

Hybrid Electric Vehicle Fleet and Baseline Performance Testing

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Idaho National Laboratory

Presentation Outline

Background & goals

Testing partners

Baseline performance testing new HEVs

Fleet testing (160k miles in 36 months)

End-of-life testing (fuel economy & battery testing at 160k miles)

WWW information location

Background

Advanced Vehicle Testing Activity (AVTA) -
part of DOE's FreedomCAR and Vehicle
Technologies Program

Goal - provide benchmark data for technology
modeling, and research and development
programs

Idaho National Laboratory manages these
activities, and performs data analysis and
reporting activities

Testing Partners

Qualified Vehicle Testers

- Electric Transportation Applications (lead)
- Arizona Public Service
- Bank One of Arizona
- Red Cross



Testing Methods

Baseline performance testing (dynamometer & closed track testing): vehicle-to-vehicle comparisons & controlled/repeatable testing

- Acceleration, max speed, braking, handling
- SAE J1634 drive-cycle fuel efficiency testing (UDS, UDS, HWFET, HWFET, 10 minute rest, UDS, UDS, HWFET, HWFET): 2 tests with air conditioning (AC) on & off

Testing Methods (cont'd)

Fleet (accelerated reliability) testing

- Fuel use, miles, maintenance & repairs, & life-cycle costs in fleet operations
- Two of each model tested to 160k miles

End-of-life (at 160k miles) testing

- Conduct battery capacity (Hybrid Pulse Power Characterization) & power testing (Static Capacity)
- Rerun SAE J1634 tests (AC on & off)

Baseline Performance Testing

2002 test vehicles


- Insight, Gen I Civic, Gen I Prius

2005 test vehicles

- Accord, Gen II Prius, Silverado (2WD), Escape (2WD)

2006 test vehicles

- Lexus RX400h, Toyota Highlander



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

2005 Honda Accord Hybrid Electric Vehicle

VEHICLE SPECIFICATIONS	PERFORMANCE STATISTICS
VEHICLE FEATURES Drive vehicle: 2005 Honda Accord Hybrid Electric Vehicle Model: Accord Hybrid Electric Vehicle Model Year: 2005 Model Code: 3.0L VTEC-E Hybrid Model Description: 4-Cylinder, 180 hp, 175 lb-ft torque Model Weight: 3500 lbs Model Length: 181.8 in Model Wheelbase: 108.3 in Model Ground Clearance: 5.1 in Model Max. Payload: 100 lbs Model Max. Towing Capacity: 1000 lbs Model Max. Trailer Capacity: 1000 lbs Model Max. Hitch Capacity: 100 lbs Model Max. Ball Capacity: 100 lbs Model Max. Axle Capacity: 100 lbs Model Max. Tire Capacity: 100 lbs Model Max. Fuel Capacity: 100 lbs Model Max. Fuel Tank Capacity: 100 lbs Model Max. Fuel Tank Volume: 100 lbs Model Max. Fuel Tank Weight: 100 lbs Model Max. Fuel Tank Height: 100 lbs Model Max. Fuel Tank Diameter: 100 lbs Model Max. Fuel Tank Area: 100 lbs Model Max. Fuel Tank Perimeter: 100 lbs Model Max. Fuel Tank Circumference: 100 lbs Model Max. Fuel Tank Surface Area: 100 lbs Model Max. Fuel Tank Volume: 100 lbs Model Max. Fuel Tank Weight: 100 lbs Model Max. Fuel Tank Height: 100 lbs Model Max. Fuel Tank Diameter: 100 lbs Model Max. Fuel Tank Area: 100 lbs Model Max. Fuel Tank Perimeter: 100 lbs Model Max. Fuel Tank Circumference: 100 lbs Model Max. Fuel Tank Surface Area: 100 lbs	PERFORMANCE STATISTICS Acceleration 0-60 mph @ 100% SOC: 11.4 seconds @ 50% SOC: 12.5 seconds @ 25% SOC: 14.5 seconds Performance Goal: 11.5 seconds Maximum Speed @ 100% SOC: 113.2 mph @ 50% SOC: 113.2 mph @ 25% SOC: 113.2 mph Performance Goal: 70 mph to one mile Driving Cycle Range w/1st Acceleration Any-Hours Cycle: 14.2 mi City Fuel Economy: 28.4 mpg City Range: 190 miles Driving Cycle Range w/1st Acceleration Any-Hours Cycle: 12.8 mi City Fuel Economy: 23.5 mpg City Range: 160 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 13.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles



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

2004 Chevy Silverado Hybrid Electric Vehicle

VEHICLE SPECIFICATIONS	PERFORMANCE STATISTICS
VEHICLE FEATURES Drive vehicle: 2004 Chevy Silverado Hybrid Electric Vehicle Model: Chevy Silverado Hybrid Electric Vehicle Model Year: 2004 Model Code: 3.0L VTEC-E Hybrid Model Description: 4-Cylinder, 180 hp, 175 lb-ft torque Model Weight: 3500 lbs Model Length: 181.8 in Model Wheelbase: 108.3 in Model Ground Clearance: 5.1 in Model Max. Payload: 100 lbs Model Max. Towing Capacity: 1000 lbs Model Max. Trailer Capacity: 1000 lbs Model Max. Hitch Capacity: 100 lbs Model Max. Ball Capacity: 100 lbs Model Max. Axle Capacity: 100 lbs Model Max. Tire Capacity: 100 lbs Model Max. Fuel Capacity: 100 lbs Model Max. Fuel Tank Capacity: 100 lbs Model Max. Fuel Tank Volume: 100 lbs Model Max. Fuel Tank Weight: 100 lbs Model Max. Fuel Tank Height: 100 lbs Model Max. Fuel Tank Diameter: 100 lbs Model Max. Fuel Tank Area: 100 lbs Model Max. Fuel Tank Perimeter: 100 lbs Model Max. Fuel Tank Circumference: 100 lbs Model Max. Fuel Tank Surface Area: 100 lbs	PERFORMANCE STATISTICS Acceleration 0-60 mph @ 100% SOC: 11.4 seconds @ 50% SOC: 12.5 seconds @ 25% SOC: 14.5 seconds Performance Goal: 11.5 seconds Maximum Speed @ 100% SOC: 113.2 mph @ 50% SOC: 113.2 mph @ 25% SOC: 113.2 mph Performance Goal: 70 mph to one mile Driving Cycle Range w/1st Acceleration Any-Hours Cycle: 14.2 mi City Fuel Economy: 28.4 mpg City Range: 190 miles Driving Cycle Range w/1st Acceleration Any-Hours Cycle: 12.8 mi City Fuel Economy: 23.5 mpg City Range: 160 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 13.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles

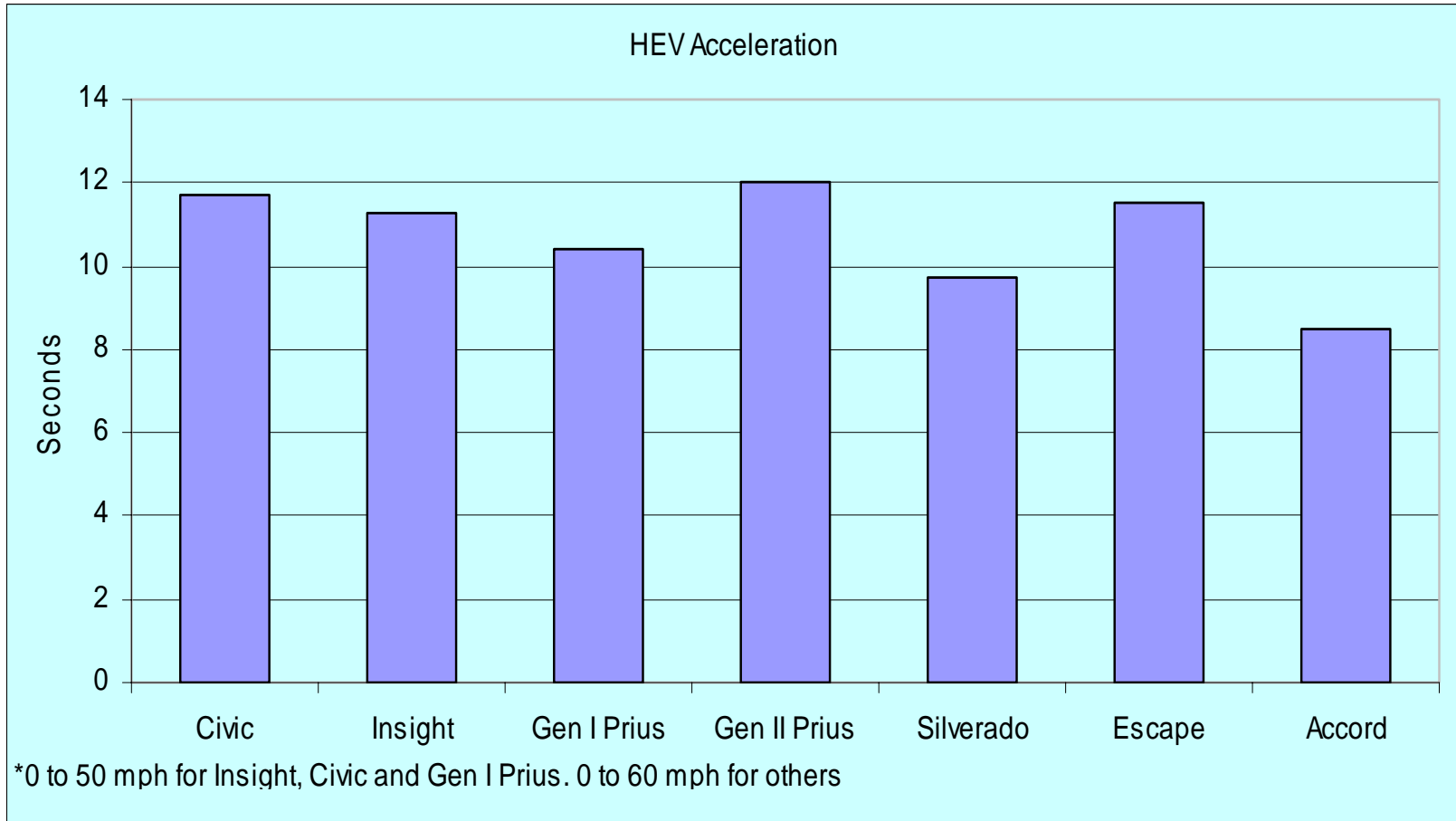


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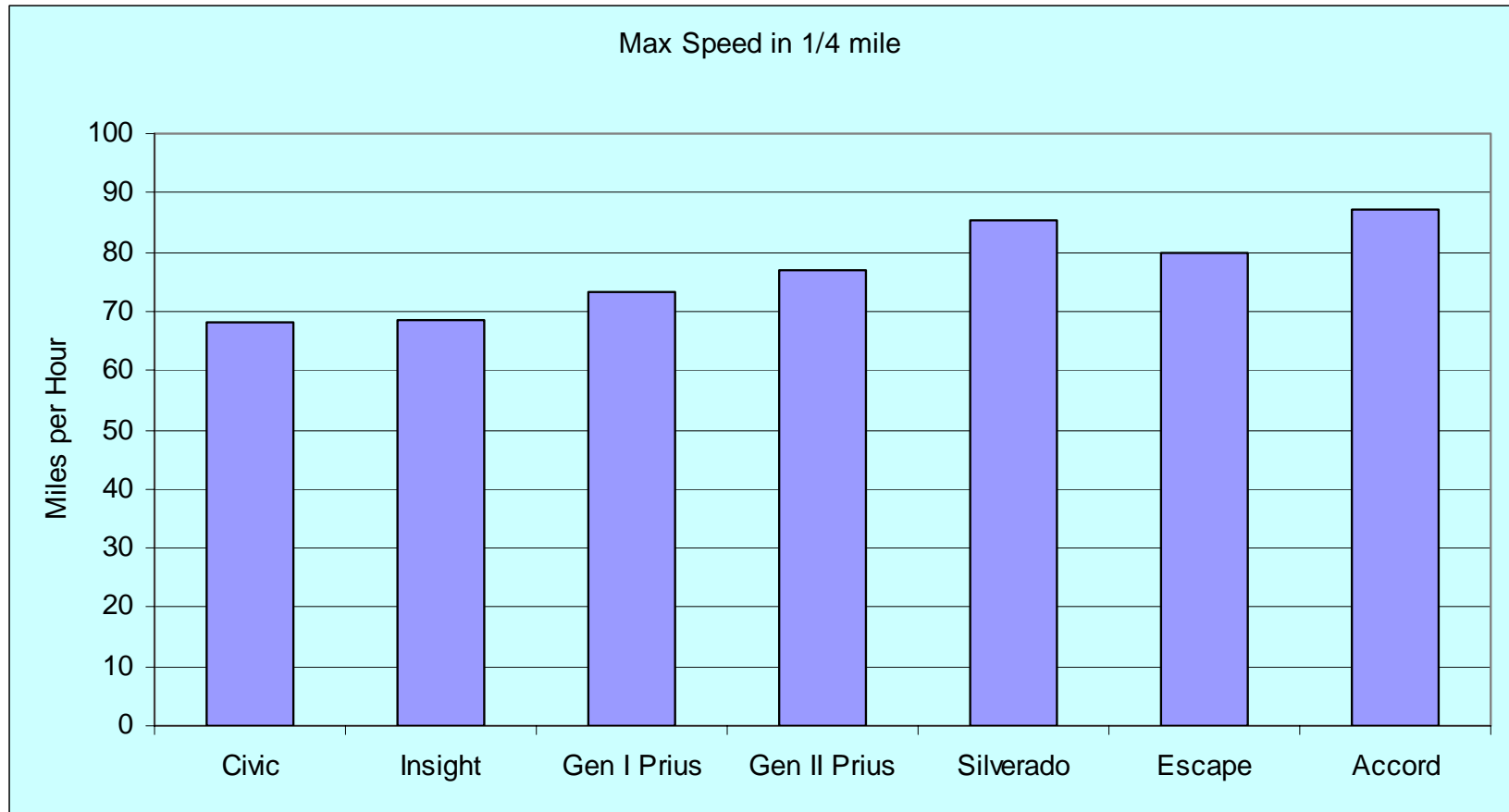
2005 Ford Escape Hybrid Electric Vehicle

VEHICLE SPECIFICATIONS	PERFORMANCE STATISTICS
VEHICLE FEATURES Drive vehicle: 2005 Ford Escape Hybrid Electric Vehicle Model: Ford Escape Hybrid Electric Vehicle Model Year: 2005 Model Code: 3.0L VTEC-E Hybrid Model Description: 4-Cylinder, 180 hp, 175 lb-ft torque Model Weight: 3500 lbs Model Length: 181.8 in Model Wheelbase: 108.3 in Model Ground Clearance: 5.1 in Model Max. Payload: 100 lbs Model Max. Towing Capacity: 1000 lbs Model Max. Trailer Capacity: 1000 lbs Model Max. Hitch Capacity: 100 lbs Model Max. Ball Capacity: 100 lbs Model Max. Axle Capacity: 100 lbs Model Max. Tire Capacity: 100 lbs Model Max. Fuel Capacity: 100 lbs Model Max. Fuel Tank Capacity: 100 lbs Model Max. Fuel Tank Volume: 100 lbs Model Max. Fuel Tank Weight: 100 lbs Model Max. Fuel Tank Height: 100 lbs Model Max. Fuel Tank Diameter: 100 lbs Model Max. Fuel Tank Area: 100 lbs Model Max. Fuel Tank Perimeter: 100 lbs Model Max. Fuel Tank Circumference: 100 lbs Model Max. Fuel Tank Surface Area: 100 lbs	PERFORMANCE STATISTICS Acceleration 0-60 mph @ 100% SOC: 11.4 seconds @ 50% SOC: 12.5 seconds @ 25% SOC: 14.5 seconds Performance Goal: 11.5 seconds Maximum Speed @ 100% SOC: 113.2 mph @ 50% SOC: 113.2 mph @ 25% SOC: 113.2 mph Performance Goal: 70 mph to one mile Driving Cycle Range w/1st Acceleration Any-Hours Cycle: 14.2 mi City Fuel Economy: 28.4 mpg City Range: 190 miles Driving Cycle Range w/1st Acceleration Any-Hours Cycle: 12.8 mi City Fuel Economy: 23.5 mpg City Range: 160 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 13.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles Braking From 60 mph w/1st Acceleration Any-Hours Cycle: 12.5 mi City Fuel Economy: 17.5 mpg City Range: 120 miles

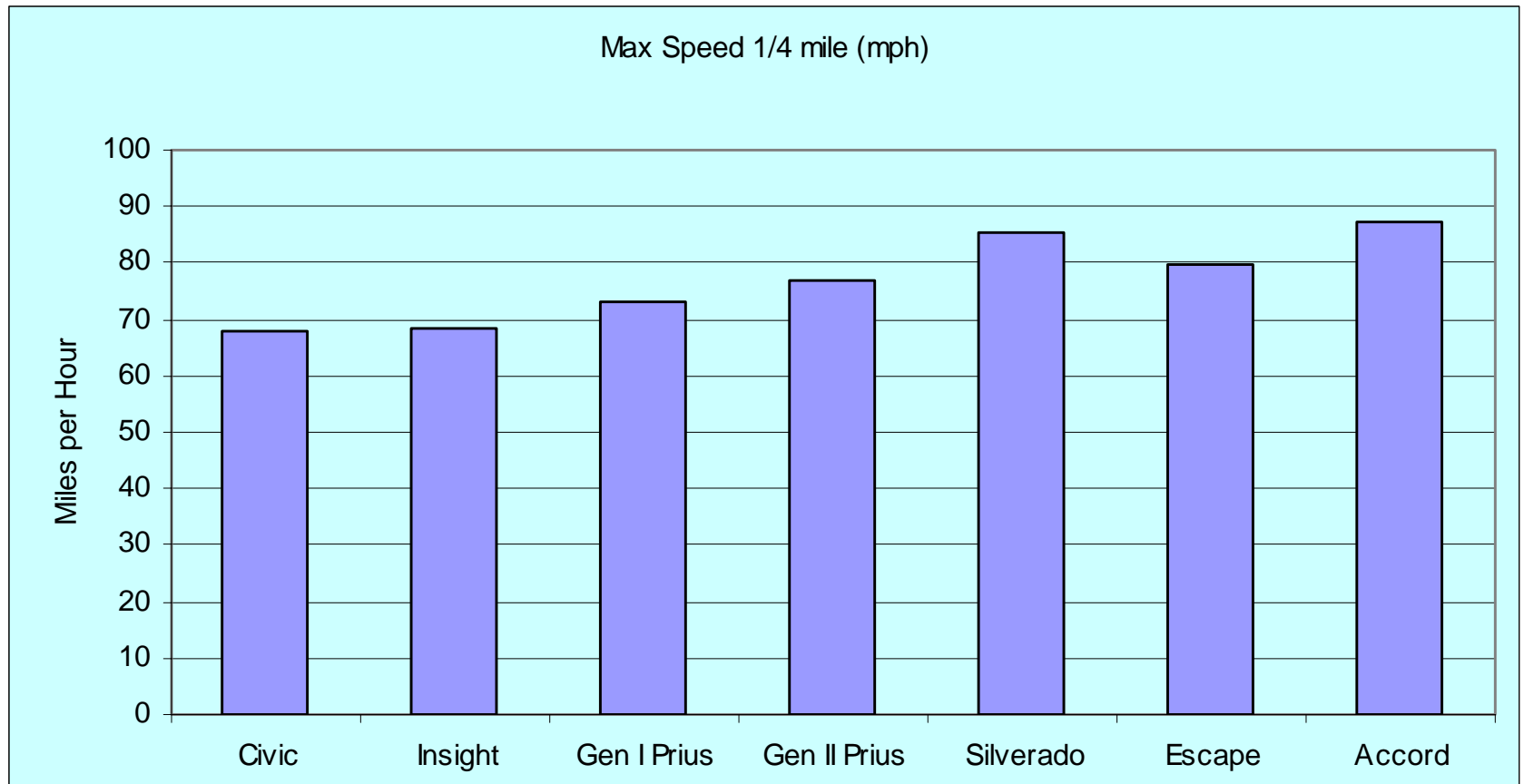
Acceleration 0 to 50 / 0 to 60 mph



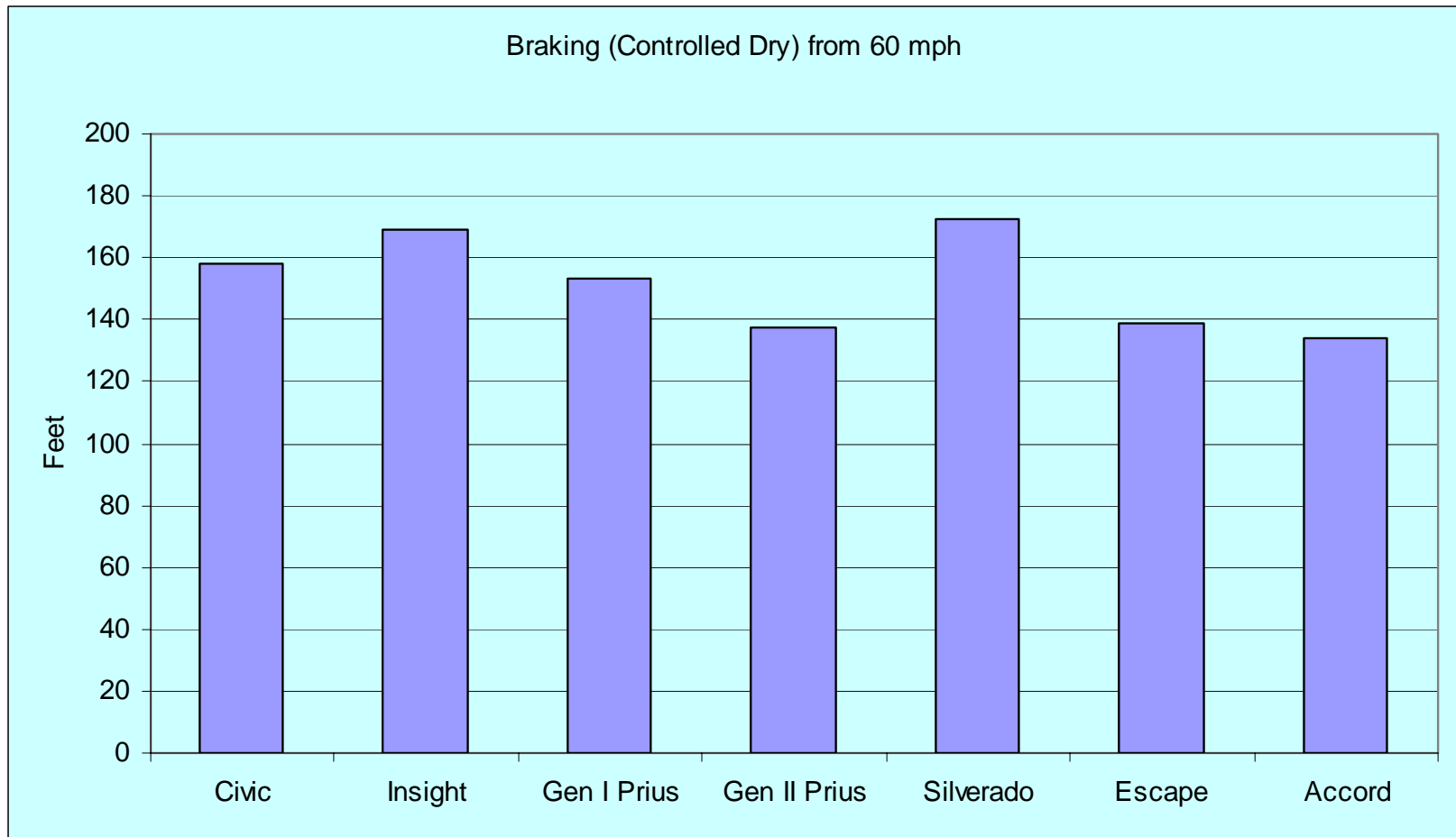
Maximum Speed in 1/4 Mile



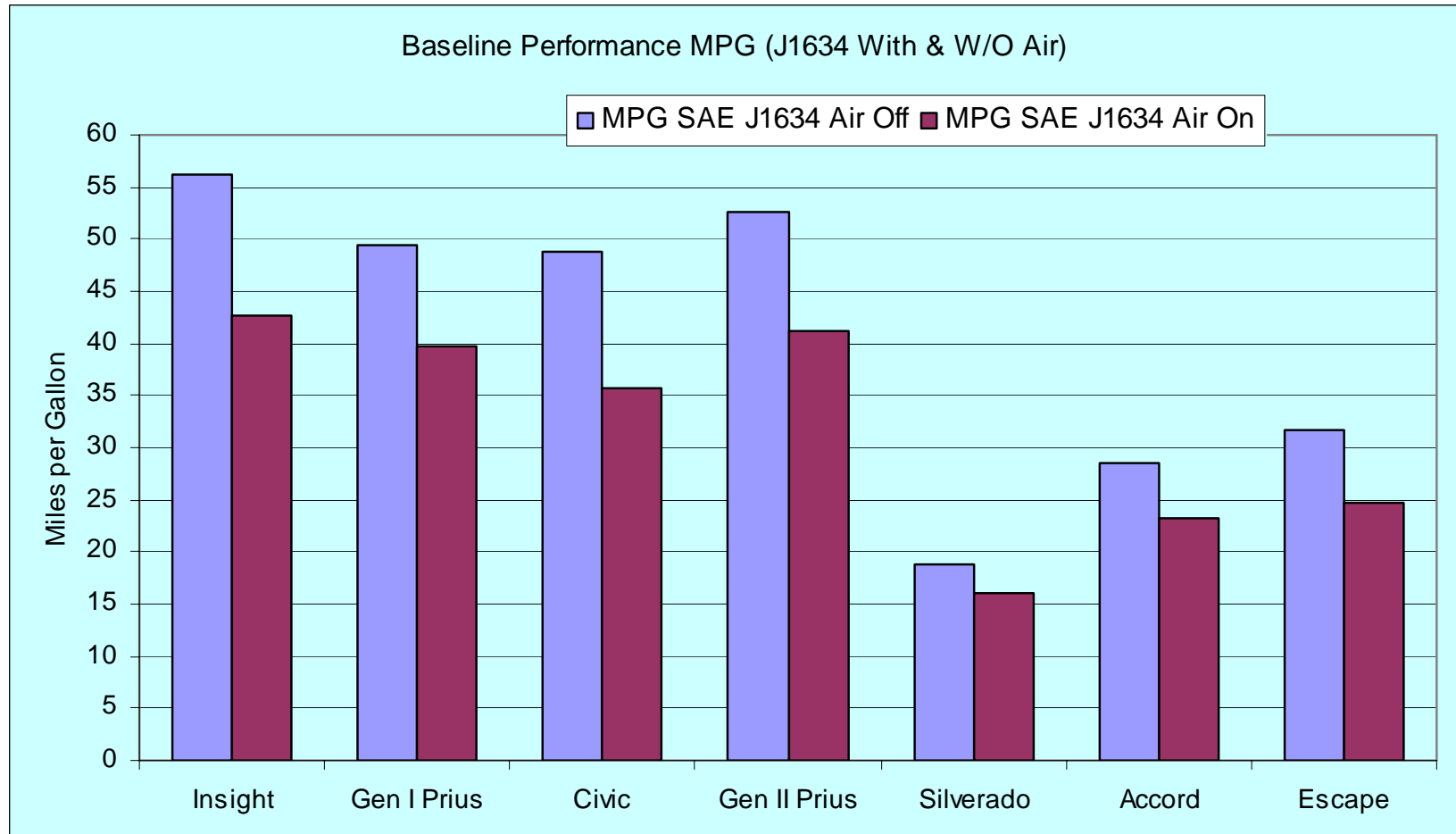
Maximum Speed @ 6% Grade



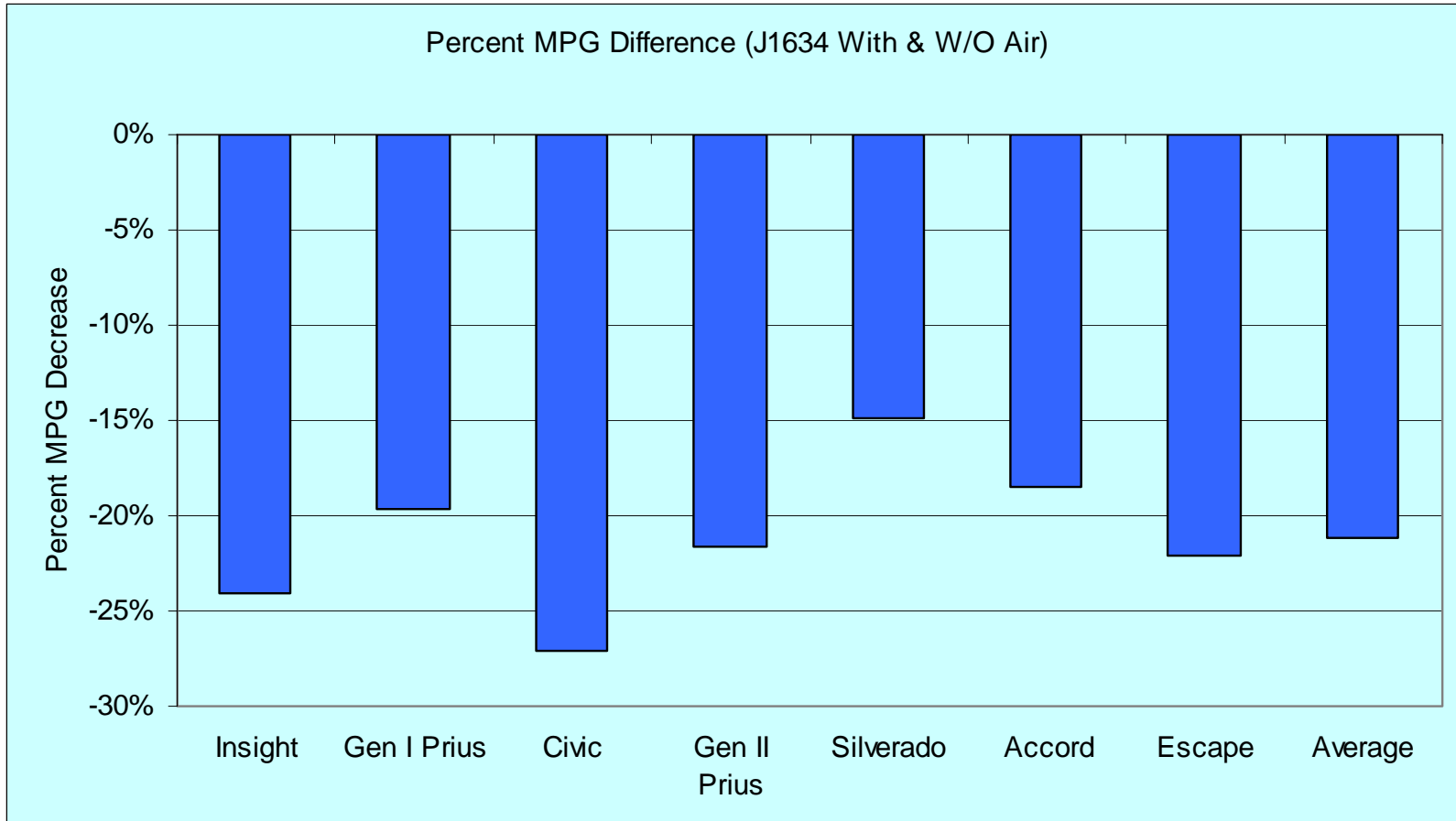
Braking: Dry from 60 mph



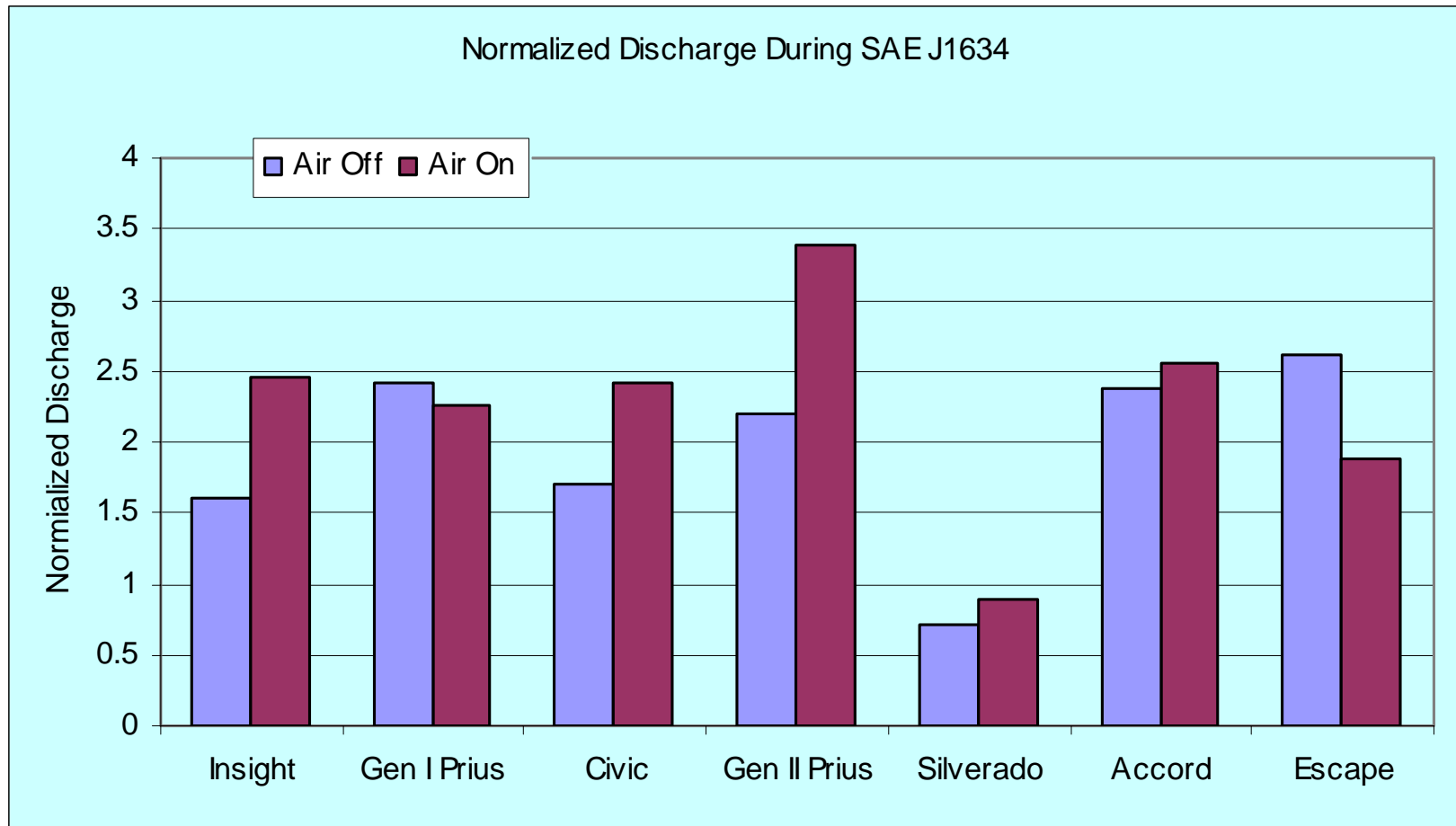
Baseline Performance MPG



MPG (J1634) - AC on/off Decrease



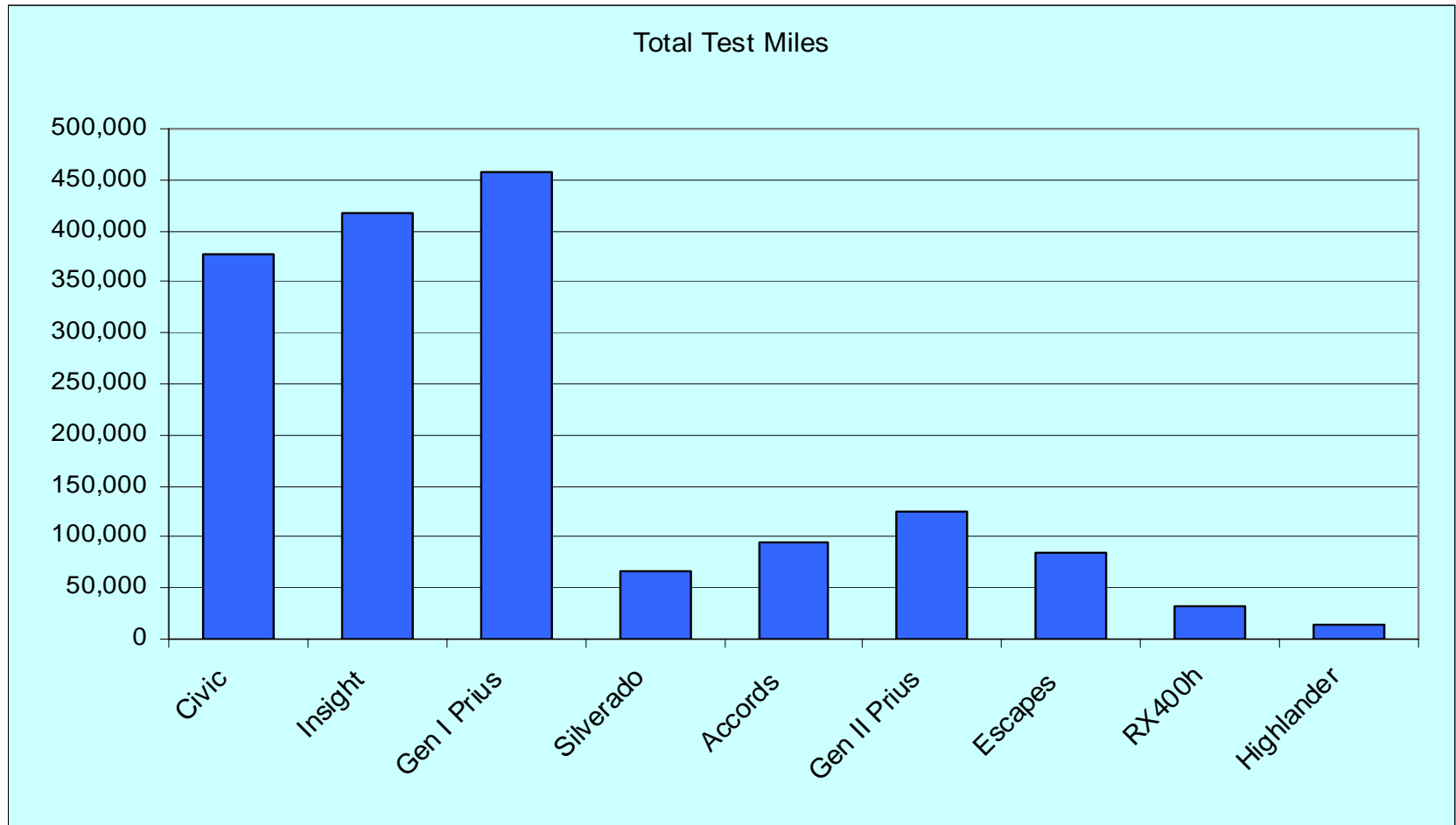
Normalized Discharge (J1634)



28 HEVs: Fleet Testing Status

6 - 2001 Insights:	Aug/01 - March/05
6 - 2002 Gen I Prius:	Nov/01 - April/05
4 - 2003 Gen I Civics:	May/02 - April/05
2 - 2004 Gen II Prius:	Nov/03 - ongoing
2 - 2004 Silverado:	Sept/04 - ongoing
2 - 2005 Accord:	Jan/05 - ongoing
2 - 2005 Escape:	April/05 - ongoing
2 - 2005 RX400h:	May/05 - ongoing
2 - 2006 Highlander:	Oct/05 - ongoing

1.7 Million HEV Fleet Test Miles



Fleet Testing Fact Sheets

Summarize real-world:

- Vehicle use
- Major maintenance & repair events
- Mileage profile
- Fuel use
- Life cycle operating costs

HEV Fleet Testing Advanced Vehicle Testing Activities



2002 Toyota Prius
MSRP \$17,995 (MSRP \$18,995)

Fleet Performance
Description: This vehicle was operated throughout the State of Arizona by Bank One of Arizona's courier pool. It was operated 24 hours a day, six days a week, transferring documents between branches and a central processing center located in Phoenix on city streets and urban freeways as well as interstate courier routes, with typical high-speed round trips of 100 to 300 miles.

Vehicle Specifications
Engine: 4-cylinder, 52 kW @ 4000 rpm
Electric Motor: 33 kW
Battery: Nickel Metal Hydride
Seating Positions: Five
Payload: 695 lbs
Features: Regenerative Braking
CVT Transmission

Major Operations & Maintenance Events:
Overheated due to high external temperature @ 87,138 miles. Cost: none
Rack and pinion failed @ 108,153 miles. Cost: Under Warranty

Operating Cost:

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle



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FREEDOMCAR & VEHICLE TECHNOLOGIES PROGRAM HEV Fleet Testing Advanced Vehicle Testing Activities



2003 Civic Hybrid
MSRP \$20,995 (MSRP \$21,995)

Fleet Performance
Description: This vehicle was operated throughout the State of Arizona by Bank One of Arizona's courier pool. It was operated 24 hours a day, six days a week, transferring documents between branches and a central processing center located in Phoenix on city streets and urban freeways as well as interstate courier routes, with typical high-speed round trips of 100 to 300 miles.


Vehicle Specifications
Engine: 4-cylinder, 76 kW @ 5700 rpm
Electric Motor: 18 kW
Battery: Nickel Metal Hydride
Seating Positions: Five
Payload: 882 lbs
Features: Regenerative Braking
CVT Transmission

Major Operations & Maintenance Events:
CVT transmission failed @ 98,102 miles. Cost: \$2,300
Catalytic converter failed @ 106,715 miles. Cost: \$1,164
Transmission failed @ 137,209 miles. Cost: \$2,438

Operating Cost:
Purchase Cost: \$23,174 (5/02)*
NADA Used Vehicle Price: \$10,043 (3/05)
Sales Price: Inoperative
Maintenance Cost: \$0.07/mile
Operating Cost: \$0.07/mile
Total Ownership Cost: \$12,226/mile

Operating Performance:
Total miles driven: 148,075
Cumulative MPG: 57.32

A Strong Energy Portfolio for a Strong America
Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.



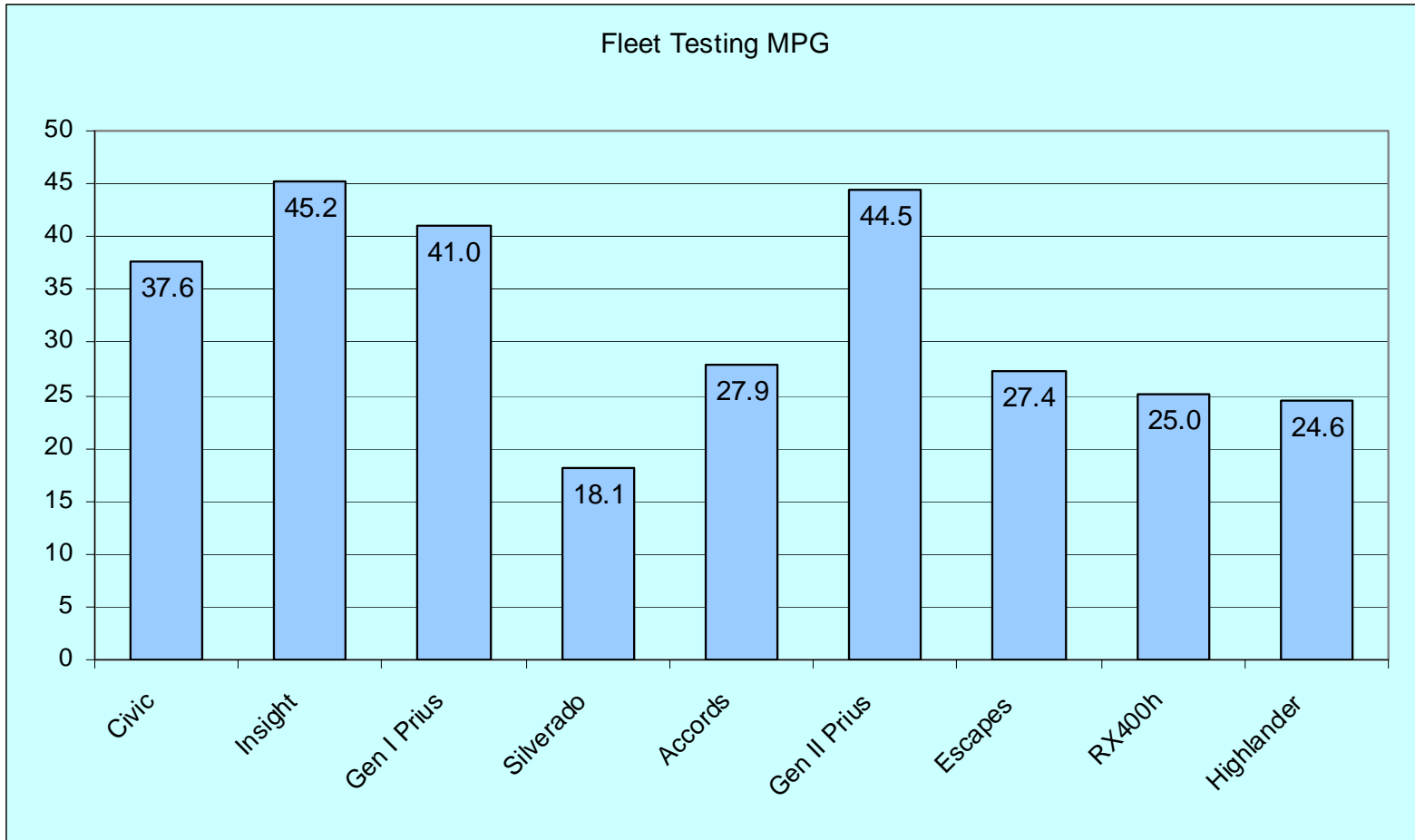
**U.S. Department of Energy
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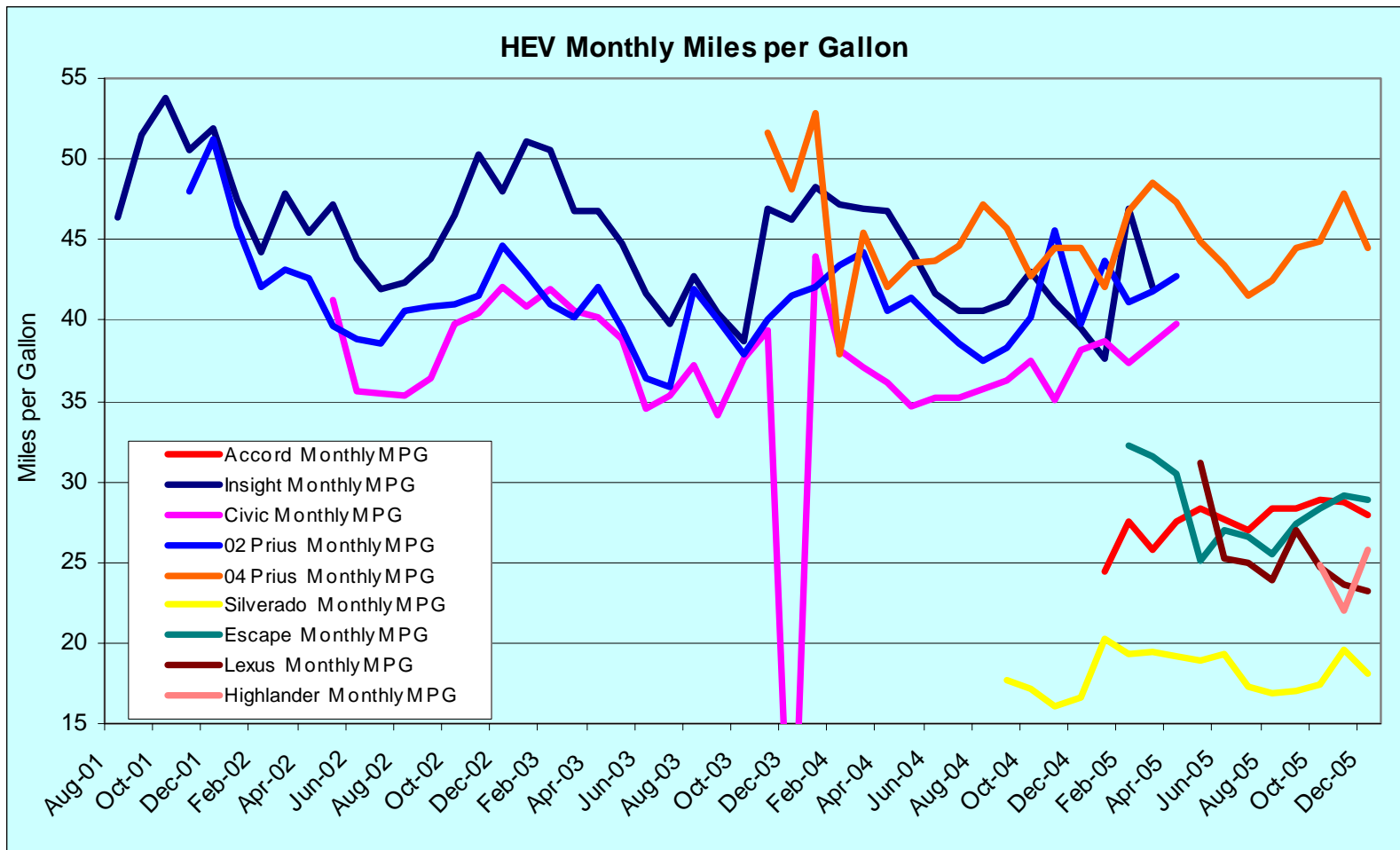
*Purchase includes dealer price with options plus taxes. It does not include title, license, registration, insurance, warranty or delivery fees.

For more information contact:
EERE Information Center
1-877-EERE-80F (1-877-337-3463)
www.eere.energy.gov

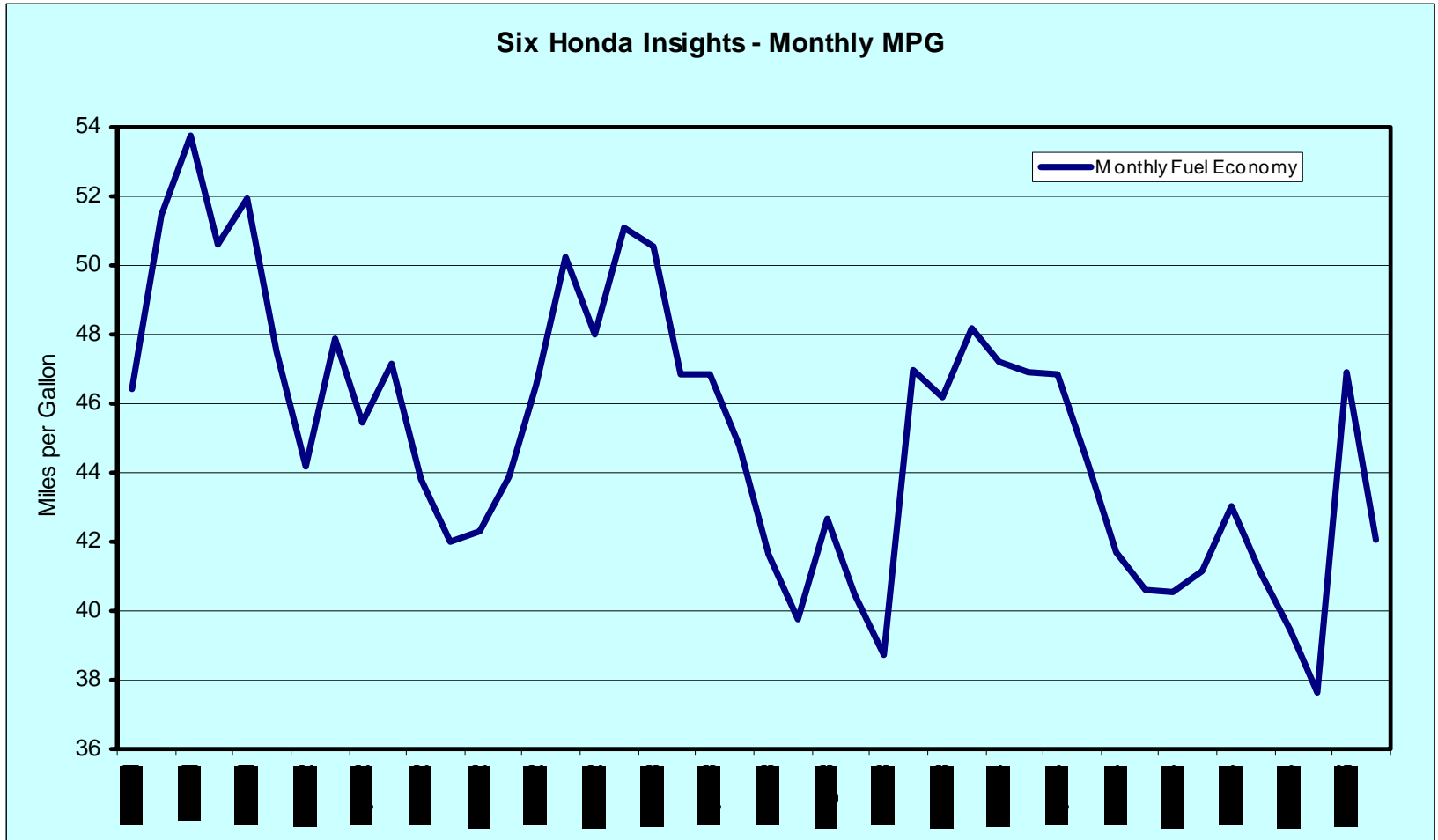
Fleet Testing Average MPG



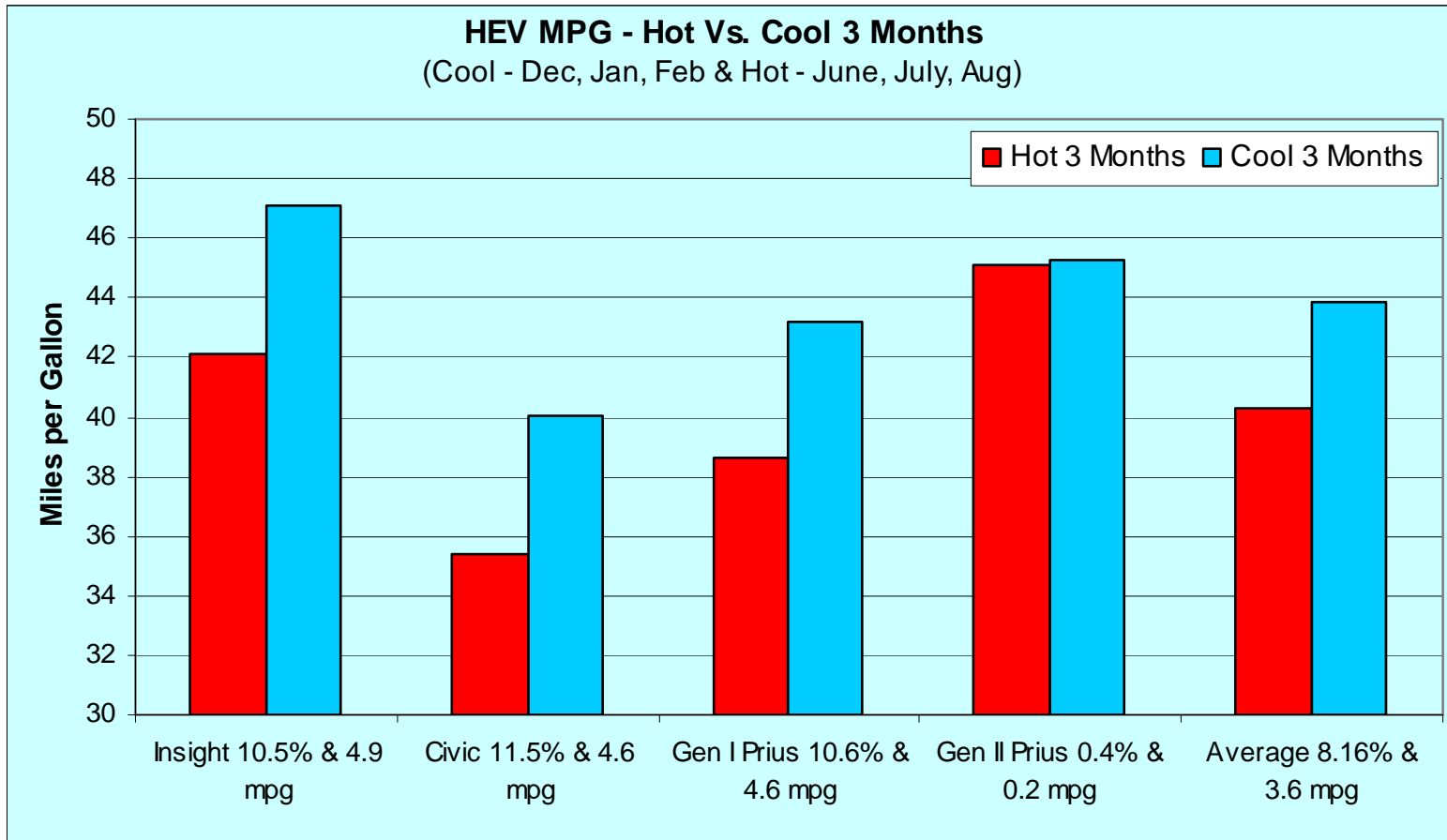
Fleet Testing Monthly MPG



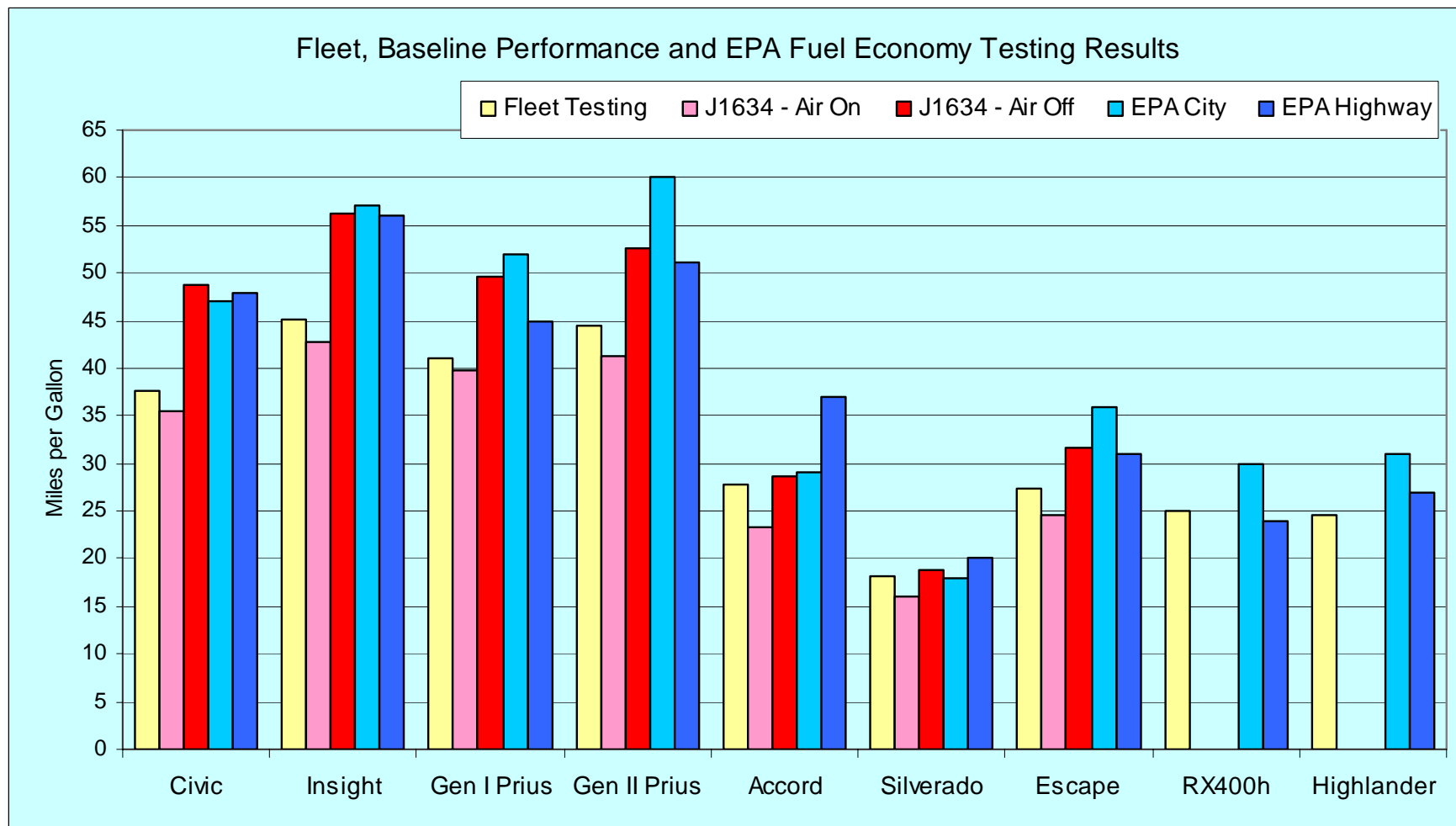
Honda Insight MPG



Fleet Testing MPG Hot/Cool Months



MPG: Fleet, SAE J1634 & EPA



Maintenance / Repairs

Date, mileage, description & cost/warranty

HEV Fleet Testing - Maintenance Sheet
2003 – Honda Civic Hybrid



Advanced Vehicle Testing Activity

VIN #JHMES96663S003864

Date	Mileage	Description	Cost
7/10/2002	5,041	Change oil and rotate tires	\$ 27.00
8/6/2002	9,979	Change oil and rotate tires	\$ 28.62
9/5/2002	15,023	15,000 mile service	\$ 231.38
9/24/2002	18,706	Repair accident damage to left front (not included in maintenance costs)	\$ 1,222.34
10/8/2002	20,142	Change oil and rotate tires	\$ 28.99
10/29/2002	25,147	Change oil and rotate tires	\$ 30.87
12/20/2002	33,270	Change oil and rotate tires	\$ 31.07
2/10/2003	43,290	45,000 mile service	\$ 341.58
2/13/2003	43,500	Repair accident damage to rear bumper (not included in maintenance costs)	\$ 834.42
3/18/2003	53,381	Change oil and rotate tires	\$ 30.67
4/22/2003	62,573	Change oil and rotate tires	\$ 30.67
5/23/2003	69,932	Change oil and rotate tires	\$ 30.67
6/6/2003	74,353	30,000 mile service	\$ 324.18
6/24/2003	77,828	Replace four tires and align front wheels	\$ 185.33
6/19/2003	77,589	Check Engine trouble light illuminated. Dealer reset, no problem found.	warranty
7/7/2003	80,425	Change oil and rotate tires	\$ 31.09
7/8/2003	80,434	Check Engine light illuminated. Dealer repaired an intermittent problem with a valve sticking.	warranty
8/27/2003	89,304	90,000 mile service	\$ 324.13
8/4/2003	86,353	Change oil and rotate tires	\$ 31.09
9/12/2003	90,507	Check Engine trouble light illuminated. Updated PCM software installed by dealer.	\$ 50.00
10/14/2003	93,616	Ignition switch replaced	\$ 50.00
10/24/2003	93,912	Change oil and replace brake pads	\$ 146.22
11/20/2003	96,556	Check Engine light illuminated. Dealer replaced the Purge System pressure sensor	\$ 50.00
1/15/2004	96,802	Transmission shifting erratically. Transmission replaced	\$ 3,503.82
1/26/2004	97,750	Check Engine trouble light illuminated. Catalytic converters replaced.	\$ 1,124.38
2/24/2004	103,901	15,000 mile service	\$ 260.83
4/6/2004	113,685	30,000 miles service and accessory 12 volt battery replacement	\$ 464.09
4/15/2004	115,649	Replace front tires	\$ 112.38
5/3/2004	119,570	Change oil and rotate tires	\$ 31.92

Maintenance / Repairs Summary

Civic & Insight - 6 CVT failures in 4 units: 97k, 99k, 89k & 77k mi. Again: 157k & 146k mi.

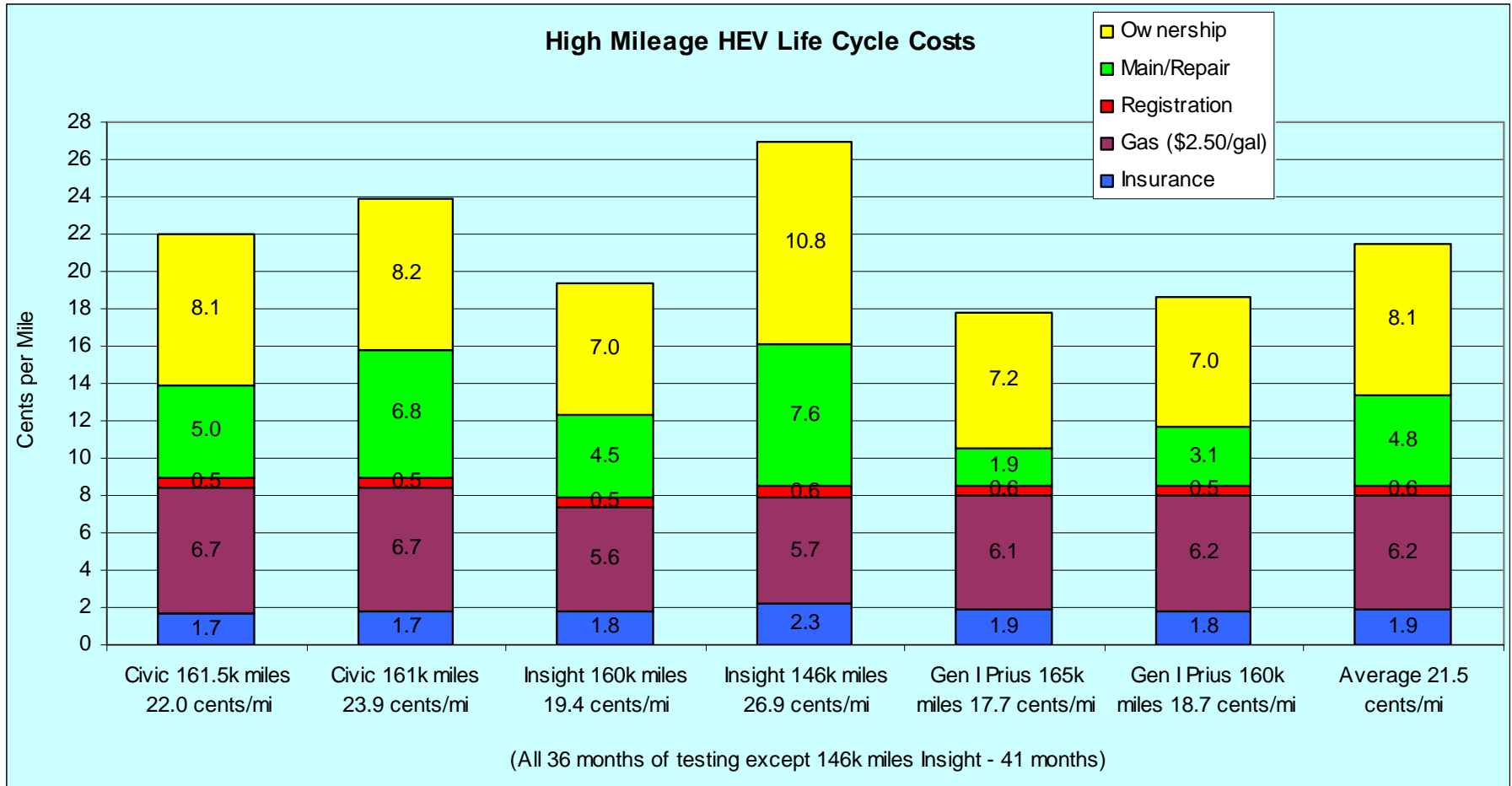
Insight battery control module & battery pack replaced: 72k miles

Insight & Civic - 7 software upgrades & 3 catalytic converters replaced

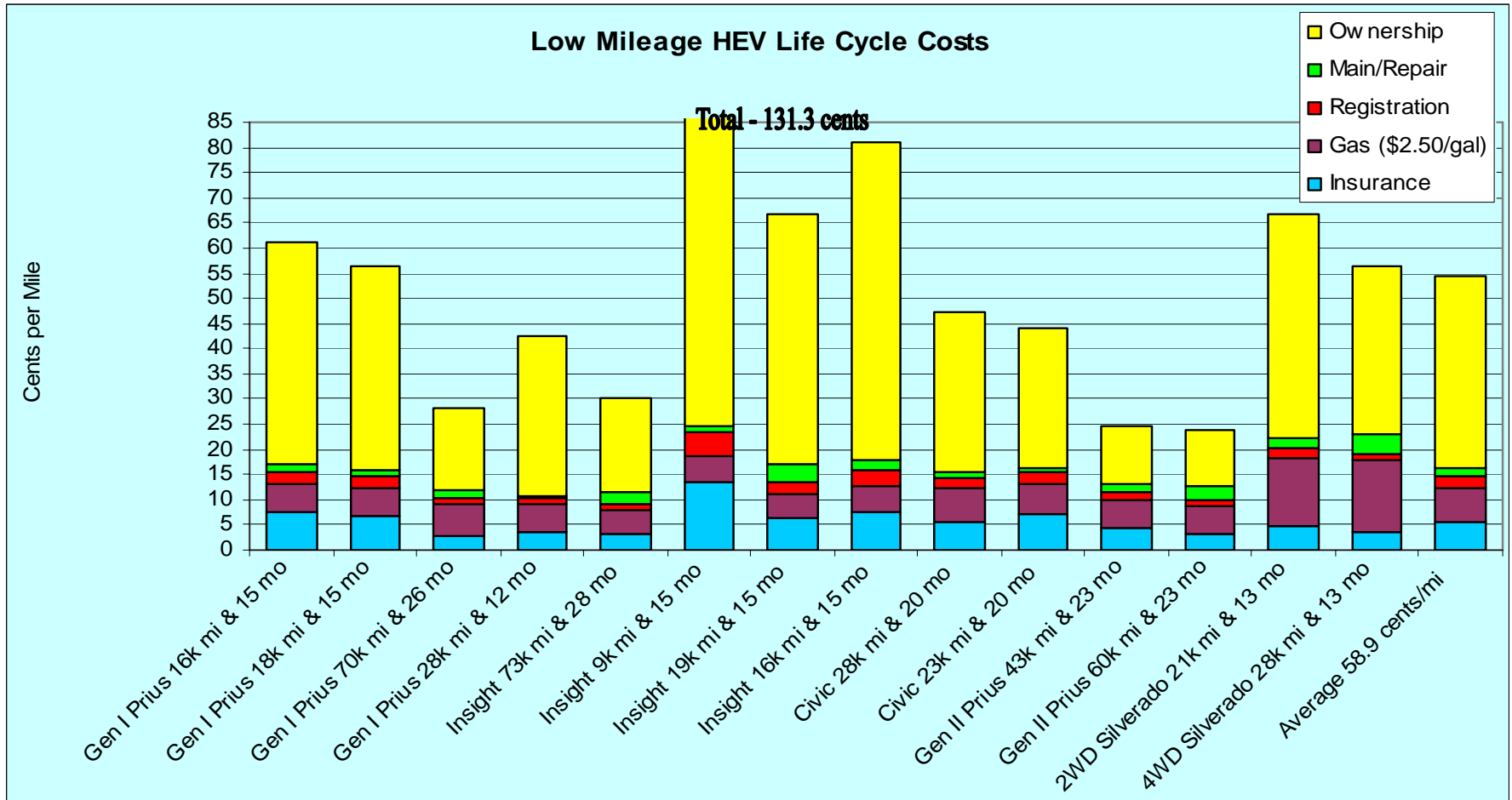
Gen I Prius - rack & pinion replacements 1st Prius: 106k, & 2nd Prius: 25k & 32k miles

Silverado battery pack replaced: 36k miles

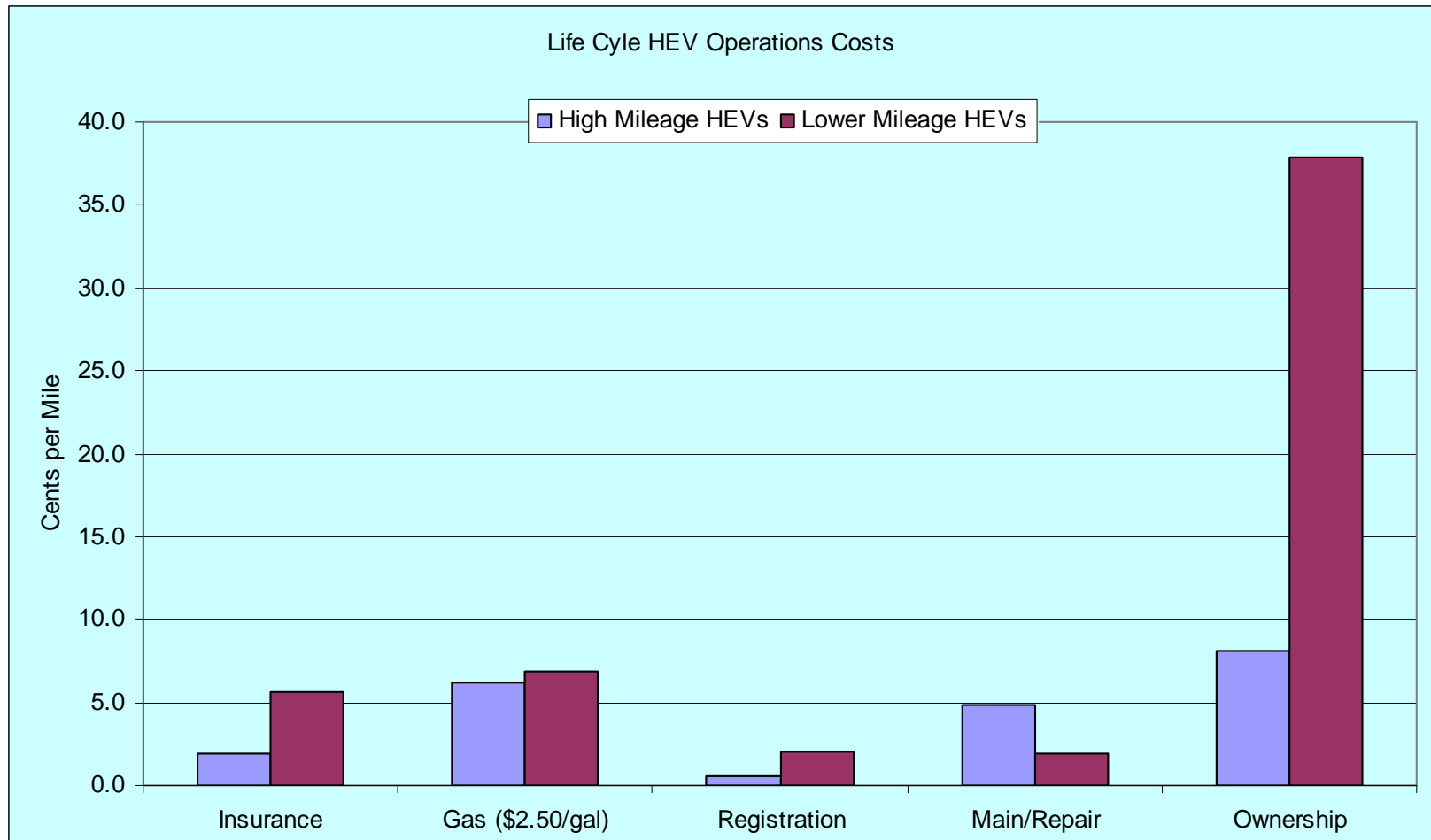
Life-Cycle Costs (high mileage HEVs)



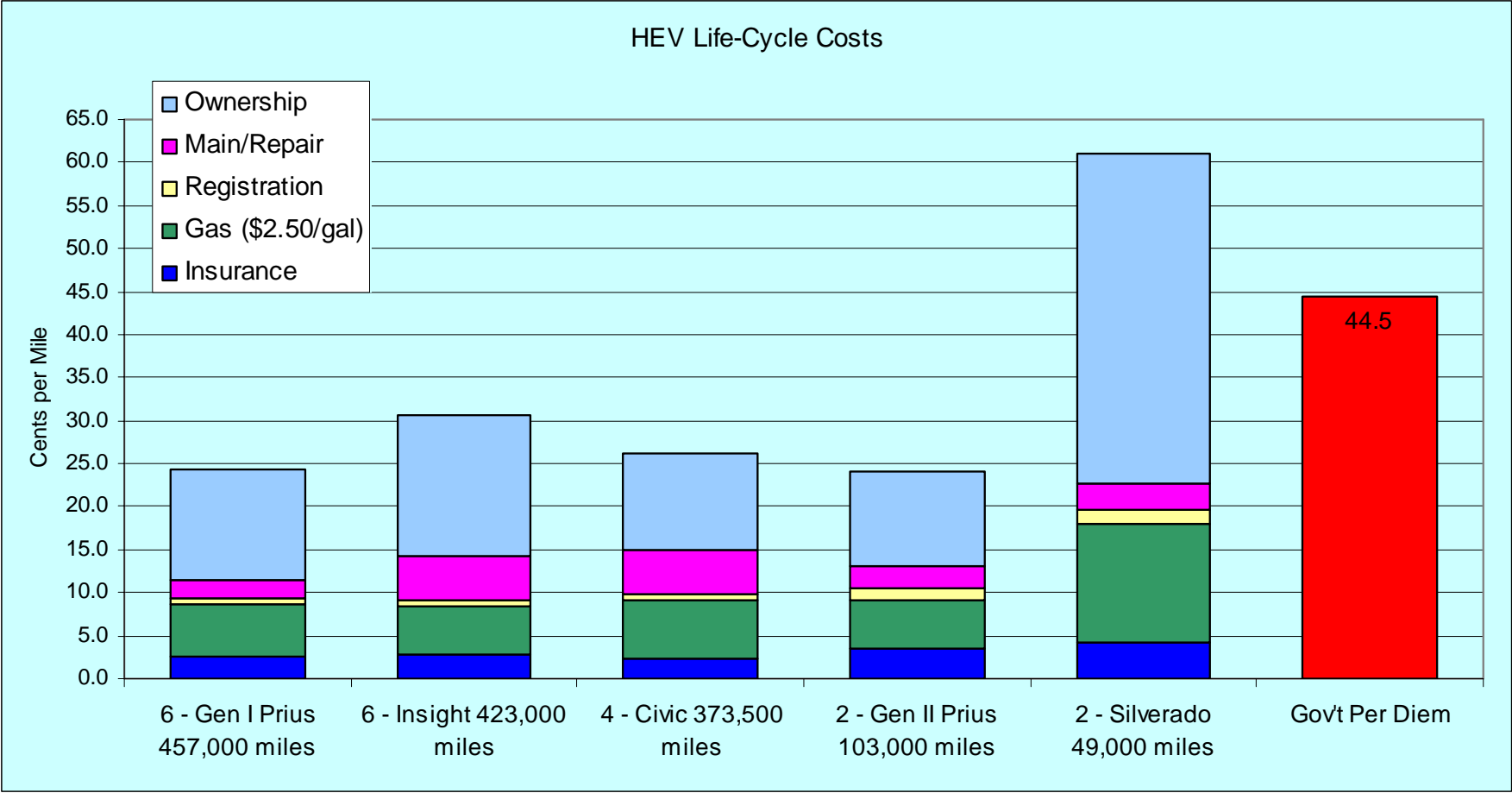
Life-Cycle Costs (low mileage HEVs)



Component Costs: High/Low mileage

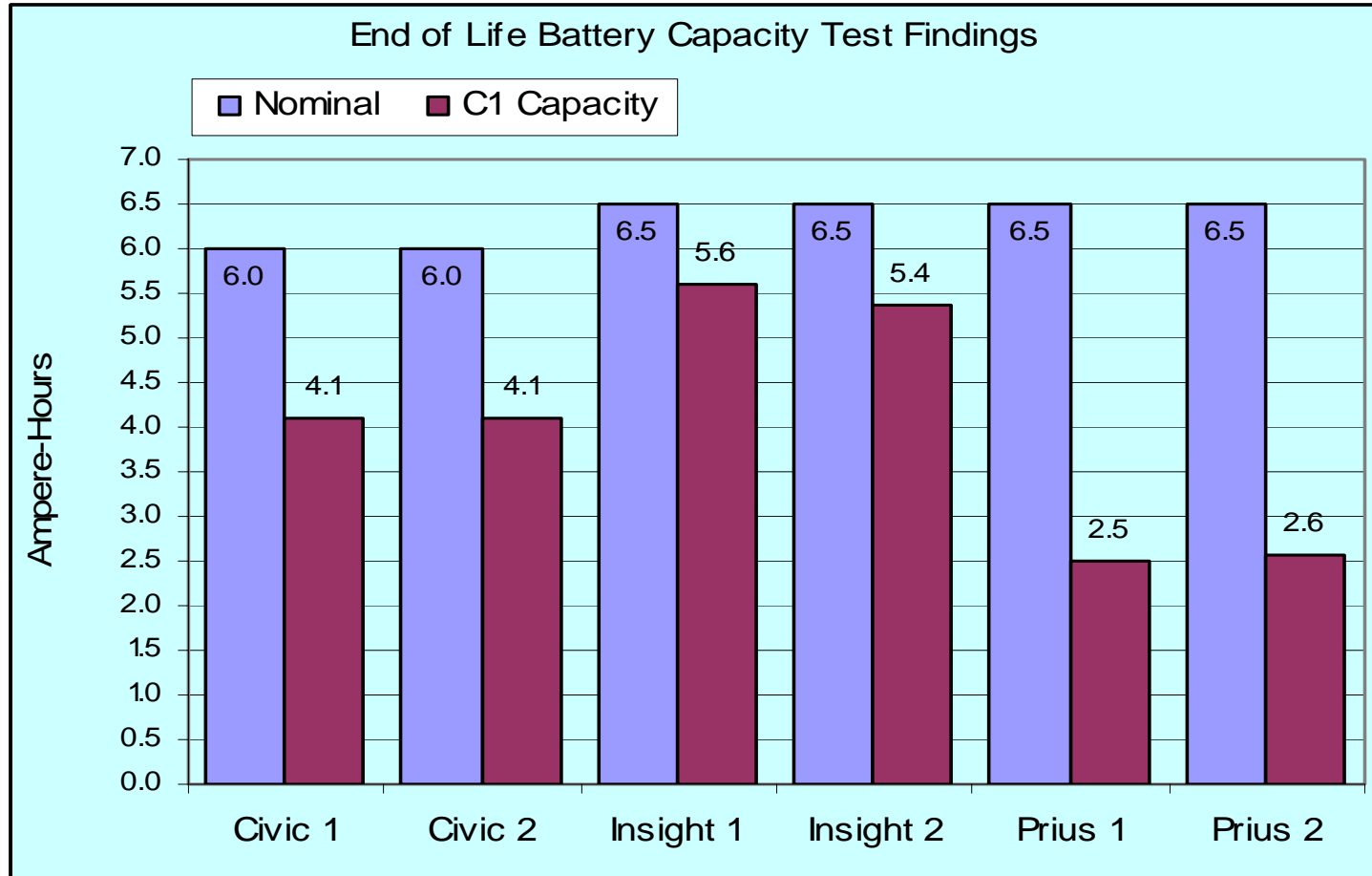


Life-Cycle Costs (Weighted by Miles)

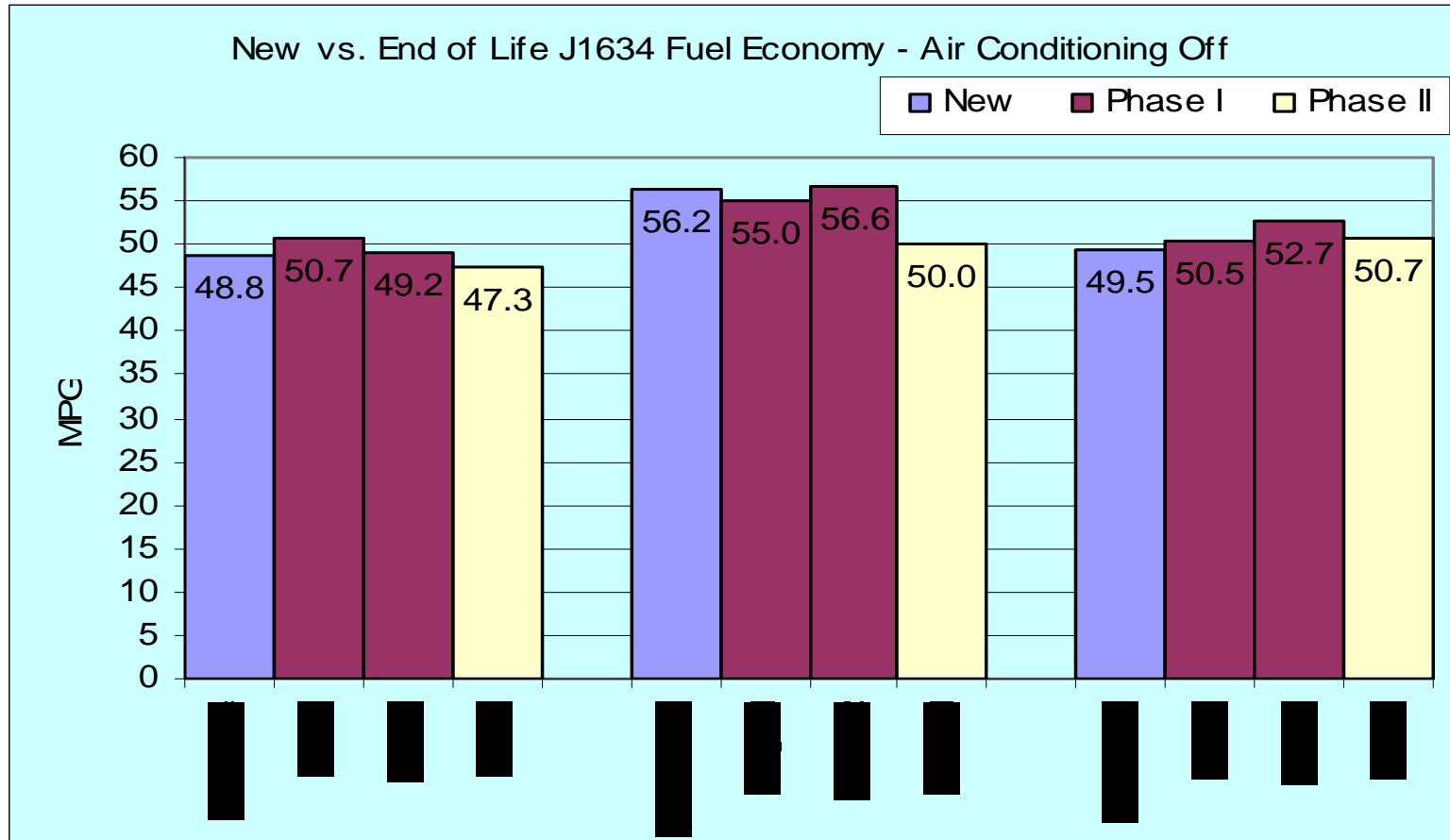


Costs include: Insurance, maintenance & repairs (excludes any collision costs), fuel @ \$2.50 gallon, registration, & purchase – sales cost (or lease cost for Silverado)

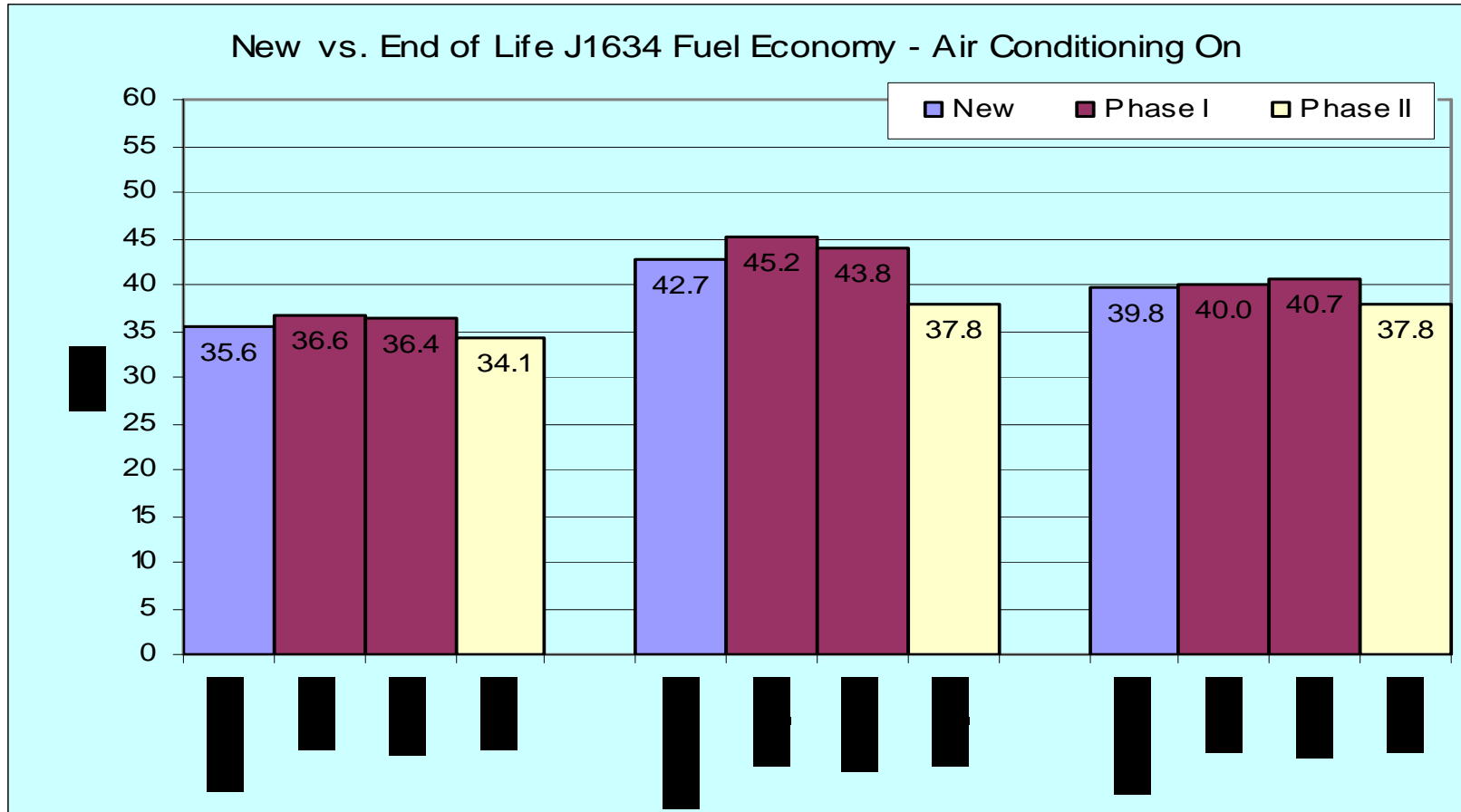
End-of-Life (160k miles) Battery Capacity



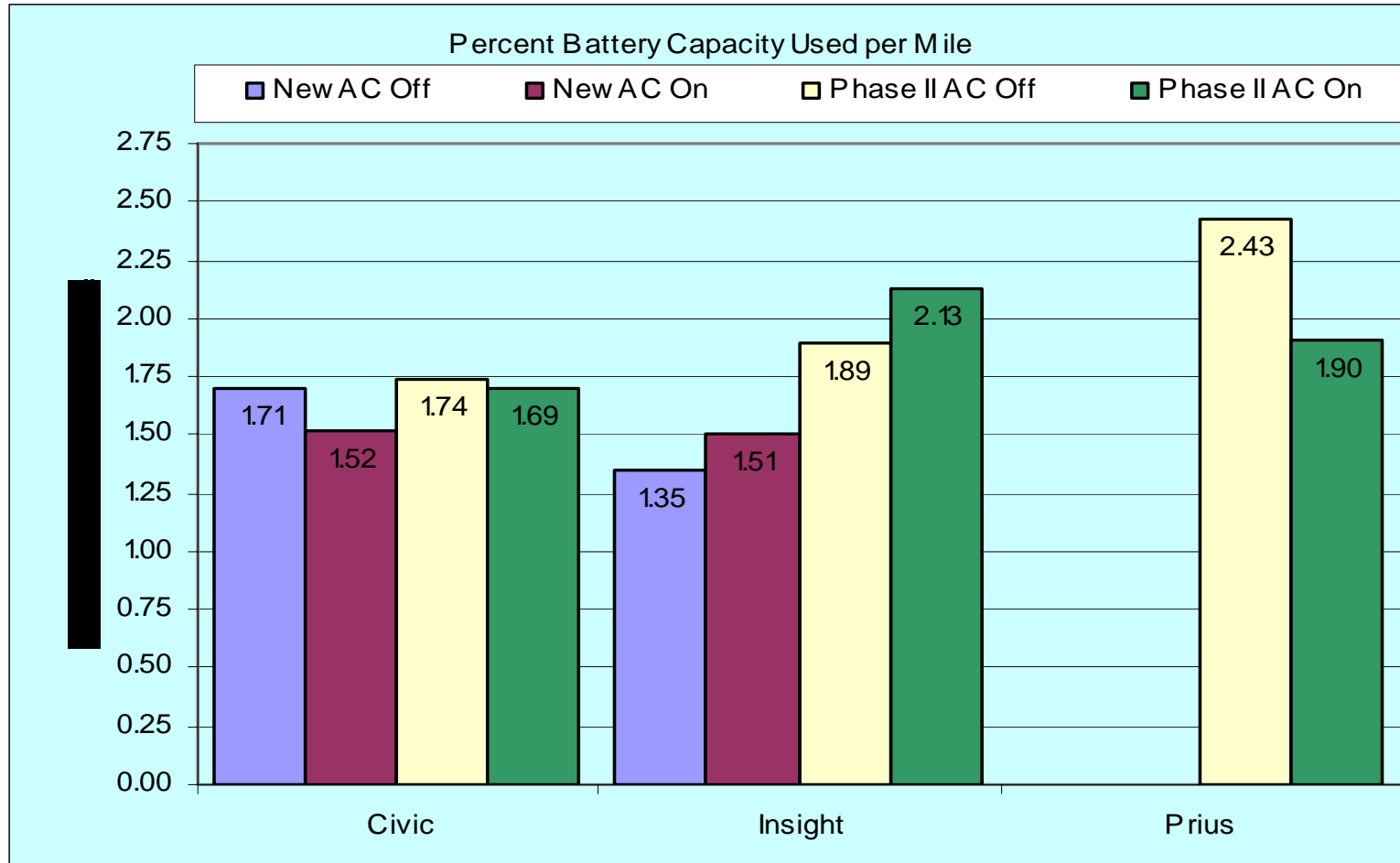
End-of-Life (160k miles) MPG: AC Off



End-of-Life (160k miles) MPG: AC On



Percent Battery Capacity Used/Mile



End-of-Life Phase II (J1634) Vs. Onboard Vehicle Computer MPG

End-of-life Phase II HEV MPG Testing	Onboard computer mpg percentage above Phase II SAE J1634 mpg
Civic 1 AC off	+21.7%
Civic 1 AC on	+21.0%
Insight 1 AC off	+11.0%
Insight 1 AC on	+11.7%
Gen I Prius AC off	+15.7%
Gen I Prius AC on	+14.7%

Additional HEV Testing

Hydrogen ICE HEV Hydrogen Prius from
SCAQMD/Quantum

Plug-in HEV Dodge Sprinter (lithium)

Plug-in HEV Escape (lithium or lead) from
Energy CS

Plug-in Prius (lithium) from Energy CS

Other OEM HEVs &/or Plug-ins (Gen II Civic &
Lexus GS 450h)

Acknowledgement

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Project Leader and VSATT Lead, Lee Slezak

<http://avt.inl.gov>

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