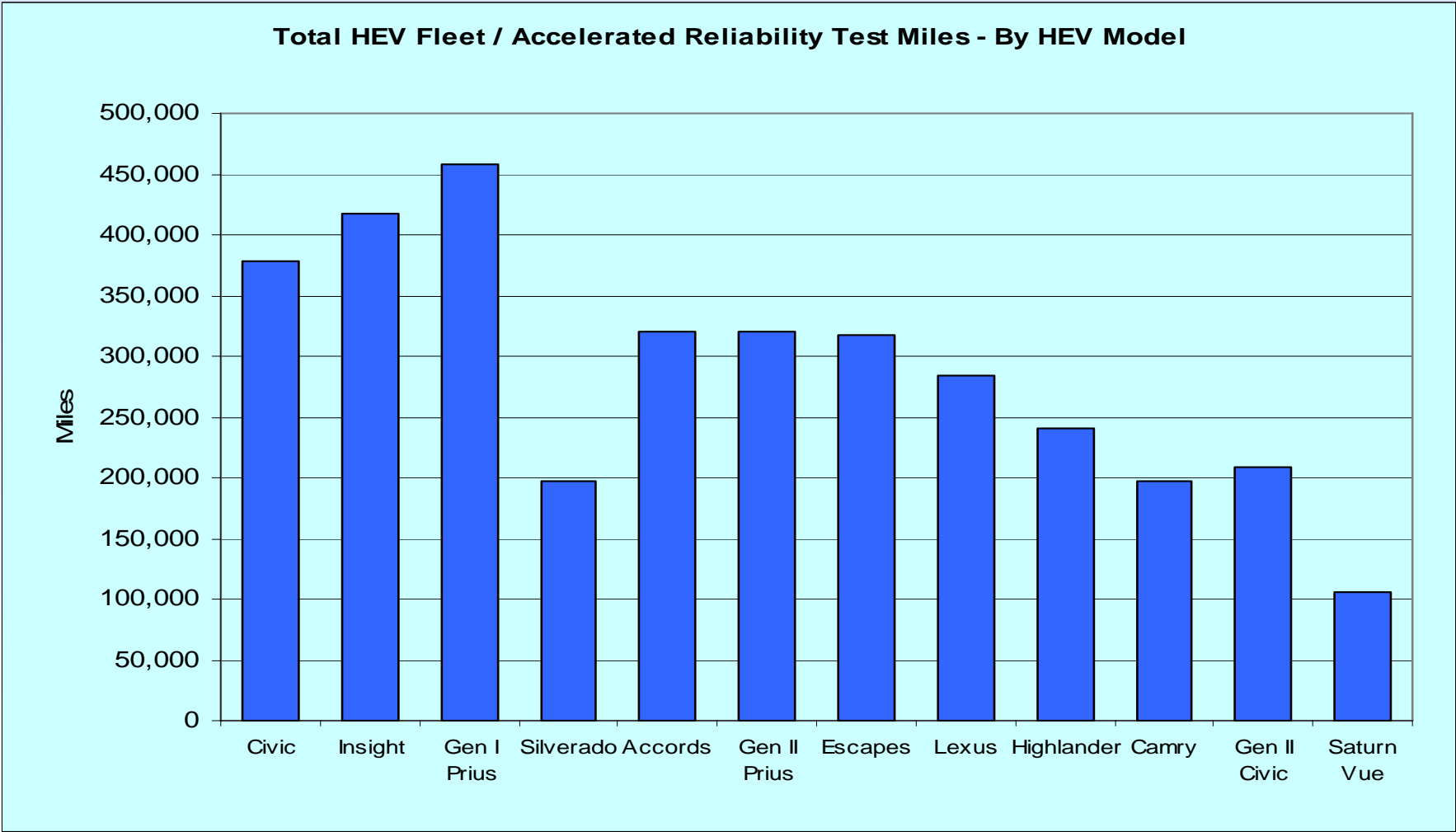
# HEVs Baseline Performance Tested



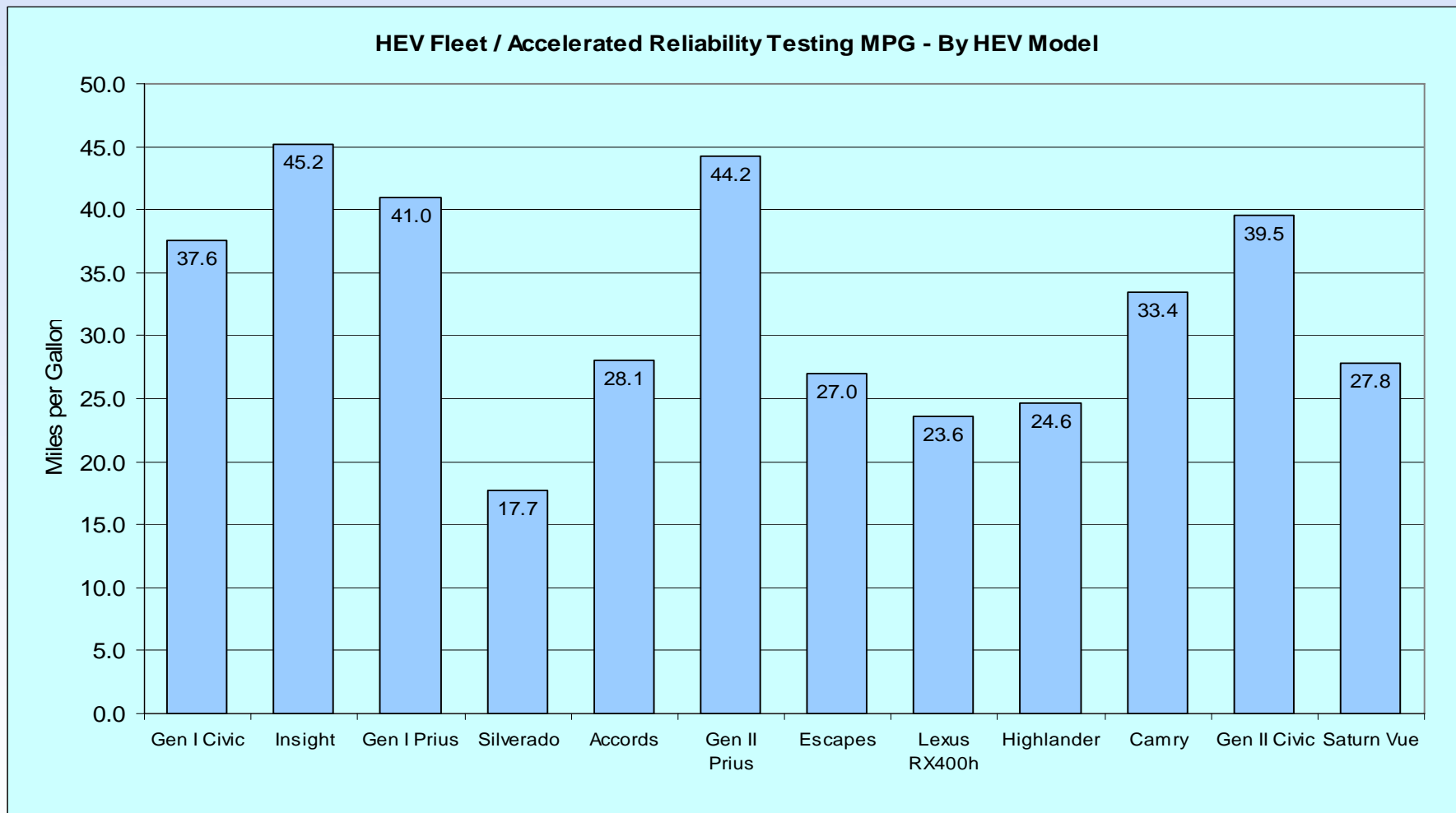
# Percent HEV MPG Decrease - A/C on



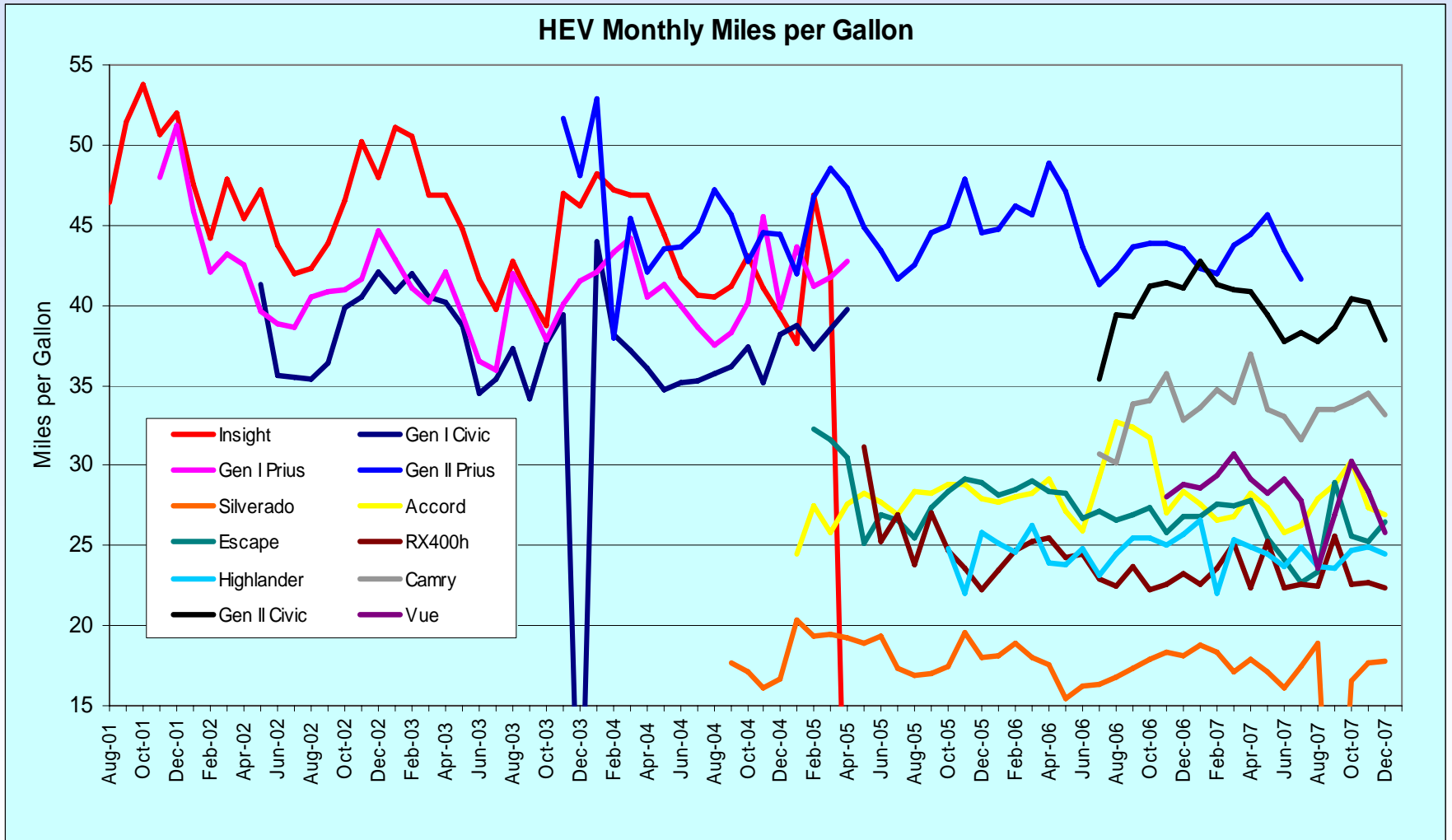
# Onroad Test miles per HEV model



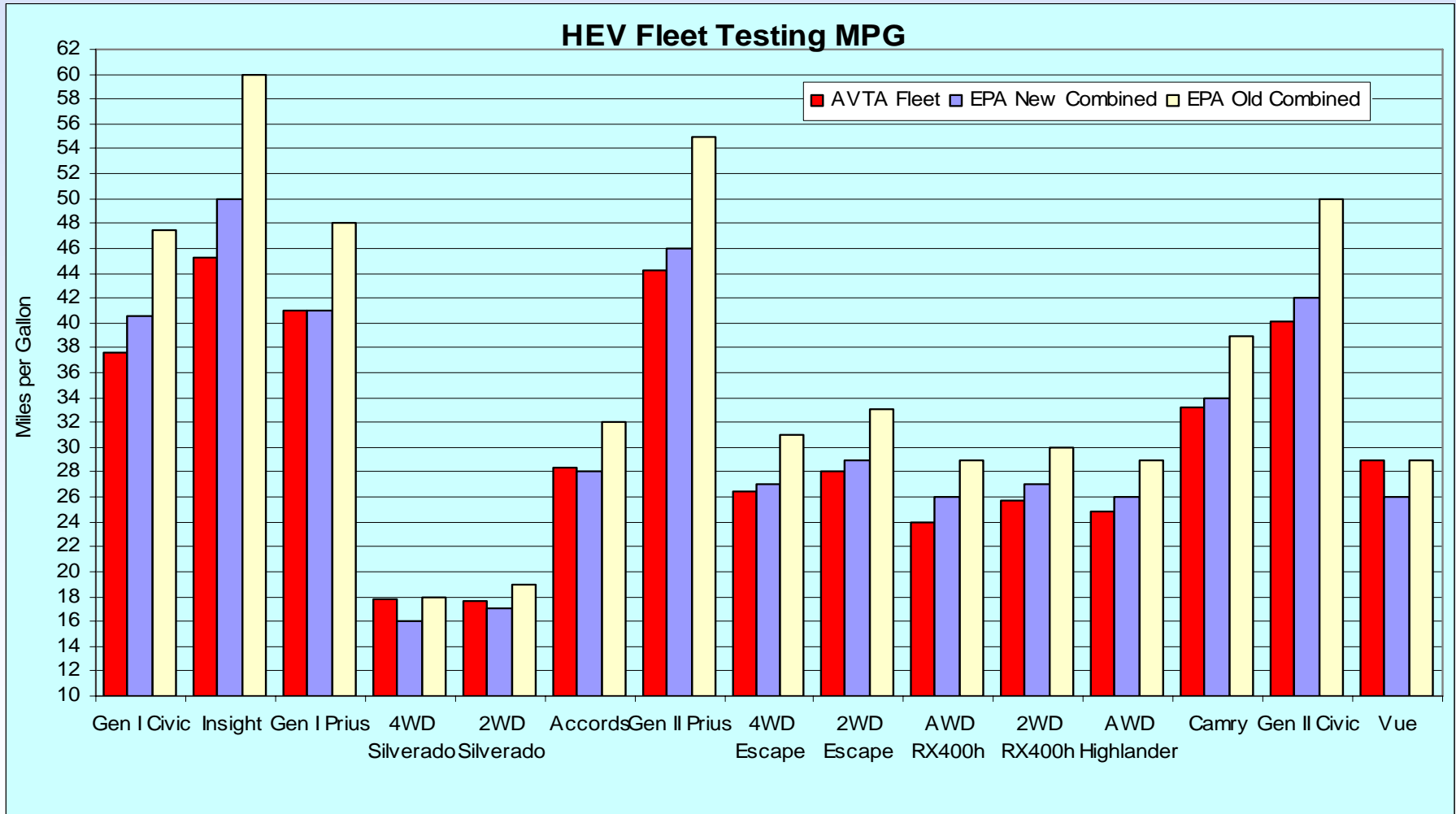
# Onroad Miles per gallon by HEV model



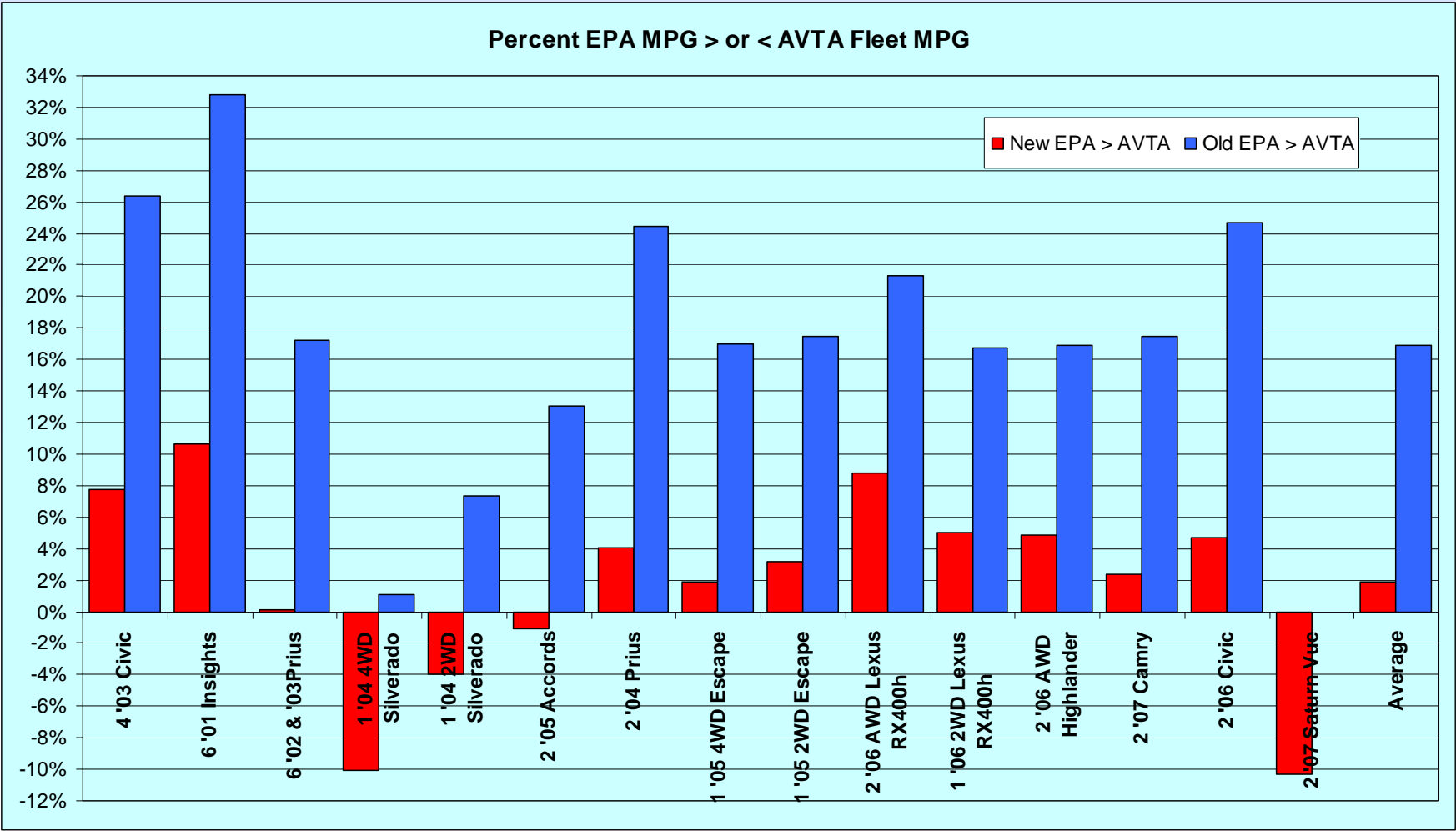
# HEV Monthly Onroad MPG



# Onroad HEV MPG vs. Old/New EPA MPG



# Onroad HEV MPG vs. Old/New EPA MPG





# HEV Maintenance and Repairs

## *FREEDOMCAR & VEHICLE TECHNOLOGIES PROGRAM*

### HEV Fleet Testing

#### Advanced Vehicle Testing Activities

#### Maintenance Sheet for 2006 – Highlander



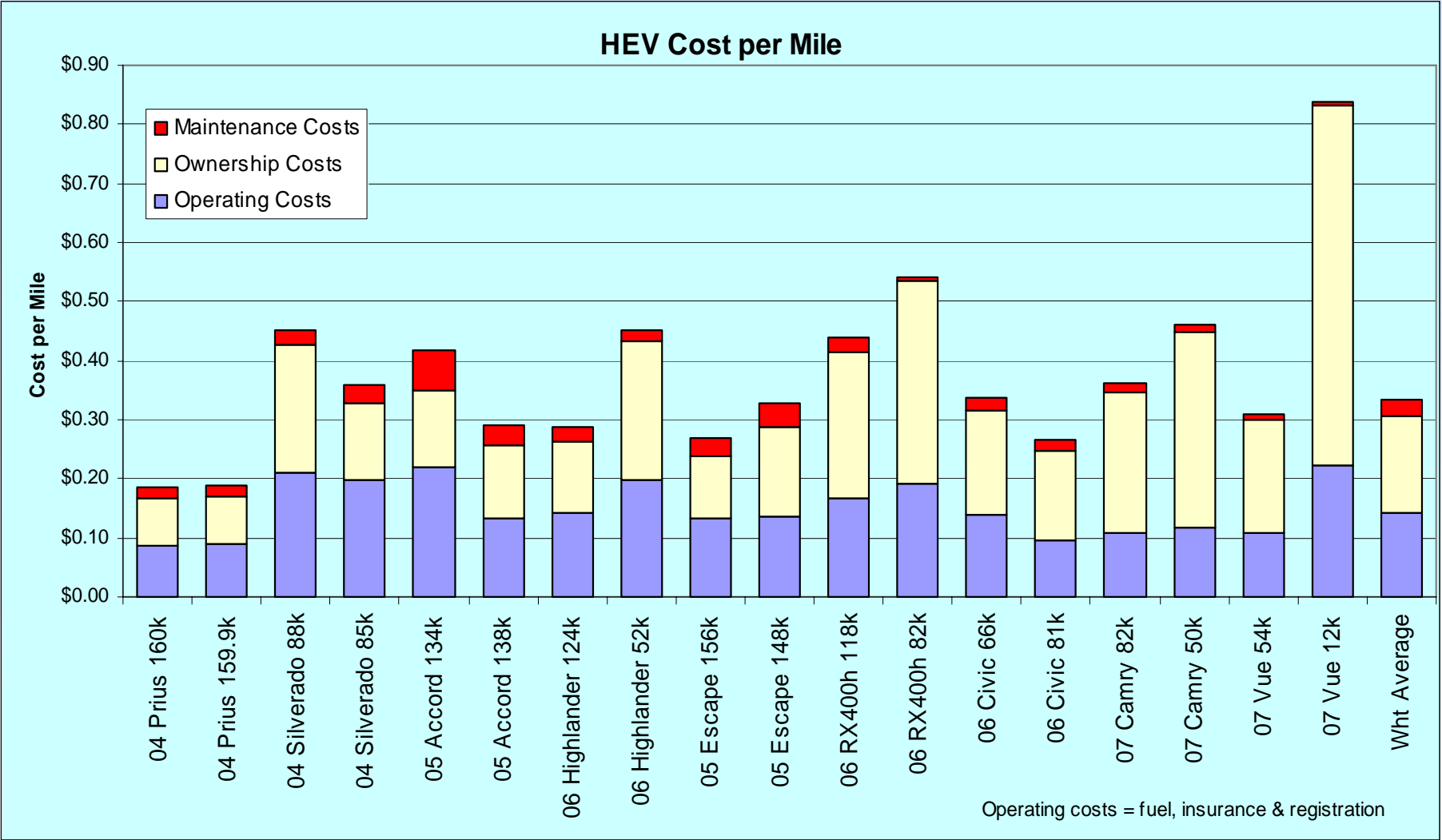
VIN # JTEDW21A160006395

Date	Mileage	Description	Cost
12/14/2005	4,855	Changed oil, rotated tires	\$31.99
1/5/2006	9,952	Changed oil, rotated tires	\$28.04
1/31/2006	15,749	15K service	\$187.05
2/22/2006	20,783	Changed oil, rotated tires	\$28.07
3/15/2006	26,197	Changed oil, rotated tires	\$28.10
4/17/2006	31,578	30K service	\$321.80
4/26/2006	36,682	Changed oil, rotated tires	\$28.99
5/18/2006	42,113	Changed oil, rotated tires	\$28.99
6/9/2006	47,475	15K interval service, 45K preventative maintenance	\$200.67
7/5/2006	53,711	Changed oil	\$38.44
7/26/2006	59,632	60K service	\$346.86
8/21/2006	65,947	Changed oil	\$38.31
9/12/2006	71,030	Changed oil, replaced wiper blades	\$57.20
9/14/2006	71,053	Check engine light on - Code PA93 Inverter cooling system malfunction inverter coolant low	warranty
9/29/2006	73,015	Replaced windshield	\$272.87
10/6/2006	75,949	75K service	\$200.67
12/6/2006	90,270	Changed oil	\$39.60



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# HEV Life-Cycle Costs per Mile



# HICEV America Roush Testing Fact Sheet



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# NEVAmerica GEM Testing Fact Sheet (Draft)



**NEVAmerica**  
U.S. DEPARTMENT OF ENERGY ADVANCED VEHICLE  
TESTING ACTIVITY

**PERFORMANCE  
STATISTICS**



2007 Global Electric Motorcars  
eL XD

**VEHICLE SPECIFICATIONS**

**Base Vehicle:** 2007 Global Electric Motorcars eL XD 2-Passenger  
**VDN:** 5ASAK27477F042896  
**Seathelt Positions:** Two  
**Standard Features:**  
 Front Wheel Drive  
 Front Disc and Rear Drum Brakes  
 Regenerative Braking With Coast Down and Over Speed  
 Three-Point Safety Belts  
 Speedometer  
 Odometer  
 State-Of-Charge Meter  
 Back-up Alarm  
 On Board Battery Charger

**BATTERY**  
**Manufacturer:** East Penn Delco  
**Type:** 8G8VGC Gel Lead Acid  
**Number of Modules:** 9  
**Weight of Modules:** 30.8 kg  
**Weight of Pack(s):** 277.6 kg  
**Pack(s) Location:** Under Seat and Under Flatbed  
**Nominal Module Voltage:** 8V  
**Nominal System Voltage:** 72V  
**Nominal Capacity (C/1):** 85 Ah

**TIRES**  
**Tire Mfg:** Nankang  
**Tire Model:** Sceptor  
**Tire Size:** P185/70R13 86T  
**Tire Pressure:** 32 psi  
**Spare Installed:** No

**WEIGHTS**  
**Design Curb Weight:** 1572 lb  
**Delivered Curb Weight:** 1734 lb  
**Distribution F/R:** 56/44 %  
**GVWR:** 3000 lb  
**GAWR F/R:** 1380/1820 lb  
**Payload:** 936 lb  
**Performance Goal:** 400 lb

**DIMENSIONS**  
**Wheelbase:** 114.0 inches  
**Track F/R:** 45.5/45.5 inches  
**Length:** 144.0 inches  
**Width:** 55.0 inches  
**Height:** 71.0 inches  
**Ground Clearance:** 7.0 inches  
**Performance Goal:** 5.0 inches

**CHARGER**  
**Level 1:**  
**Location:** On-board  
**Type:** Conductive  
**Input Voltages:** 115/230 VAC  
**Level 3:**  
**Location:** Off-board  
**Type:** Conductive  
**Input Voltages:** 208 VAC 3-Phase  
 240 VAC 1-Phase

**Acceleration (0-20 mph) @ 332 lbs Payload**  
 At 100% SOC: 5.6 seconds  
 At 50% SOC: 5.9 seconds  
**Performance Goal:** 6.0 seconds

**Maximum Speed @ 170 lbs Payload (FMVSS 49 CFR 571.500 S5.a)**  
 At 100%: 24.9 mph  
**Performance goal** ≤ 25 mph

**Maximum Speed @ 332 lbs Payload**  
 At 100% SOC: Top Speed: 24.7 mph  
 At 50% SOC: Top Speed: 24.7 mph

**Maximum Speed Range<sup>1</sup>**  
**Range:** 50.4 miles  
**Energy Used:** 7.28 kWh  
**Average Power:** 3.59 kW  
**Efficiency:** 144.4 Wh-DC/mile  
**Specific Energy:** 26.22 Wh/kg

**Braking From 20 mph**  
**Controlled Dry:** 26 feet

**Gradeability (Calculated)**  
**Maximum Speed @ 3%:** 21.9 mph  
**Maximum Speed @ 6%:** 18.4 mph  
**Maximum Grade:** 33.3 %

**Charging Efficiency:**  
**Efficiency:** 292.4 Wh-Ac/mi  
**Energy Cost:** @ \$0.10/kWh: \$0.029/mi

**Level 1 Charger:**  
**Max Ground Current:** <0.01 mA  
**Max Battery Leakage:** <0.01 MIU  
**Max DC Charge Current:** 11.8 A  
**Max AC Charge Current:** 10.5 A  
**Peak AC Demand:** 1.28 kW  
**Time to Recharge:**  
 To 80%: 7.4 Hours  
 To 100%: 10.4 Hours  
 To Complete: 14.5 Hours  
**Performance Goal:** 100% SOC within 12 hours

**Level 3 Charger<sup>3</sup>**  
**Max Ground Current:** <0.01 mA  
**Max Battery Leakage:** <0.01 MIU  
**Max DC Charge Current:** 102.9 A  
**Max AC Charge Current:** 35.8 A  
**Peak Demand:** 10.36 kW  
**Time to Recharge:**  
 To Complete<sup>4</sup>: 1.1 Hours, 72.8% of Ahr Discharged

**TEST NOTES:**  
 1. Vehicle was operated at maximum attainable speed until 20 mph, coast no longer be maintained.  
 2. As delivered payload was 936 Lbs.  
 3. Level 3 charging was completed using 208 VAC 3-Phase input voltage.  
 4. Hours were calculated at time that charger indicated completion.

This vehicle meets all EV America Minimum Requirements listed on back.  
 Values in red indicate the Performance Goal was not met. \* All Power and Energy Values are DC unless otherwise specified.

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# eGSEAmerica FMC Pushback Tractor Testing Fact Sheet


**GSEVAMERICA**  
 U.S. DEPARTMENT OF ENERGY ADVANCED VEHICLE TESTING ACTIVITY



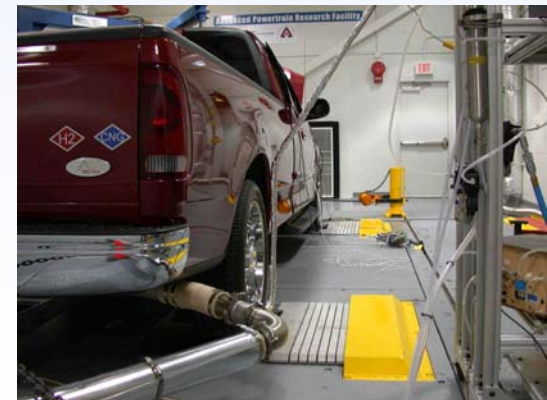
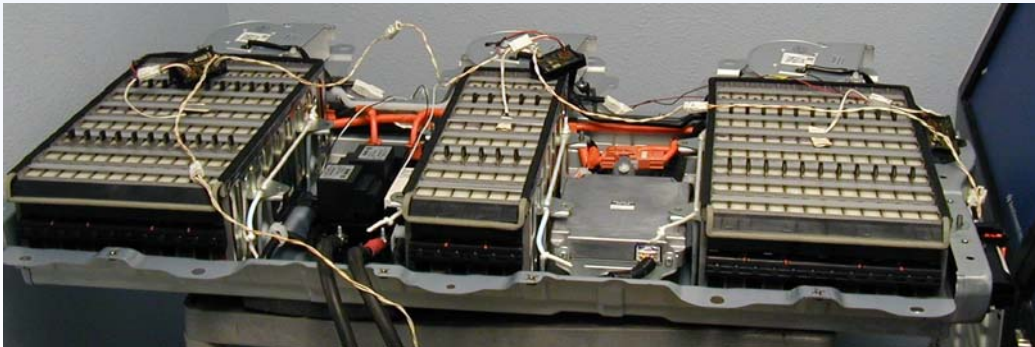
**FMC 160e Pushback Tractor**

VEHICLE SPECIFICATIONS	PERFORMANCE STATISTICS
<p><b>VEHICLE DESCRIPTION</b></p> <p>Vehicle Model: Expediter 160e                      Manufacturer: FMC                      Pushback Method: Towbar-less                      Rated Tow Capability: 160 M/T                      Installed Features:                      Windshield Wiper                      Turn Signal                      Universal Charger (offboard)                      Hazard Lights                      FWC Charge Inlet                      Dome Light                      Dual Drive Controls                      Pickup Camera                      Information Screen</p> <p><b>BATTERY</b></p> <p>Manufacturer: Sonnenschein                      Type: VRLA Gel                      Number of Modules: 56                      Pack(s) Location: Throughout chassis behind driver cabin area                      Nominal Module Voltage: 6 VDC                      Nominal System Voltage: 336 V                      Nominal Pack Capacity<sup>1</sup>: 180 Ah</p>	<p><b>WEIGHTS</b></p> <p>Delivered Curb Weight: 29,480 lbs                      Front Axle Weight: 24,950 lbs                      Rear Axle Weight: 4,530 lbs                      Distribution F/R: 84.6/15.4 %</p> <p><b>DIMENSIONS</b></p> <p>Wheelbase: 118.8 in                      Track F/R: 101.6/118.0 in                      Length: 285.5 in                      Width: 148.0 in                      Height: 70.0 in</p> <p><b>TIRES</b></p> <p>Tire Mfg: Michelin                      Tire Model: Stabix XZM                      Tire Size: 35S/65R15                      Tire Pressure F/R: 145/145psi                      Spare Installed: No</p> <p><b>MOTOR</b></p> <p>Model: SKAF405SS2188P                      Manufacturer: General Electric                      Type: Hydrostatic Drive                      Rated Efficiency @ Full Load: 95%                      Rated Output Power: 118 HP/88.1kW</p>
<p><b>TEST NOTES:</b></p> <ol style="list-style-type: none"> <li>1. Manufacturer rated capacity C/3 rate.</li> <li>2. Vehicle maximum force limited to 7000 lbs of force due to software control.</li> <li>3. Maximum force at speeds &gt;4 MPH.</li> <li>4. Maximum force at speeds &gt;9 MPH.</li> <li>5. Opportunistically fast charger.</li> <li>6. Overnight charger.</li> </ol> <p style="font-size: small; text-align: center;">This vehicle meets all HEV America Minimum Requirements listed on back of this sheet.                      Values in italics indicate the Performance Goal was not met. All Power and Energy Values are DC unless otherwise specified.</p>	<p><b>Maximum Speed</b></p> <p>No Load ~100% SOC: 5.3 MPH                      Performance Goal: 5 MPH                      No Load ~50% SOC: 5.4 MPH                      Performance Goal: 5 MPH</p> <p><b>Maximum Static Force</b></p> <p><b>100% SOC:</b>                      Maximum Measured Force: 11,172 lbs                      Required Battery Power: 72.1 kW  <b>50% SOC:</b>                      Maximum Measured Force: 4,250 lbs                      Required Battery Power: 33.6 kW</p> <p><b>Maximum Dynamic Force</b></p> <p><b>100% SOC:</b>                      Maximum Measured Force: 5,000 lbs                      Required Battery Power: 79.0 kW  <b>50% SOC:</b>                      Maximum Measured Force: 8,500 lbs                      Required Battery Power: 89.8 kW</p> <p><b>Charge Data</b></p> <p>Capacity Delivered: 49 Ahr                      Peak Demand: 15.5 kW                      Time to Recharge: 1.4 hours                      Performance Goal<sup>2</sup>: 12 hours</p>

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# FY08 Overall Testing Plans

- Continue role as DOE's whole vehicle system field tester
- Conduct baseline performance, accelerated and fleet testing on new vehicles with new technologies
- Continue to provide feedback to domestic automotive industry and other advanced technology stakeholders
- Continue presentations at industry and public events and disseminating testing results via the www
- FY08 budget is \$1,800k, with ~\$600k spent to date



# FY08 HEV Testing Plans

- **HEV accessory testing**
  - **Initial FY07 results from “parking lot test”**
    - **Camry exhibited ~1.5 kW peak demand**
    - **Highlander exhibited ~3.9 kW peak demand**
    - **Modeled assumptions are significantly lower**
  - **FY08 expanded testing to include Prius and Escape HEV accessory load testing**
    - **Power steering no input and at lock stop**
    - **Air conditioning at full compressor load and defrost compressor load**
    - **All optional accessories off at idle (initial condition) versus maximum blower speed, all accessory loads, power window operation, service brake operation and engine start**

# **FY08 HEV Testing Plans – cont'd**

- Initiate baseline performance testing of new HEVs available during FY08, including the Nissan Altima and two-mode General Motors Tahoe**
- Initiate 160,000 accelerated testing on 2 of each Altima and Tahoe HEV models**
- Continue accelerated testing on 2 Highlander, 2 Vue, 2 Civics, 2 Camry, and 2 Silverado HEVs**
- Conduct beginning of life testing on Tahoe and Altima HEV batteries**
- Conduct EoL HEV battery testing (at 160,000 miles) on Escape, Accord, Gen II Prius and Lexus RX400h HEVs**
- Continue to analyze data from onboard data loggers**
- Continue to provide 160,000-mile vehicles and components to other DOE laboratories for EoL testing**



# FY08 Testing Plans

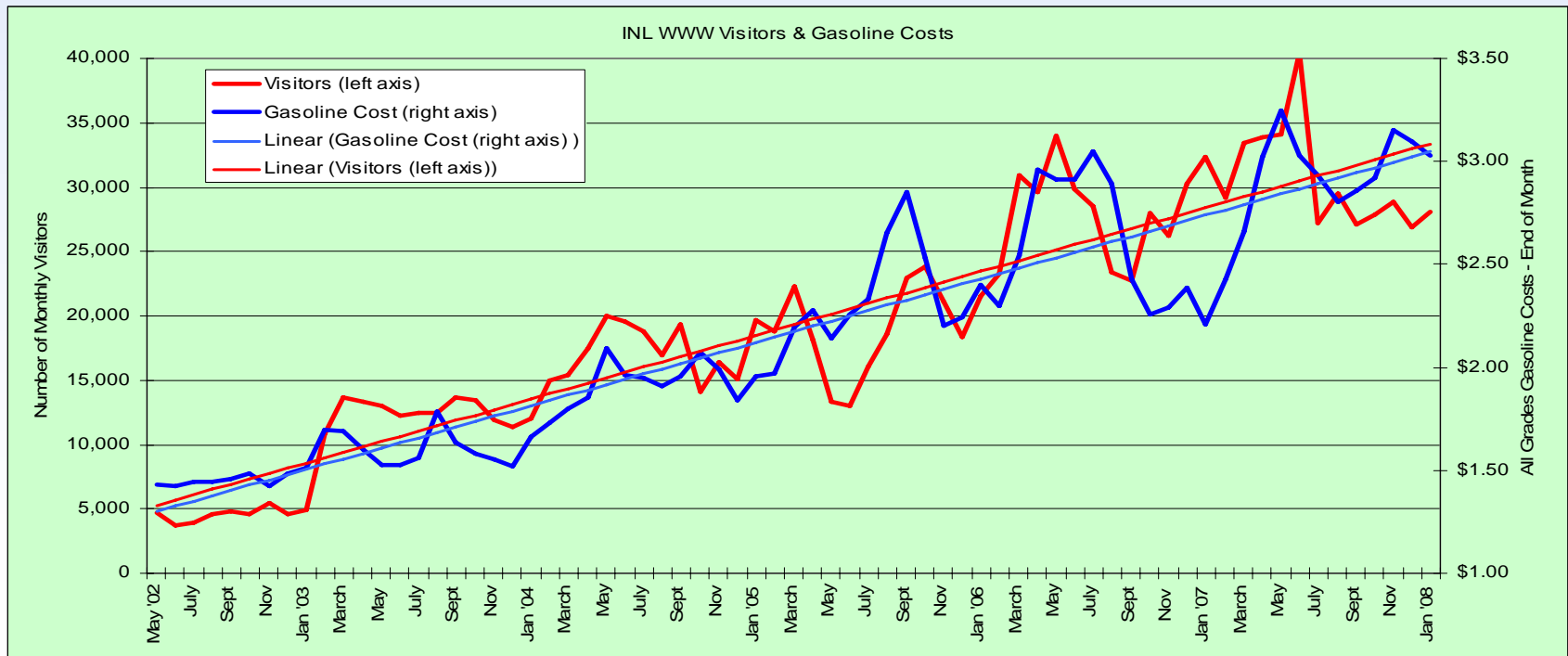
- **HICE Vehicles**
  - Continue to operate the eight HICE vehicles fueled at IWHUP and document fuel use, vehicle performance, and any additional effects hydrogen has on vehicle subsystems
  - Continue to analyze vehicle performance from onboard data loggers
  - Continue to evaluate candidate test vehicles and when appropriate, perform baseline performance and fleet testing on them
- **NEVs**
  - Initiate testing on two more GEM NEVs, one ZEN NEV, and one Miles Automotive NEV
  - Given the potential of this market and the expanding use of NEVs, the AVTA will support CARB and continue to test new entrants

# Vehicle Testing Summary

- **Continue to utilize testing partnerships to provide maximum test value to DOE**
  - **All testing activities are cost shared with private sector, such as the JPMorgan fleet that operates HEVs for the AVTA**
  - **All NEV and eGSE baseline performance testing is cost shared with manufacturers**
- **Battery testing results are provided to the energy storage technical team**
- **HEV testing results are provided to domestic OEMs via the vehicle simulation and analysis technical team every other month**
- **Testing results and life-cycle costs are used by vehicle modelers**
- **Partnering with private sector testers provides low-cost access to many testing facilities on a per-need basis**

# Vehicle Testing Summary – cont'd

- NEV testing for CARB supports higher vehicle standards in this vehicle segment
- AVTA testing results provide independent analysis of emerging technologies to Federal and other fleets that are early adaptors of advanced vehicle technologies
- Public use of AVTA webpages increases every year



# Acknowledgement

This work is supported by DOE's  
Vehicle Technologies Program

Hybrid Electric Systems Leader, Tien Duong

Vehicles and Systems Simulation and Testing Leader,  
Lee Slezak

## Additional Information

<http://avt.inl.gov>

or

<http://www1.eere.energy.gov/vehiclesandfuels/avta/>

INL/CON-08-13848