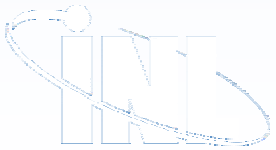
Idaho National Laboratory



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)**

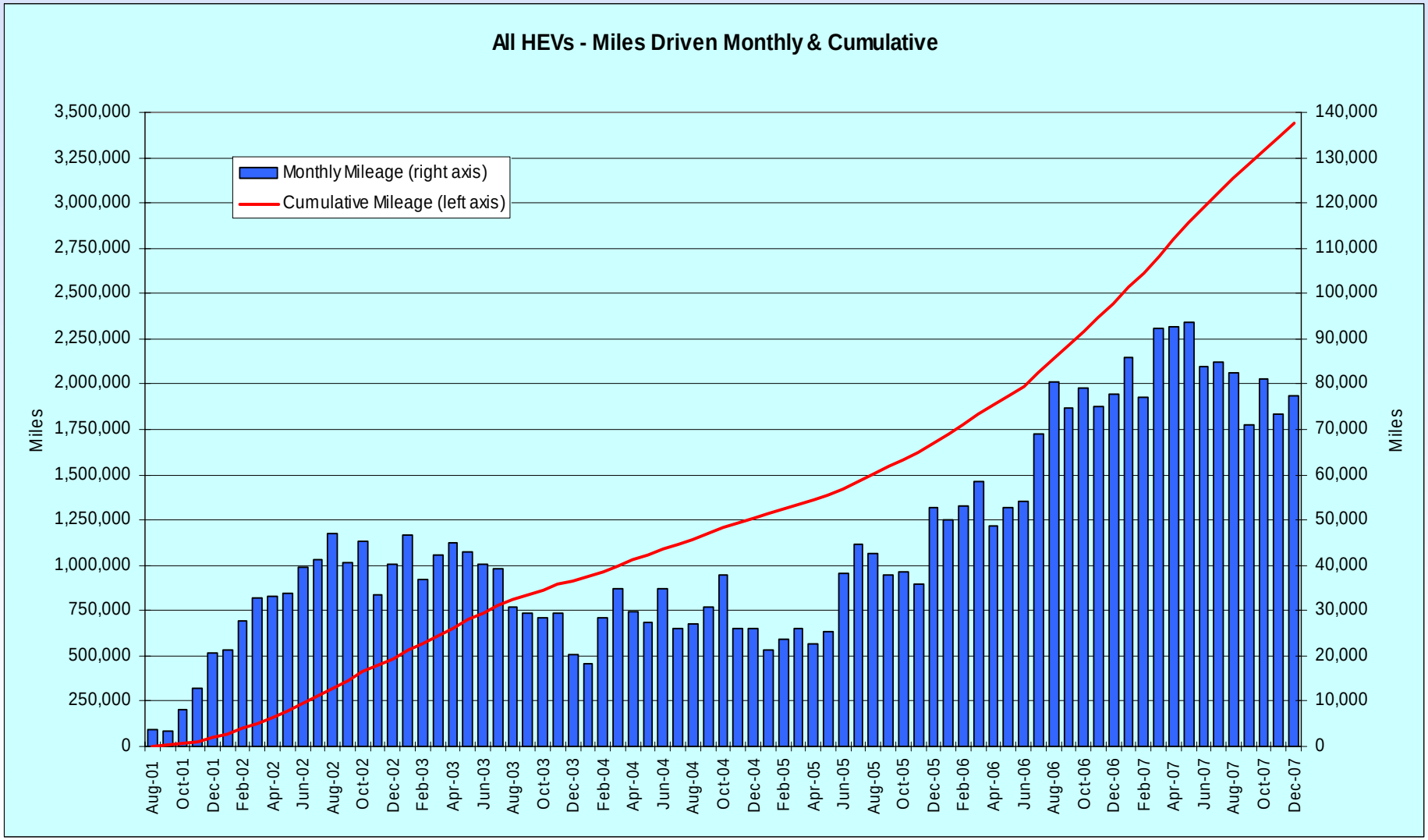
FY07 Testing Accomplishments – cont'd

- 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 subsidy
- 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

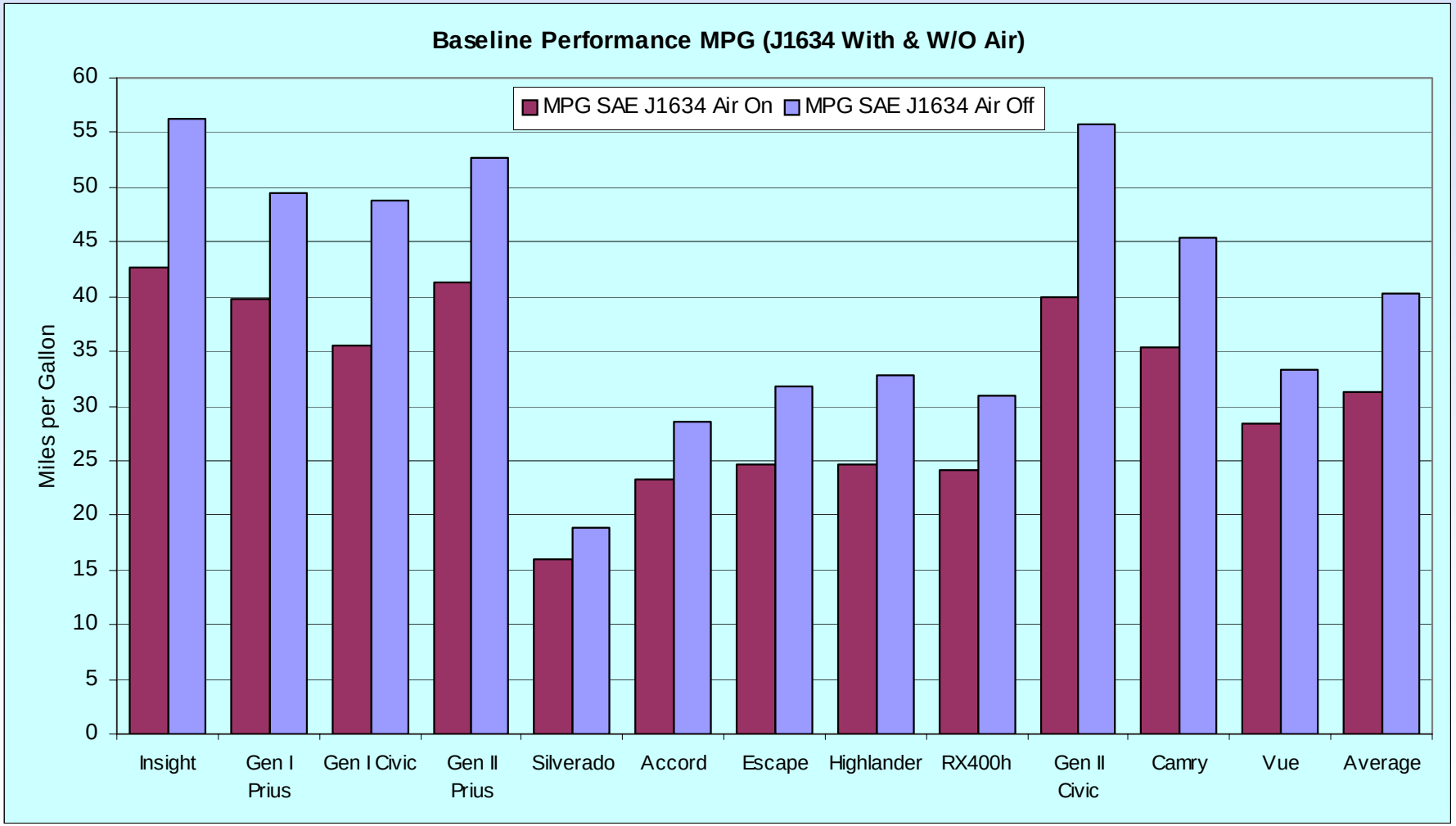
HEVs in Testing

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

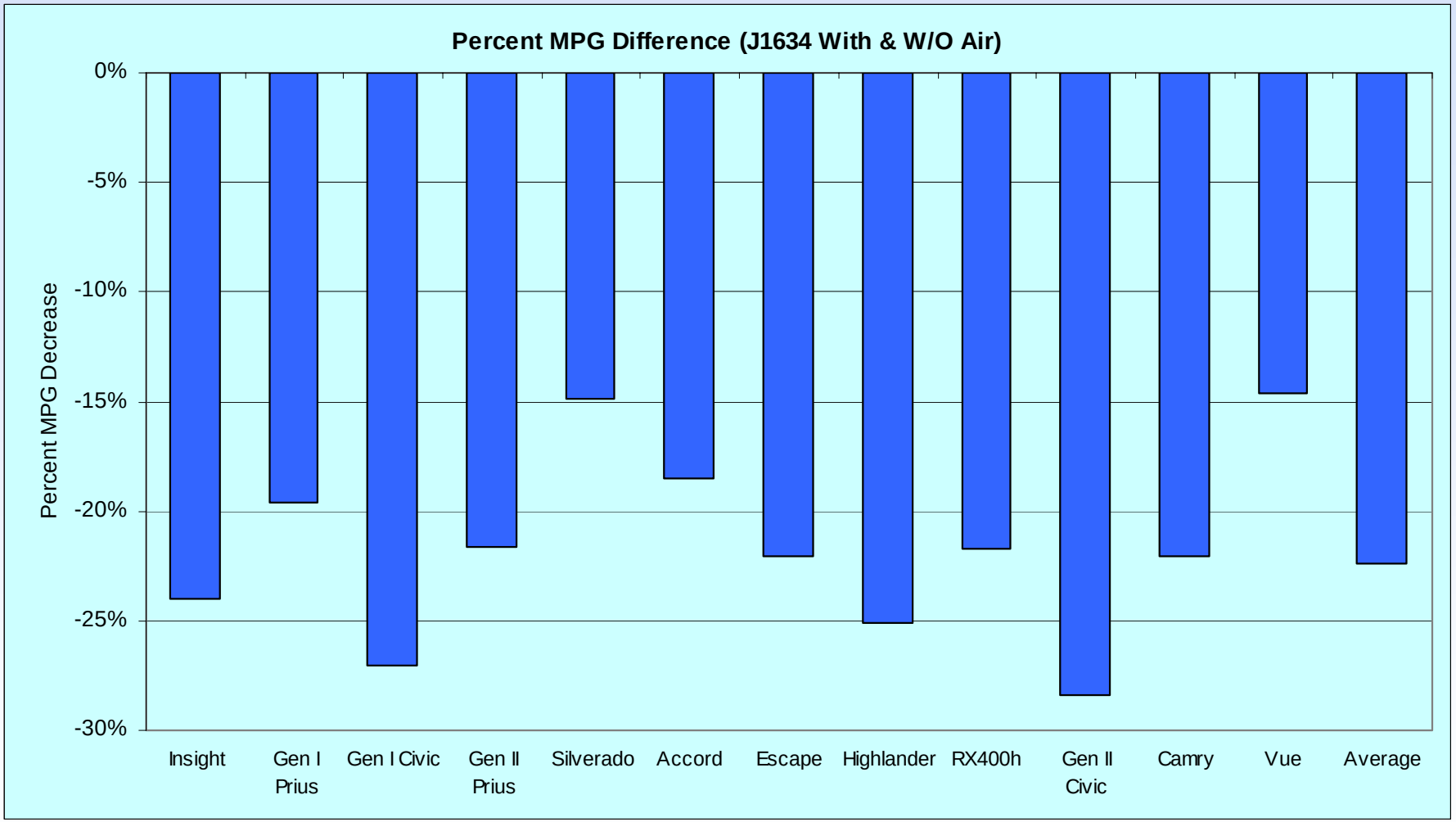
3.4 Million HEV Onroad Test Miles



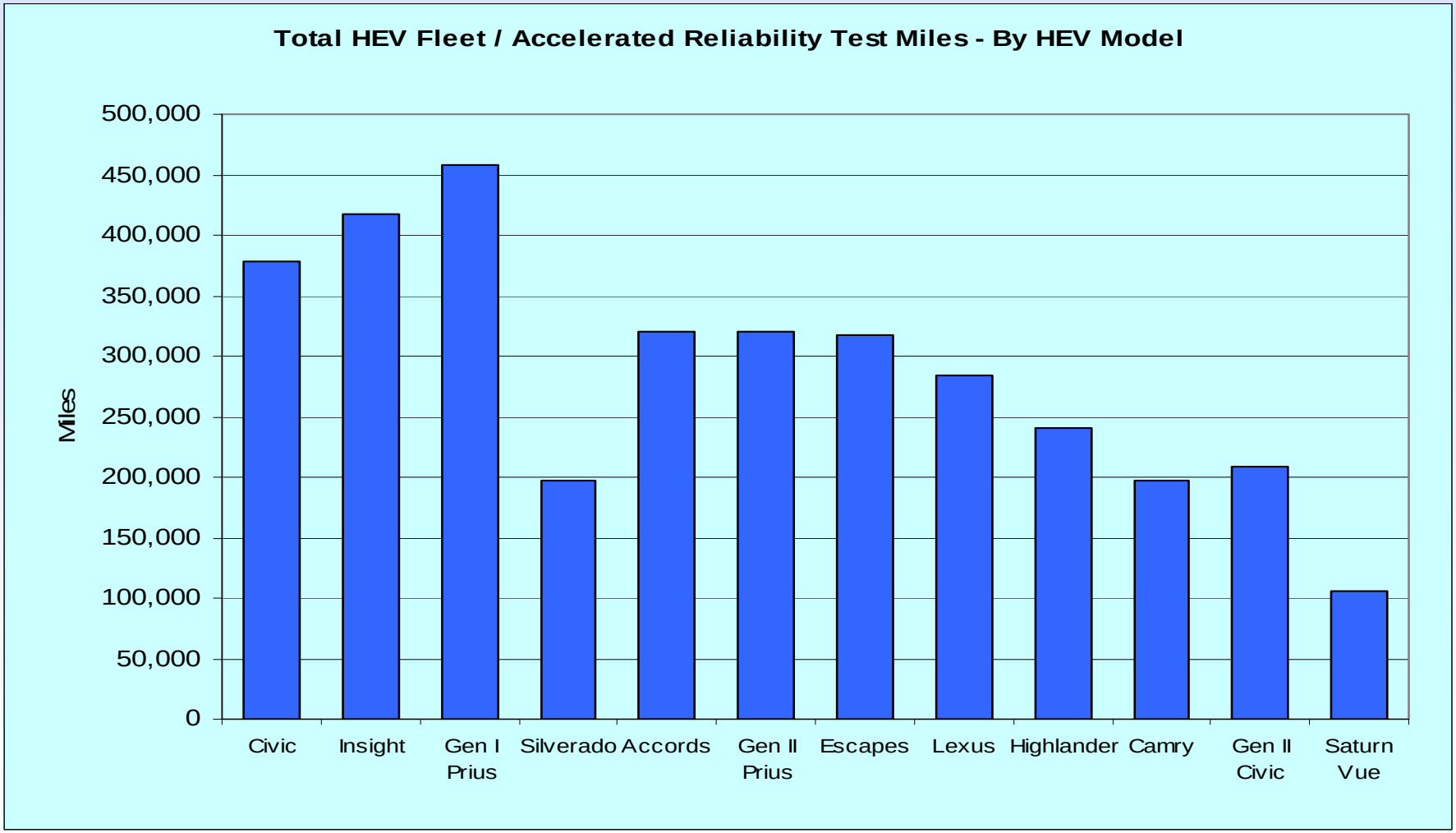
HEVs Baseline Performance Tested



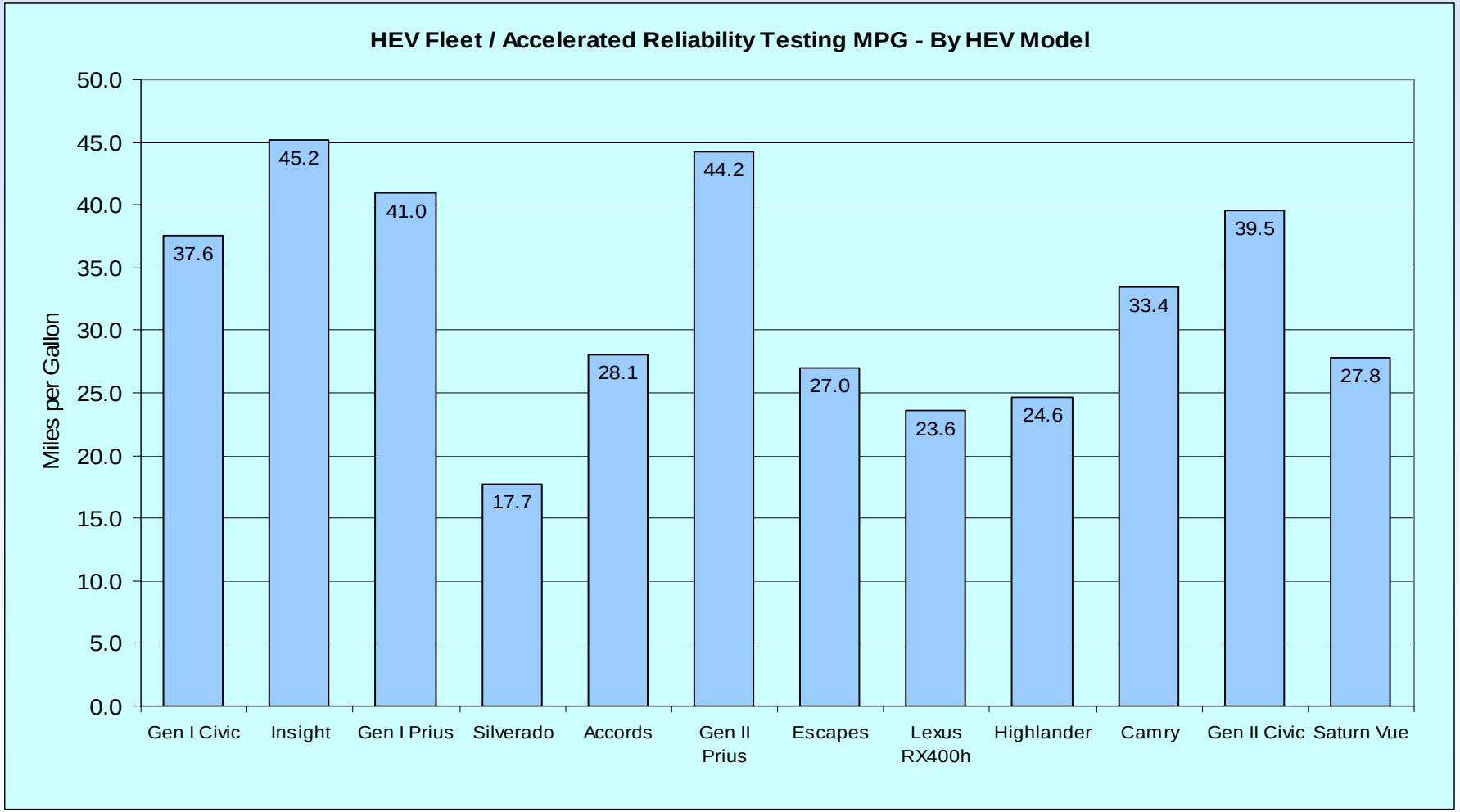
Percent HEV MPG Decrease - A/C on



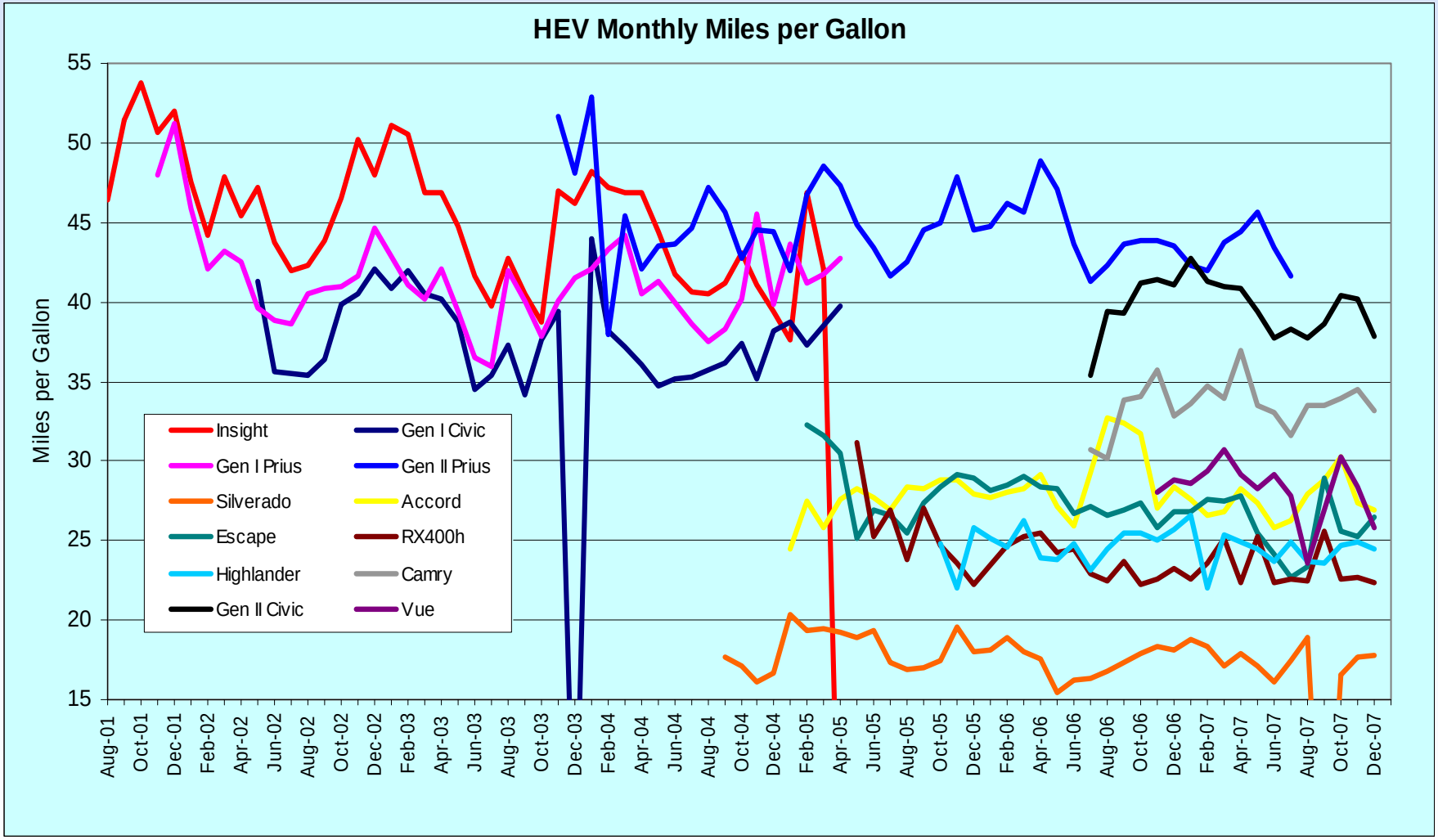
Onroad Test miles per HEV model



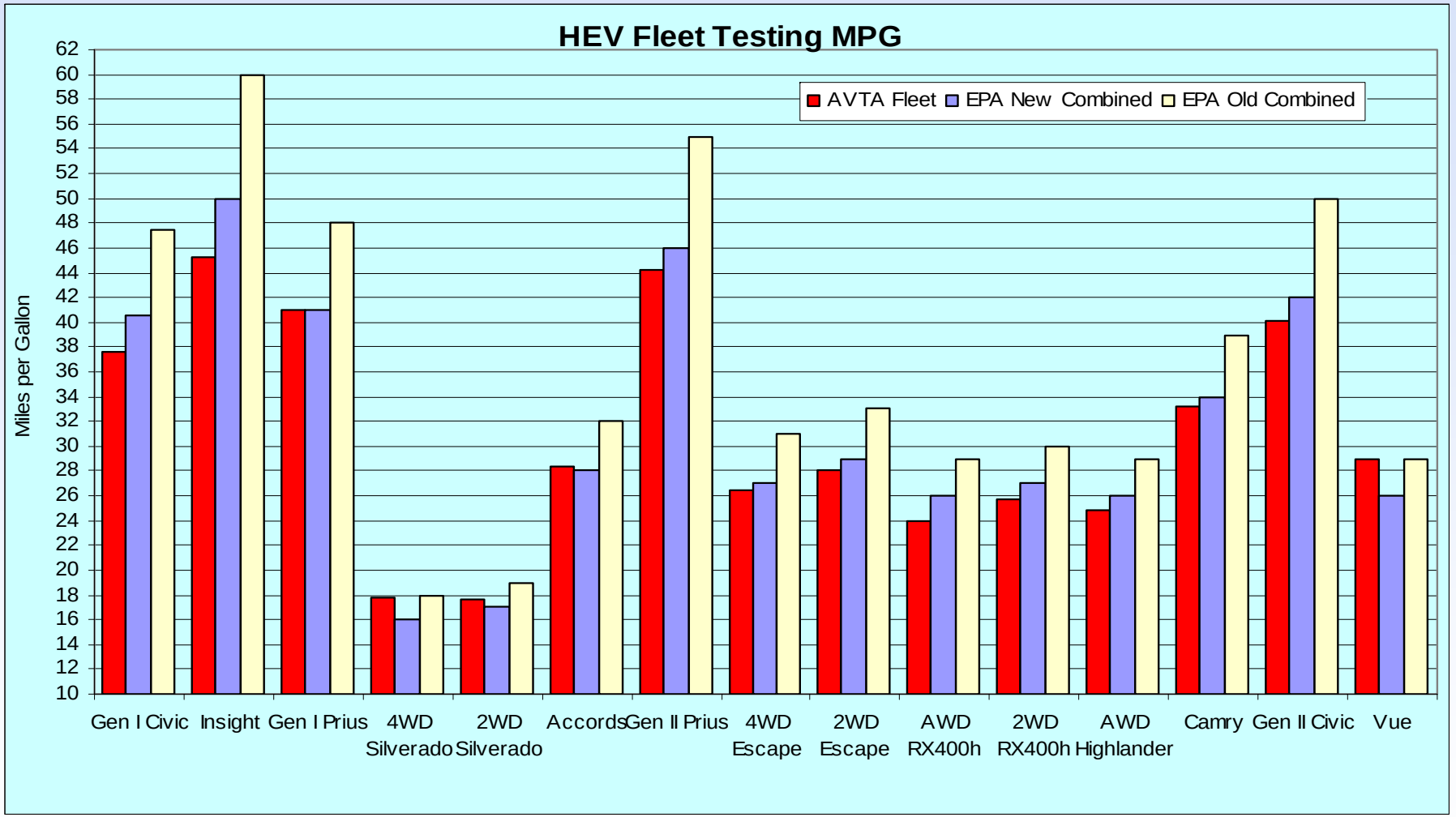
Onroad Miles per gallon by HEV model



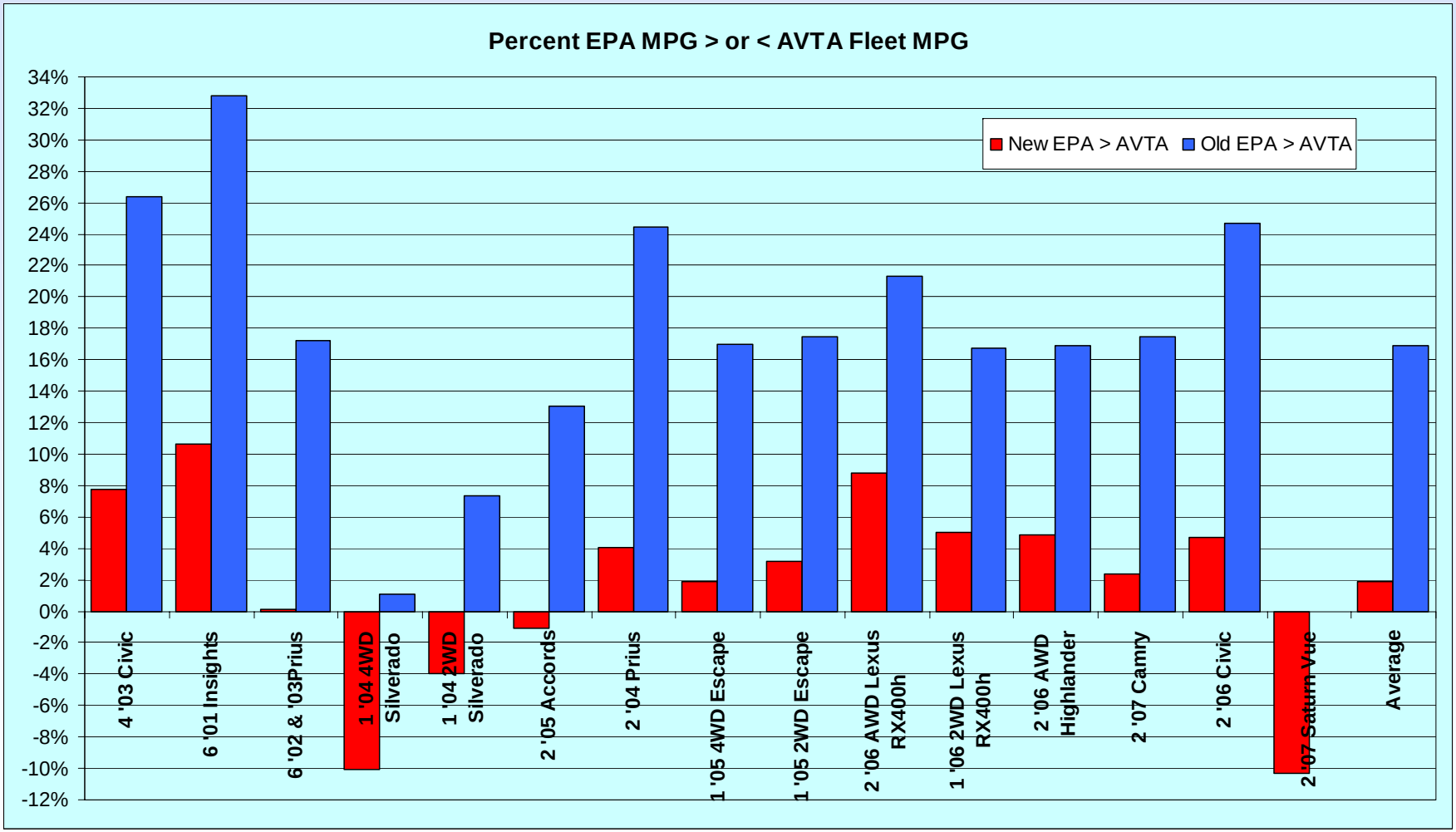
HEV Monthly Onroad MPG



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

U.S. Department of Energy
Energy Efficiency and Renewable Energy
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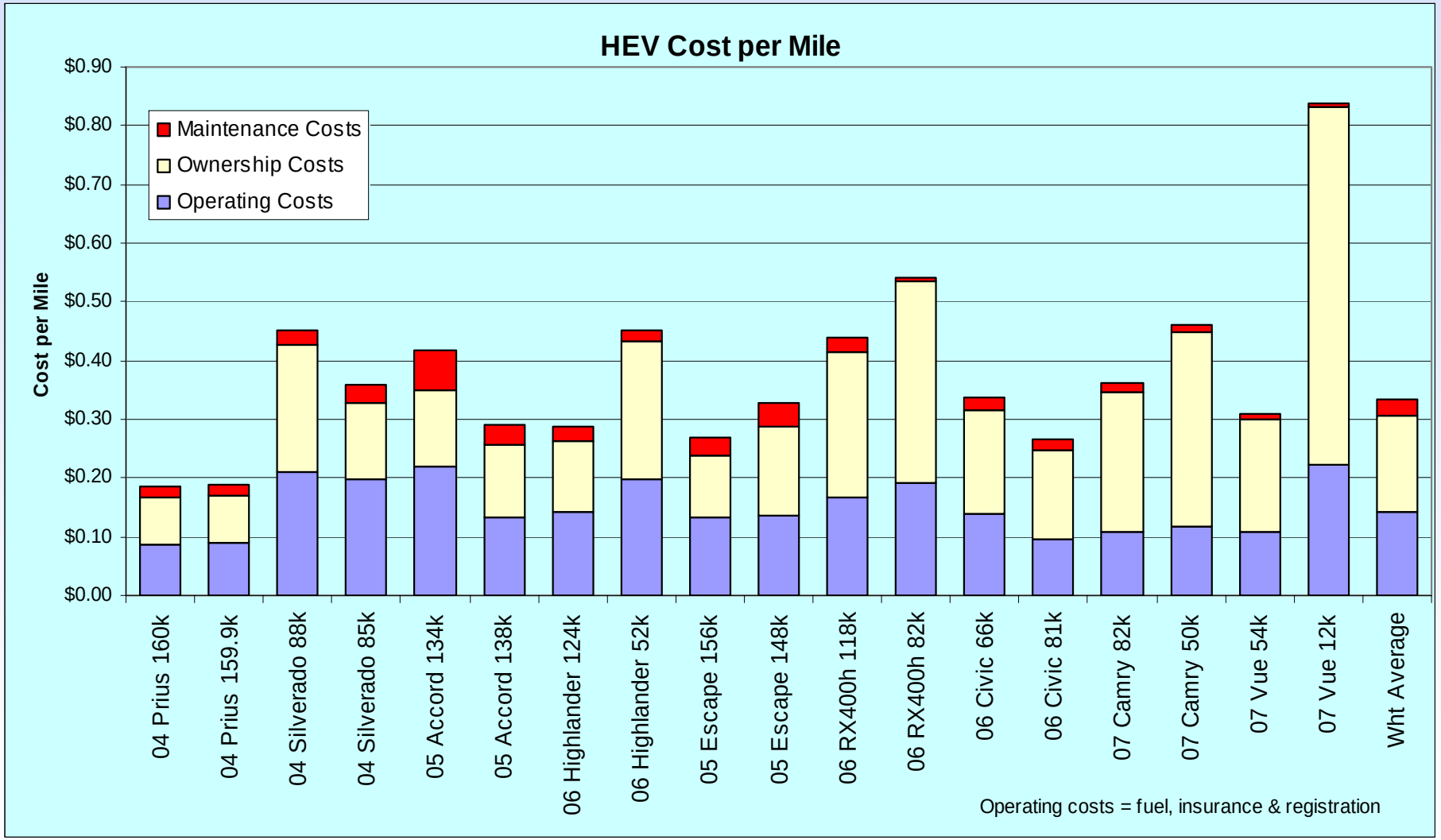
HEV Life-Cycle Costs per Mile



HICEVAmerica Roush Testing Fact Sheet

HICEV AMERICA

US DOE ADVANCED VEHICLE TESTING ACTIVITY

2005 Hydrogen ICE[1] Truck

VEHICLE SPECIFICATIONS

CONVERSION VEHICLE
Base Vehicle: 2005 Chevy Silverado
VIN: 1GCGC13U95F889816
Seatbelt Positions: Six
Features:
- 6.0L V8
- Fuel Injected
- 4 Speed Automatic Transmission
- Power Locks and Windows
- Front and Rear Disk Brakes
- Rear Wheel Drive
- Power Steering
- Air Conditioning
- AM/FM Stereo w/ CD Player
- Dual Airbags

FUEL TANKS
Manufacturer: Dynetek
Model: W15HI350G8
DOT Type 3[3]
Description: Carbon Fiber Wrap/ Aluminum Liner
Number of Tanks: 3
Tank Liquid Volume: 150 liters
Total Liquid Volume: 450 liters
Nominal Pressure: 5000 psi
Maximum Pressure: 6350 psi
Fuel Capacity[4]: 10.5 GGE[7]
Fueling Inlet: WEH C1C136

WEIGHTS
Base Design Curb Weight: 6300 lbs
Delivered Curb Weight: 5825lbs
Distribution F/R: 53/47%
GVWR: 8600 lbs
GAWR F/R: 4410/6000 lbs
Payload: 2775 lbs
Requirement: ≥ 400 lbs

DIMENSIONS
Wheelbase: 153.0 inches
Track F/R: 68.6/66.0 inches
Length: 237.2 inches
Width: 79.7 inches
Height: 77.0 inches
Rear Overhang: 48.6 inches
Ground Clearance: 7.4 inches
Requirement: ≥ 5.0 inches

TIRES
Tire Mfg: Bridgestone
Tire Model: V-Steel 265
Tire Size: 245/75 R16
Tire Pressure F/R: 50/80psi
Spare Included: Yes

TEST NOTES

1. Internal Combustion Engine.
2. 40 CFR 571.304
3. Maximum speed was determined from acceleration runs where overdrive was not used.
4. Fuel consumption was determined using the Ideal Gas Law.
5. Rough Road testing showed no damages to the fuel system or any other component of the vehicle.
6. At nominal pressure and 25°C.
7. Gasoline Gallons Equivalent

This vehicle meets all HICEV America Minimum Requirements listed on back.
Values in red indicate the Performance Goal was not met.

PERFORMANCE STATISTICS

Acceleration

ACCELERATION 0-60 mph
Acceleration Time: 21.98 seconds
Performance Goal: 13.5 seconds

MAXIMUM SPEED
Speed At One Mile: 79.2[5] mph
Performance Goal: ≥ 70 mph
Speed At Quarter Mile: 60.2 mph

CONSTANT SPEED FUEL ECONOMY
Distance Traveled: 61.78 miles
Average Speed: 44.94 mph
Fuel Consumed: 2.288[6] GGE[7]
Fuel Economy: 27.0 miles/GGE[7]

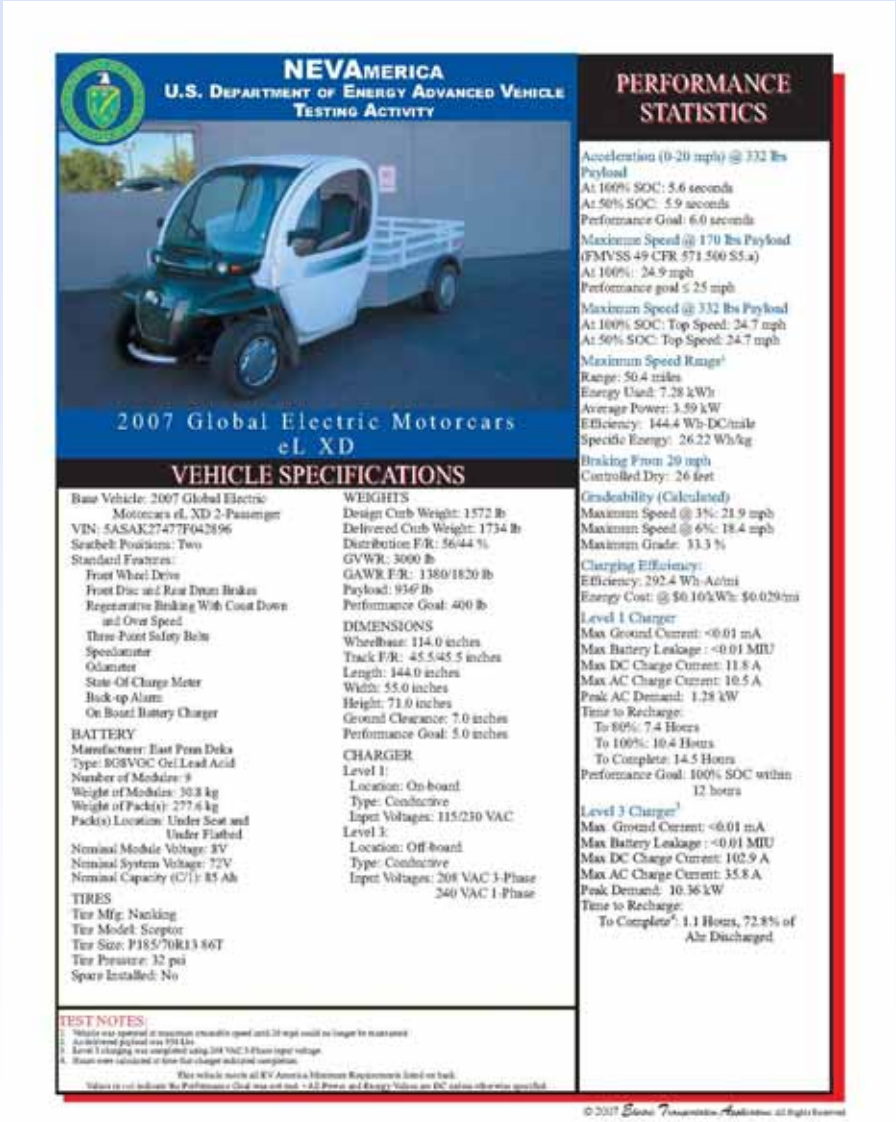
SAE J1634 DRIVING CYCLE FUEL ECONOMY (A/C OFF)
Distance Traveled: 35.2 miles
Fuel Consumed: 1.91[6] GGE[7]
Fuel Economy: 17.7 miles/GGE[7]

SAE J1634 DRIVING CYCLE FUEL ECONOMY (A/C ON)
Distance Traveled: 35.2 miles
Fuel Consumed: 2.22[6] GGE[7]
Fuel Economy: 15.2 miles/GGE[7]

BRAKING FROM 60 mph
Controlled Dry: 246.8 feet

GRADEABILITY (CALCULATED)
Maximum Speed @ 3%: 62.6 mph
Maximum Speed @ 6%: 52.1 mph
Maximum Grade: 33.2%

NEVAmerica GEM Testing Fact Sheet (Draft)



NEVAMERICA
U.S. DEPARTMENT OF ENERGY ADVANCED VEHICLE TESTING ACTIVITY

2007 Global Electric Motorcars eL XD

VEHICLE SPECIFICATIONS

Base Vehicle: 2007 Global Electric Motorcars eL XD 2-Passenger
VIN: 5ASAK27477F042896
Seatbelt 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 Deka
Type: 8G8VGC Gel Lead Acid
Number of Modules: 8
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: Nanking
Tire Model: Scepter
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

TEST NOTES:

PERFORMANCE STATISTICS

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[1]
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[3]
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[4]: 1.1 Hours, 72.8% of Ah Discharged

eGSEAmerica FMC Pushback Tractor Testing Fact Sheet

GSEVAmerica
U.S. Department of Energy Advanced Vehicle Testing Activity

FMC 160e Pushback Tractor

VEHICLE SPECIFICATIONS

VEHICLE DESCRIPTION
Vehicle Model: Expeditor 160e
Manufacturer: FMC
Pushback Method: Towbar-less
Rated Tow Capability: 160 M/T
Installed Features:
Windshield Wiper
Turn Signal
Universal Charger (offboard)
Hazard Lights
IWC Charge Inlet
Dome Light
Dual Drive Controls
Pickup Camera
Information Screen

BATTERY
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[1]: 180 Ah

WEIGHTS
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 %

DIMENSIONS
Wheelbase: 118.8 in
Track F/R: 101.6/118.0 in
Length: 285.5 in
Width: 148.0 in
Height: 70.0 in

TIRES
Tire Mfg: Michelin
Tire Model: Stabilx X2M
Tire Size: 355/65R15
Tire Pressure F/R: 145/145psi
Spare Installed: No

MOTOR
Model: 5KAF405SS2188P
Manufacturer: General Electric
Type: Hydrostatic Drive
Rated Efficiency @ Full Load: 95%
Rated Output Power: 118 HP/88.1kW

TEST NOTES:

PERFORMANCE STATISTICS

Maximum Speed
No Load ~100% SOC: 5.3 MPH
Performance Goal: 5 MPH
No Load ~50% SOC: 5.4 MPH
Performance Goal: 5 MPH

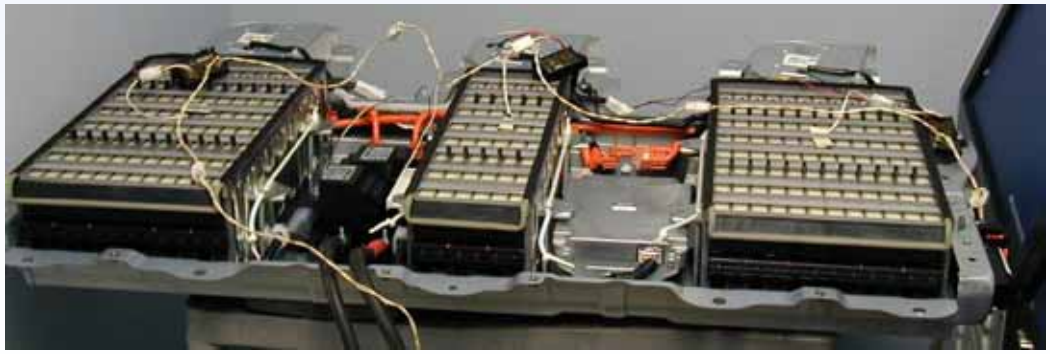
Maximum Static Force
100% SOC:
Maximum Measured Force: 11,172 lbs
Required Battery Power: 72.1 kW
50% SOC[2]:
Maximum Measured Force[2]: 4,250 lbs
Required Battery Power: 33.6 kW

Maximum Dynamic Force
100% SOC[3]:
Maximum Measured Force: 5,000 lbs
Required Battery Power: 79.0 kW
50% SOC[4]:
Maximum Measured Force: 8,500 lbs
Required Battery Power: 89.6 kW

Charge Data
Capacity Delivered: 49 Ahr
Peak Demand: 15.5 kW
Time to Recharge[5]: 1.4 hours
Performance Goal[6]: 12 hours

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

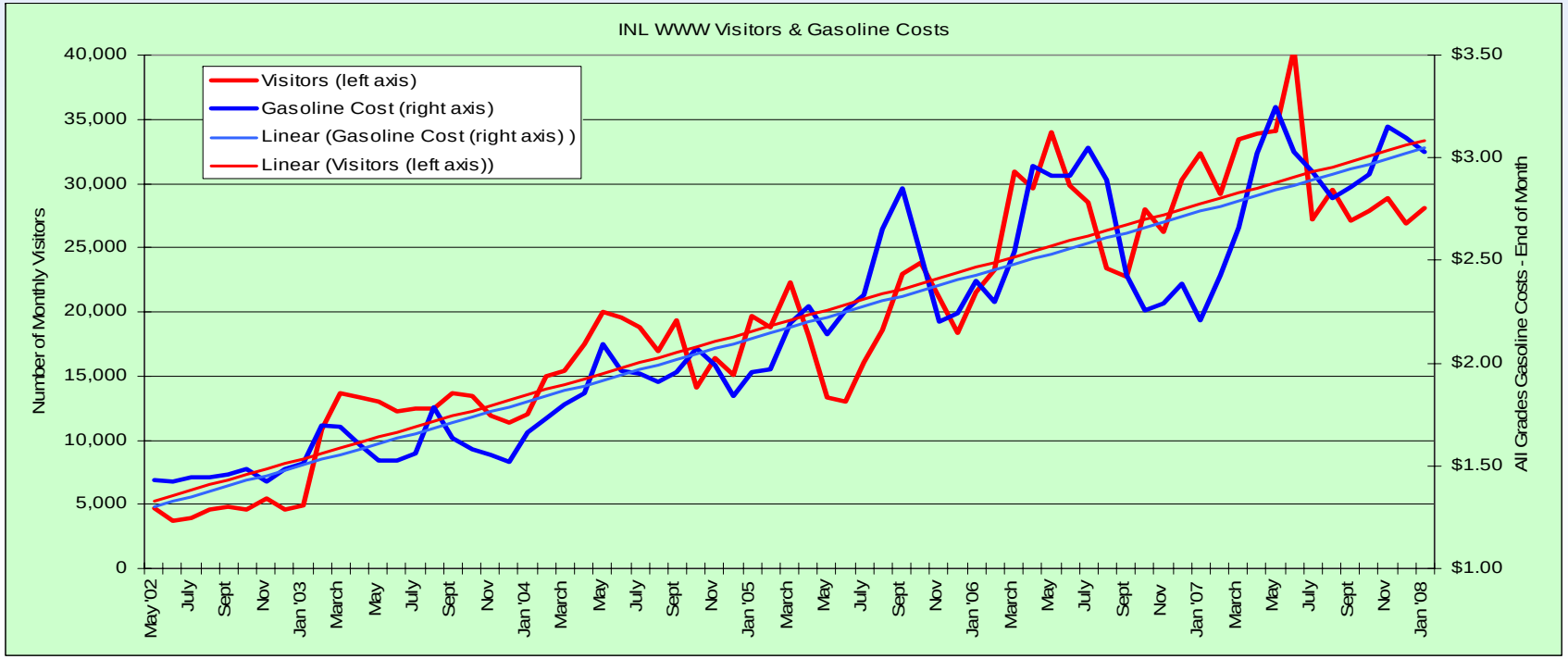
- **HICE Vehicles**
  - **Continue to operate the eight HICE vehicles fueled at IWHUP and document fuel use, vehicle performance, and any additional effects hydrogen has on vehicle subsystems**
  - **Continue to analyze vehicle performance from onboard data loggers**
  - **Continue to evaluate candidate 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