

EVS 23

December 2 – 5, 2007

**SUSTAINABILITY:
THE FUTURE OF TRANSPORTATION**
ANAHEIM, CALIFORNIA USA

Hybrid Electric and Plug-in Hybrid Electric Vehicle Testing Activities

James Francfort

US DOE's Advanced Vehicle Testing Activity (AVTA)

Idaho National Laboratory (INL)

HOSTED BY:

EDTA[®]

Electric Drive Transportation Association

In partnership with the World Electric
Vehicle Association (WEVA)

AVTA Background and Goal

- **The AVTA is part of the U.S. Department of Energy's Office of Vehicle Technologies**
- **The AVTA is conducted by the INL and Electric Transportation Applications (ETA - Phoenix, AZ), with Argonne National Laboratory performing dynamometer testing**
- **AVTA Goal**
 - ▶ Provide benchmark data to technology modelers, R&D programs, and target setters
 - ▶ Assist fleet managers in making informed vehicle purchase, deployment and operating decisions

AVTA Testing History

- **Hydrogen internal combustion engine vehicles**
 - ▶ 6 models, 400,000 test miles
- **Full-size electric vehicles**
 - ▶ 40 EV models, 5+ million test miles
- **Neighborhood electric vehicles**
 - ▶ 15 models, 200,000 test miles
- **Urban electric vehicles**
 - ▶ 3 models, 1 million test miles

Baseline Performance Testing

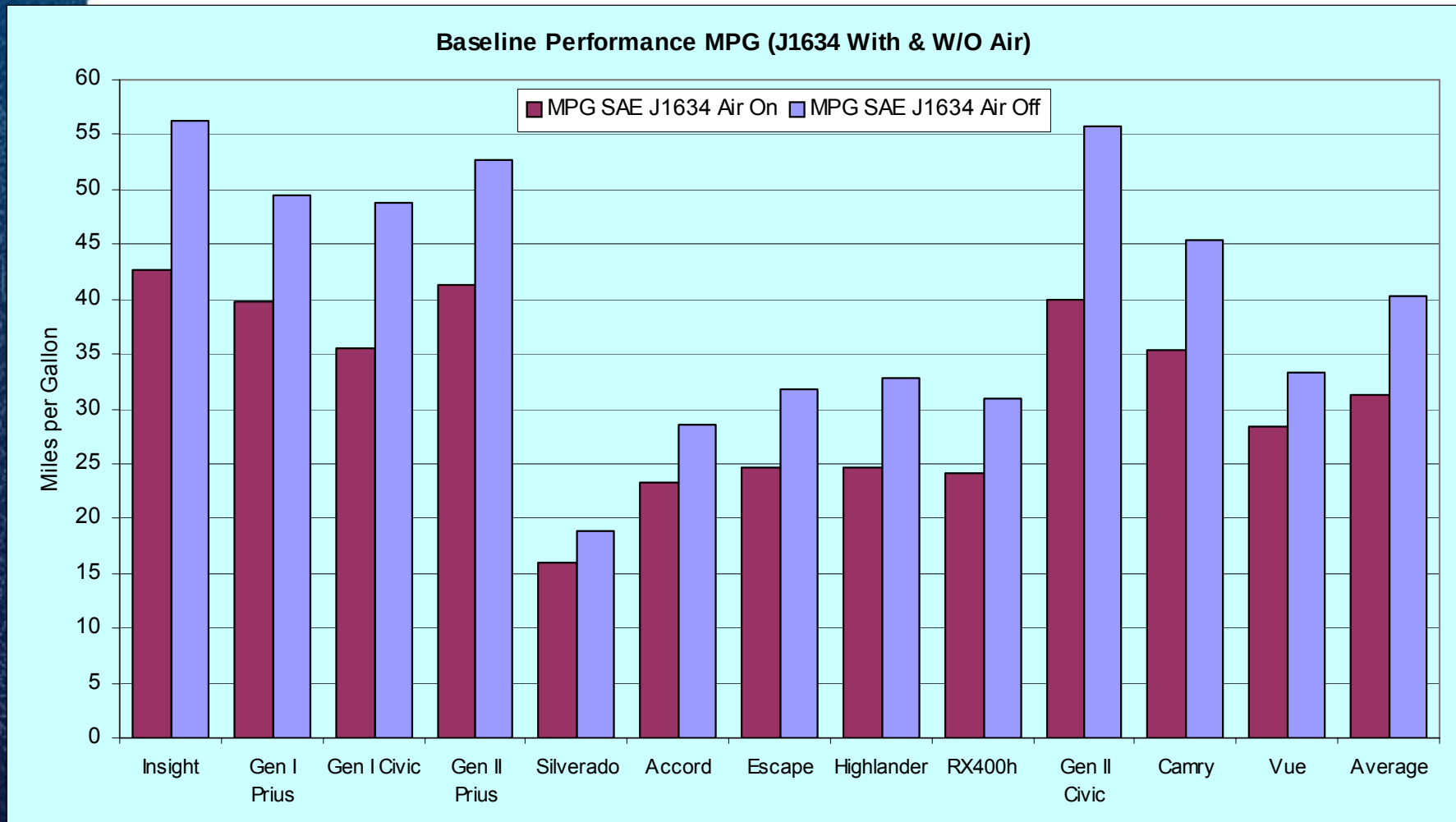
- **Closed track testing**
 - ▶ Coastdown (dynamometer coefficients), charging, acceleration, top speed, and durability tests
- **Depending on vehicle technology, a two- to five-day dynamometer testing regime is used:**
 - ▶ Urban Dynamometer Driving Schedule (UDDS) and Highway Fuel Economy Test (HWFET) primary dynamometer tests
 - ▶ Charge depleting and sustaining test cycles
 - ▶ Includes air conditioning (AC) off and on cycles
 - ▶ Hot and cold starts
 - ▶ PHEV testing includes at least 26 drive cycle tests

Onroad Fleet and Accelerated Testing

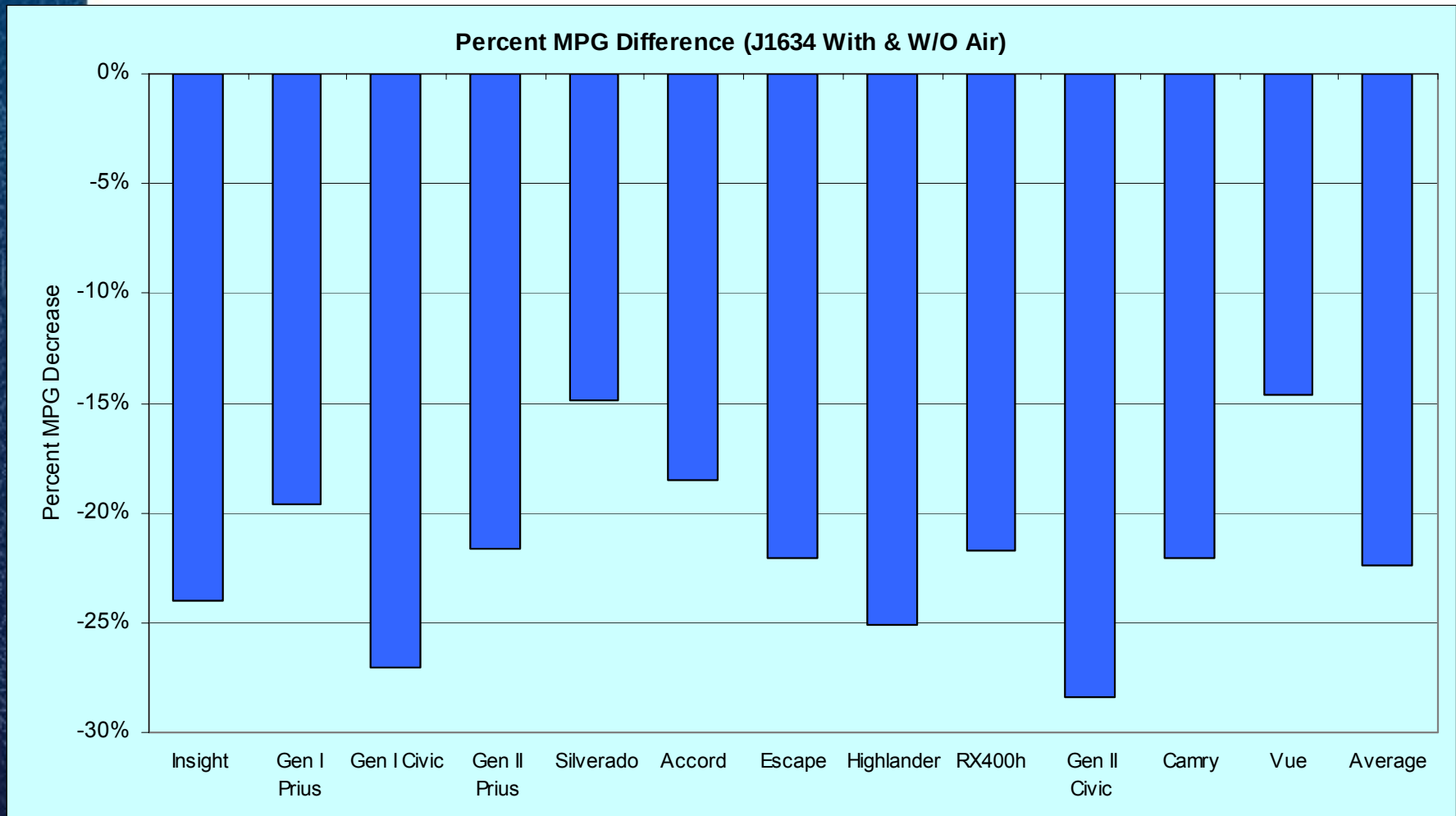
- **HEVs are tested for 160,000 miles and three years in high mileage fleets**
- **PHEVs are initially onroad tested in defined 10-mile city and highway loops for 5,440 miles, and placed in fleets**
- **Mission selection based on vehicle performance characteristics, fuel use, and technology subsystems**

Hybrid Electric Vehicle (HEV) Testing

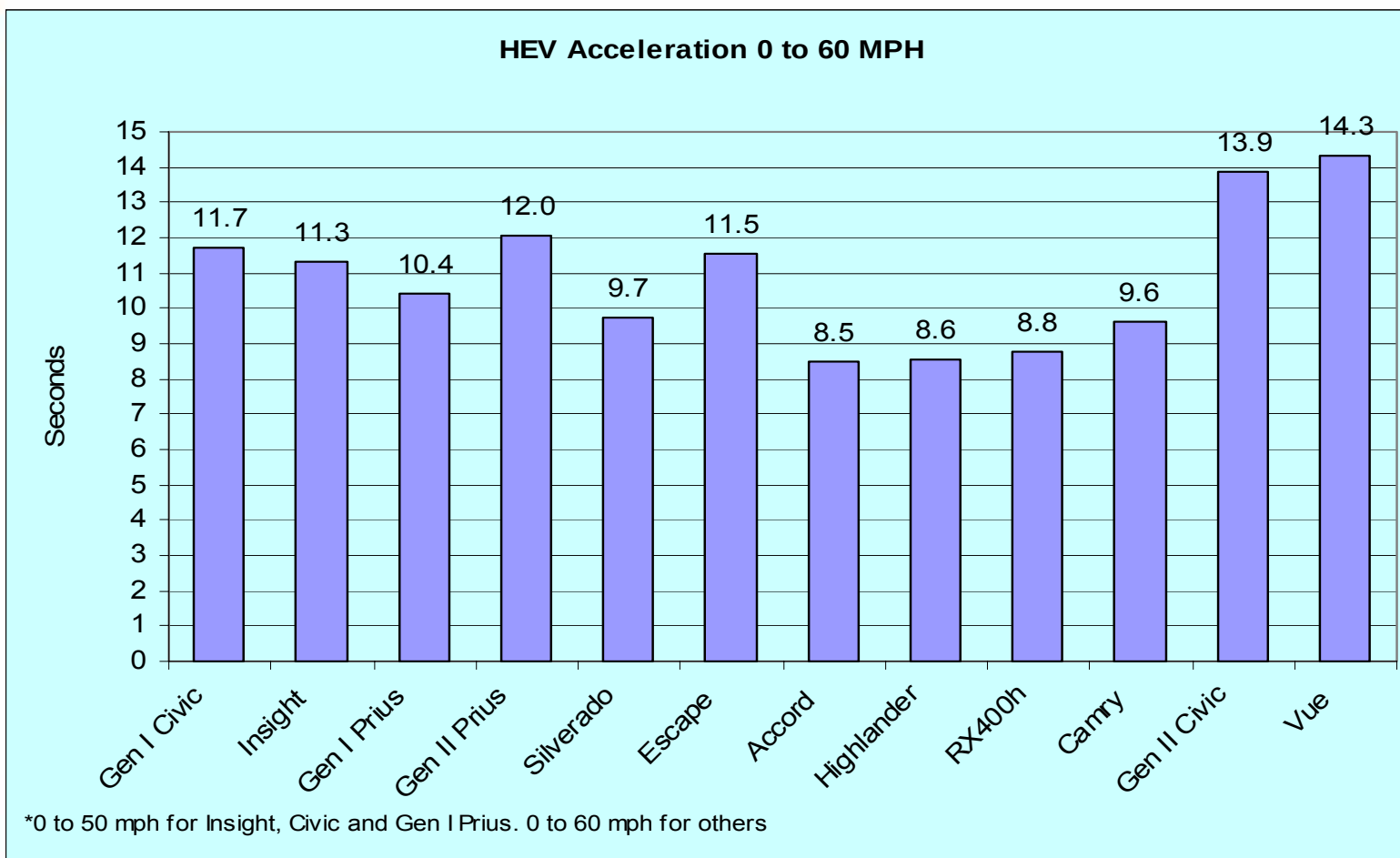
12 HEV models baseline tested to date



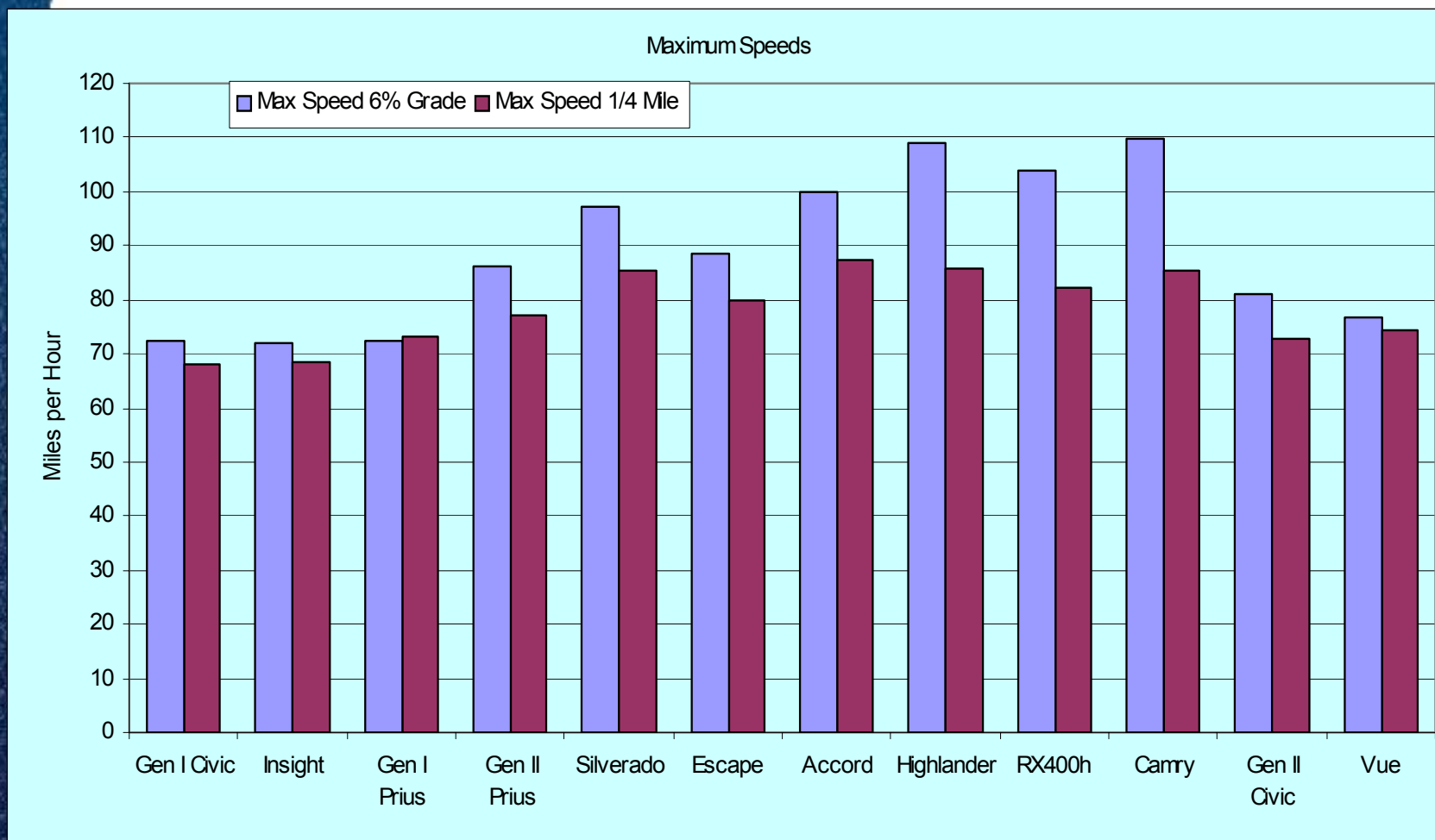
HEV Percentage mpg decrease - A/C on



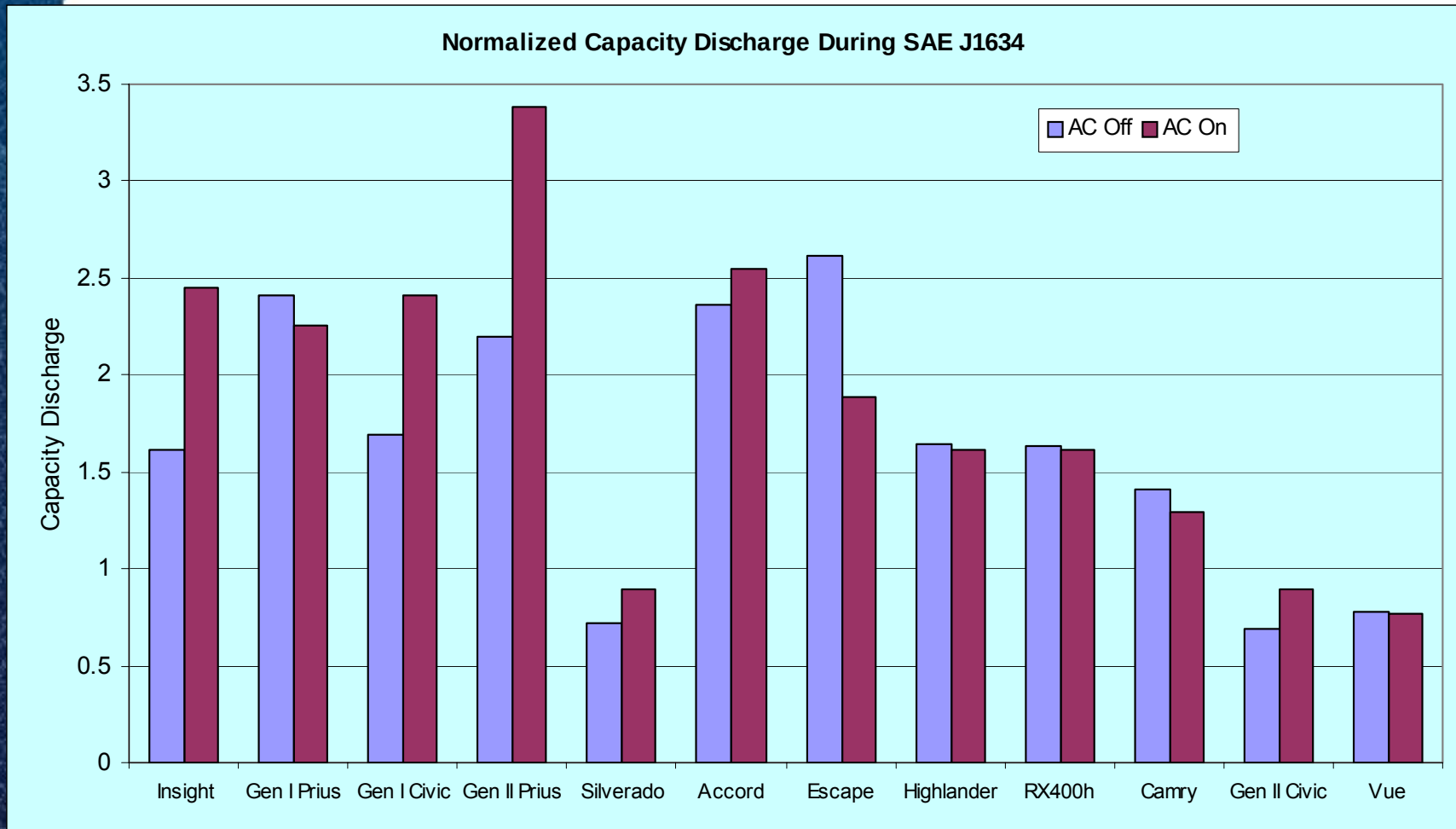
HEV Acceleration



HEV Maximum Speeds



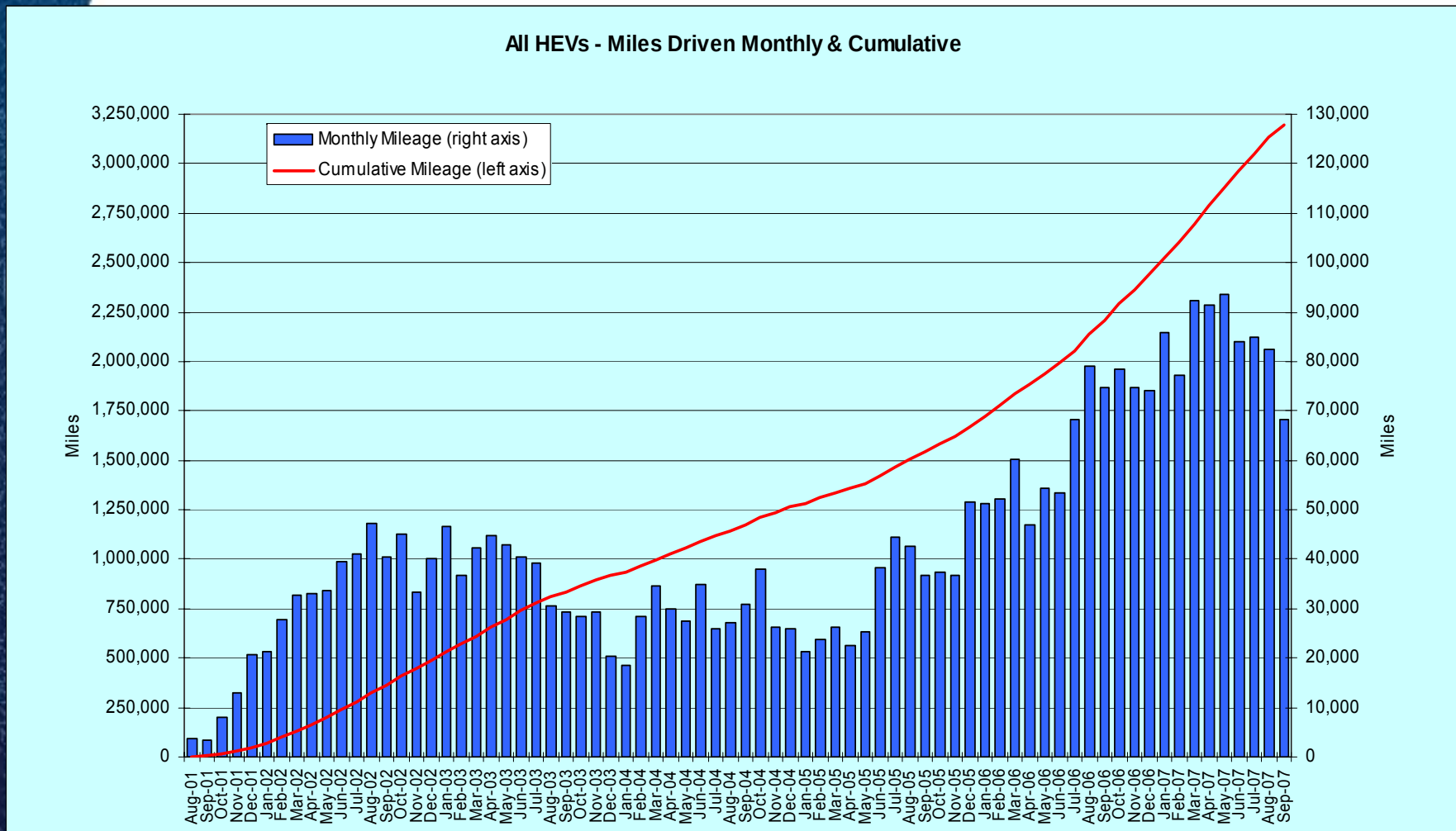
HEV Normalized Capacity



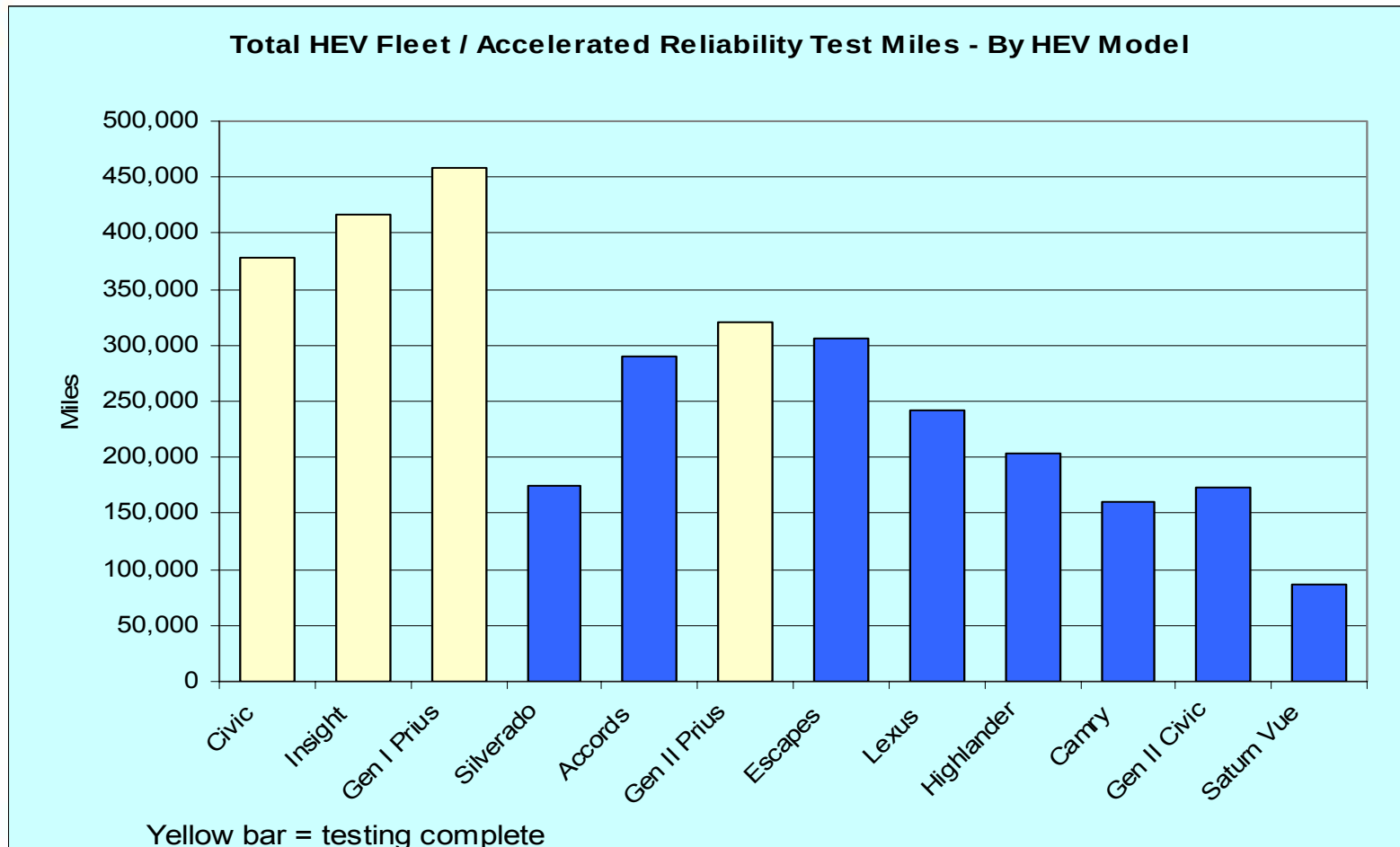
HEVs in Onroad Testing

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
200X Nissan Altima	2	Ongoing
200X GM 2-mode vehicles	?	Not Started
Total test or in testing	37 to date	

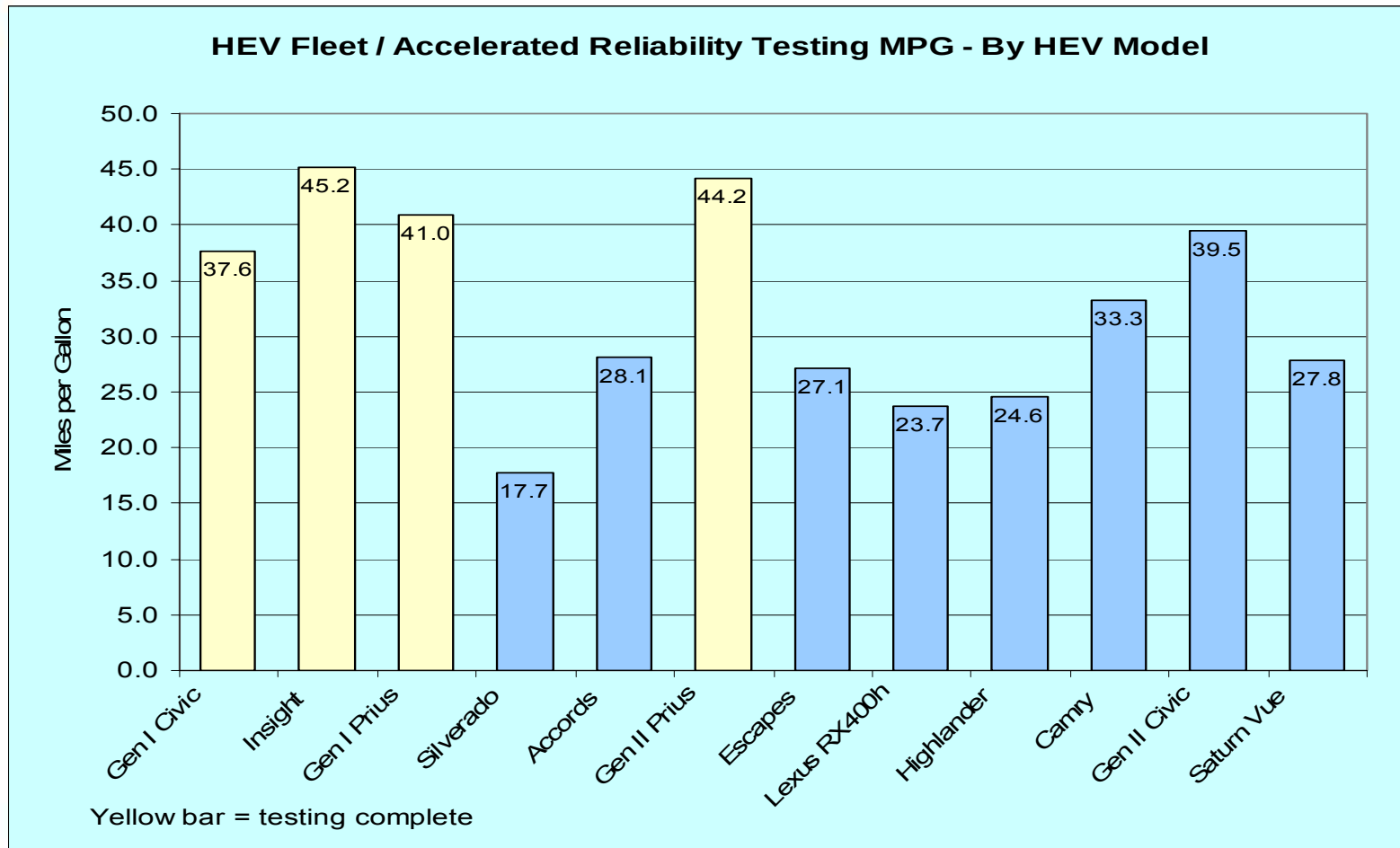
3.2 Million HEV Onroad Test Miles



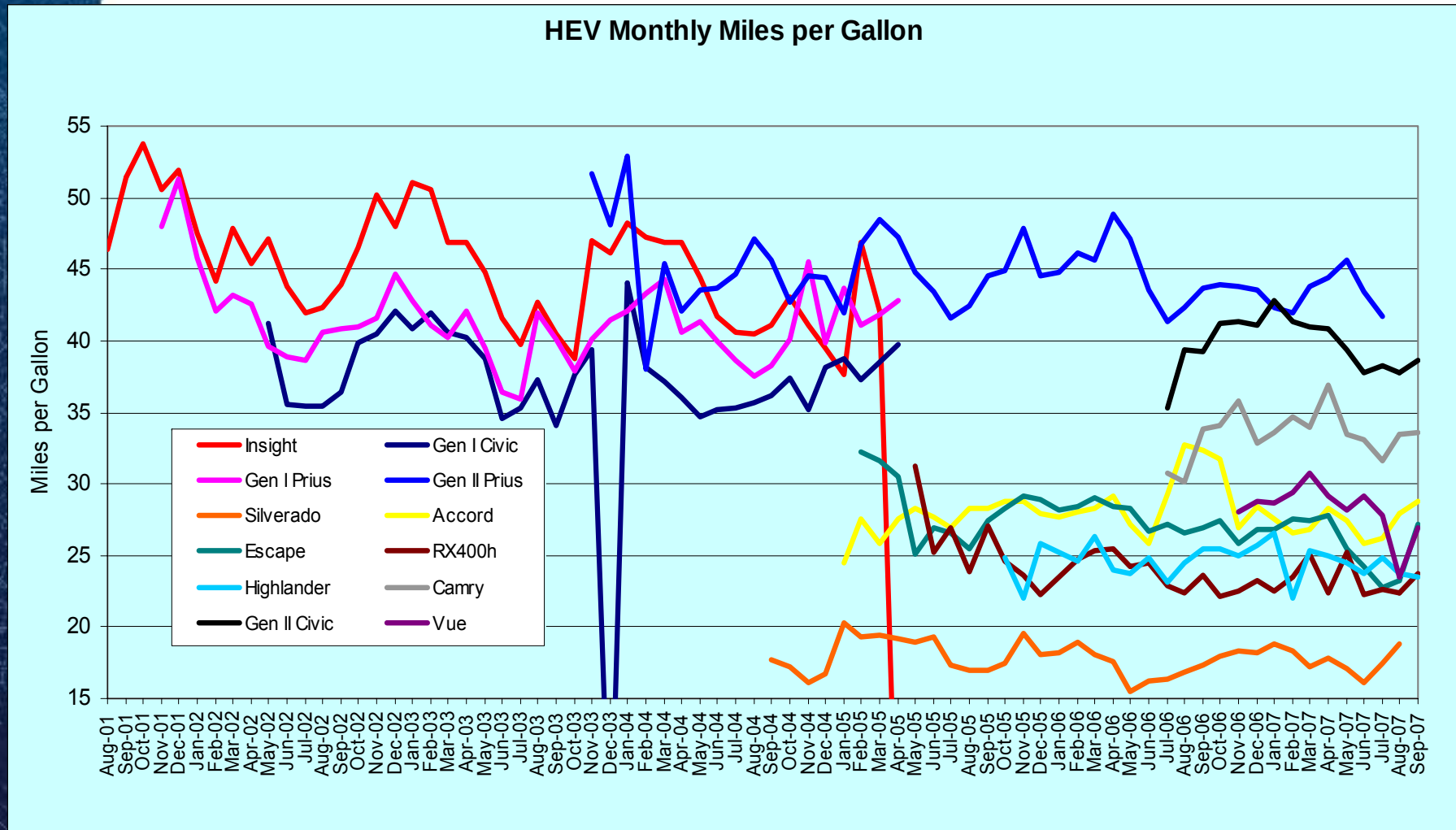
Onroad Test miles per HEV model



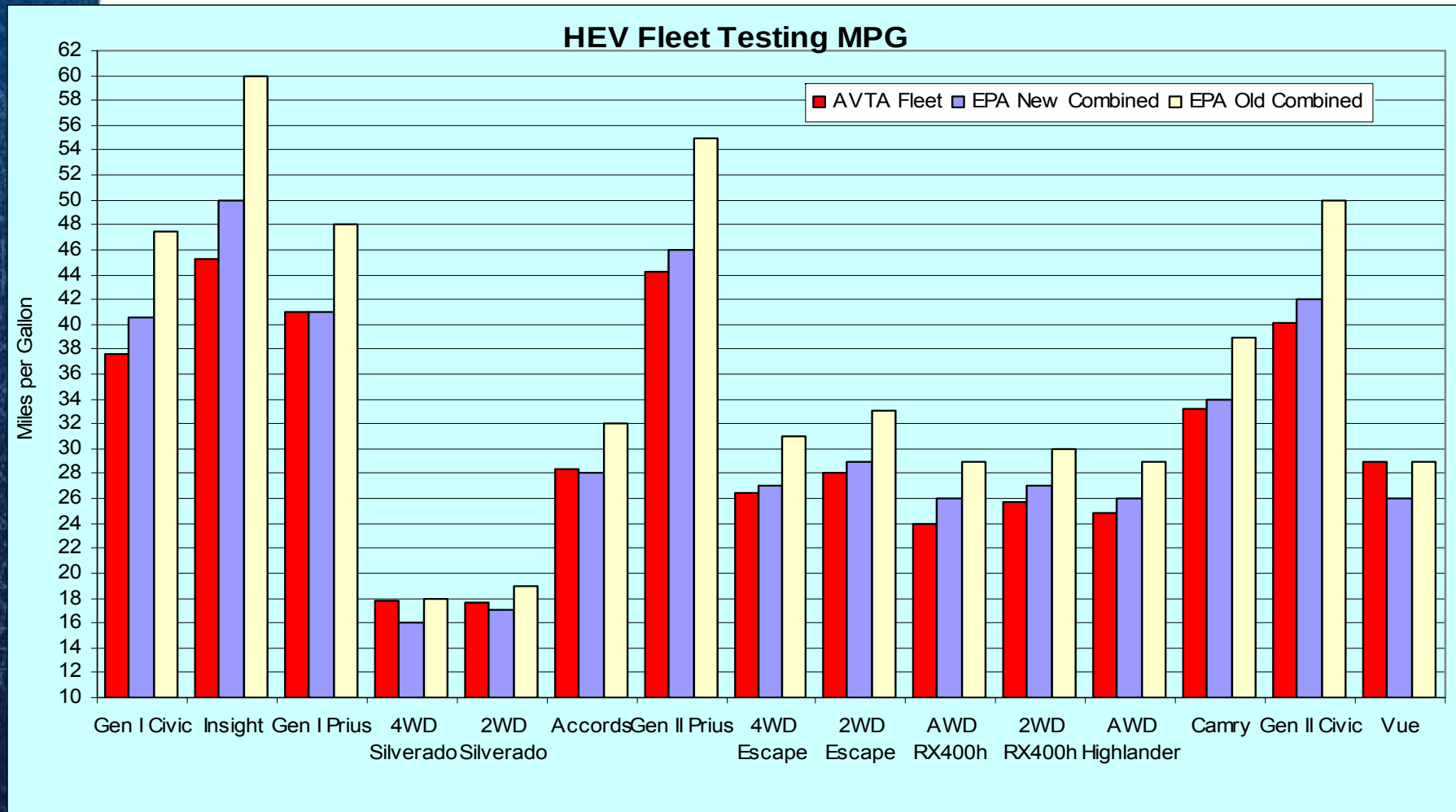
Onroad Miles per gallon by HEV model



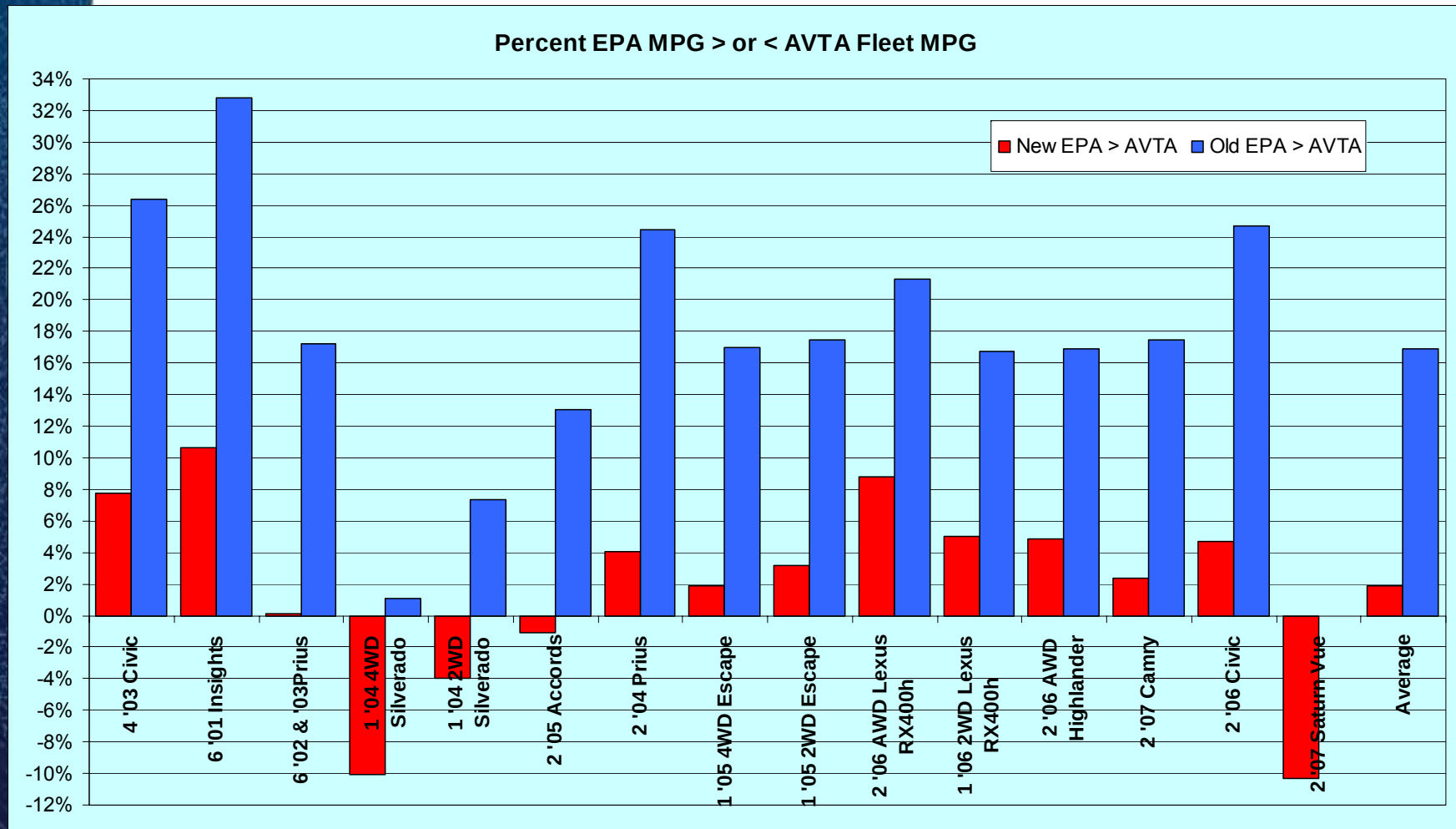
HEV Monthly miles per gallon



Onroad HEV testing and EPA MPG



Onroad HEV testing and EPA MPG



HEV Maintenance and Repairs

FREEDOMCAR & VEHICLE TECHNOLOGIES PROGRAM

HEV Fleet Testing

Advanced Vehicle Testing Activities

Maintenance Sheet for 2006 – Highlander



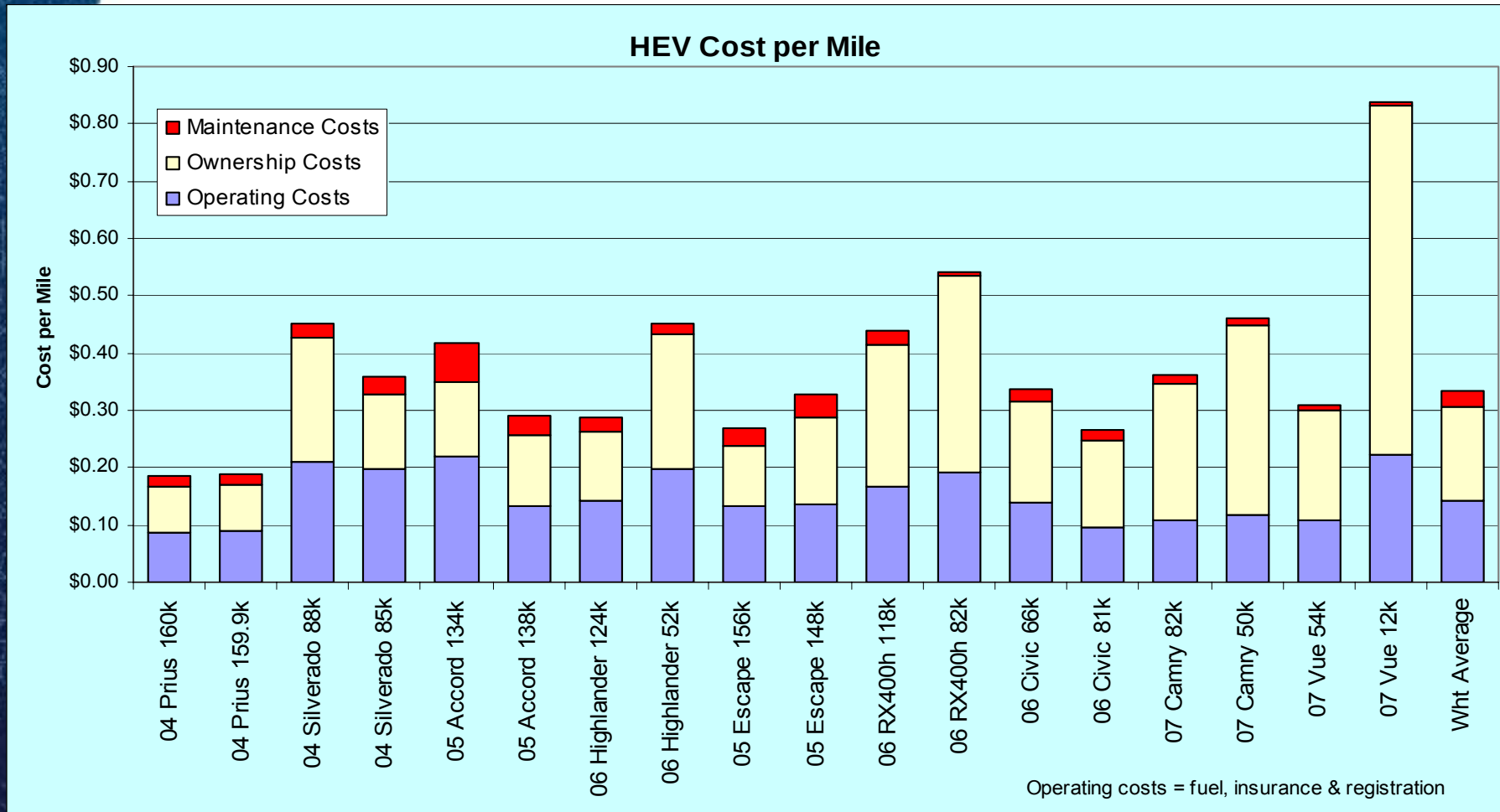
VIN # JTEDW21A160006395

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 P043 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



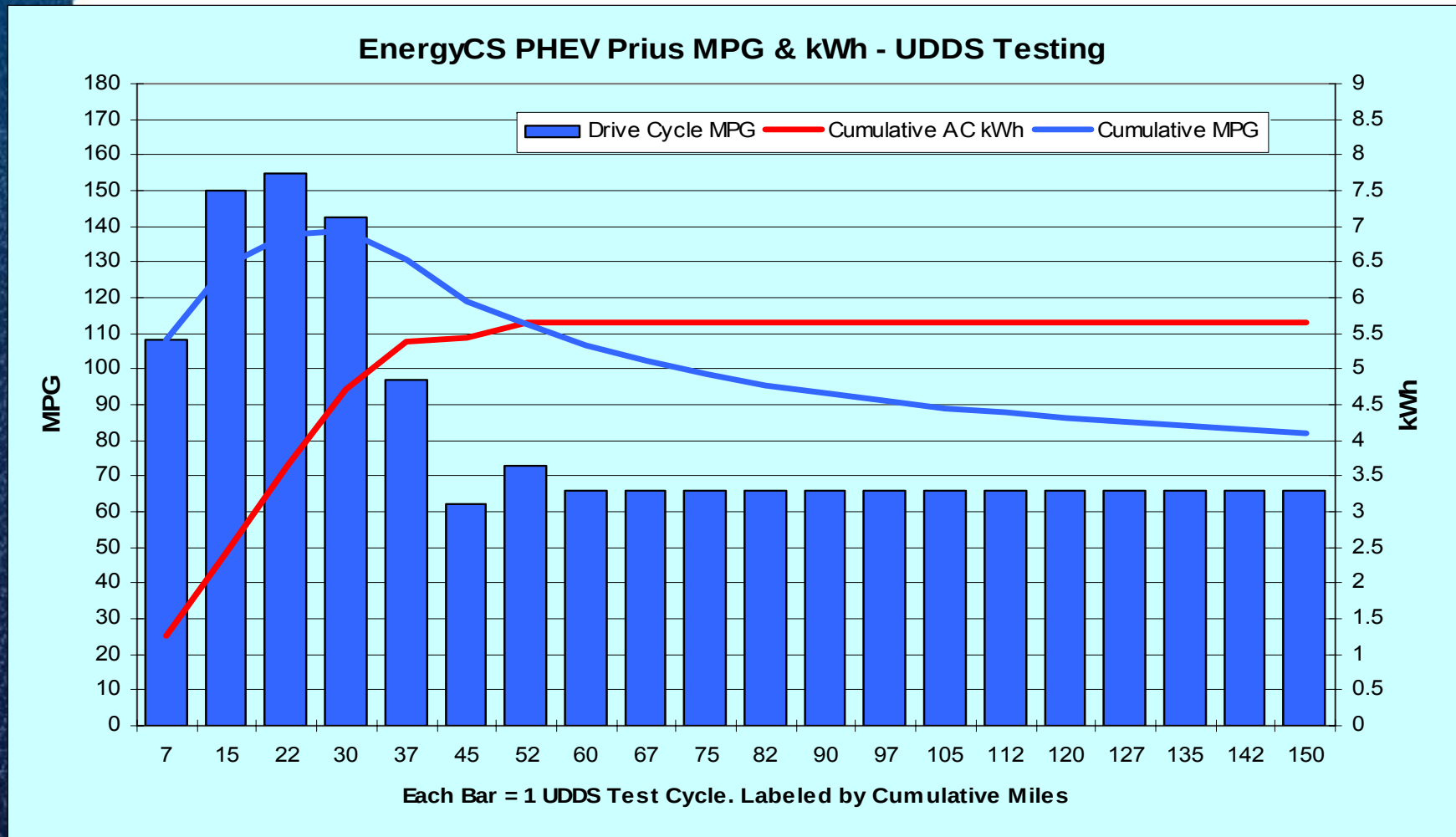
U.S. Department of Energy
Energy Efficiency and Renewable Energy
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HEV Life-Cycle Costs per Mile

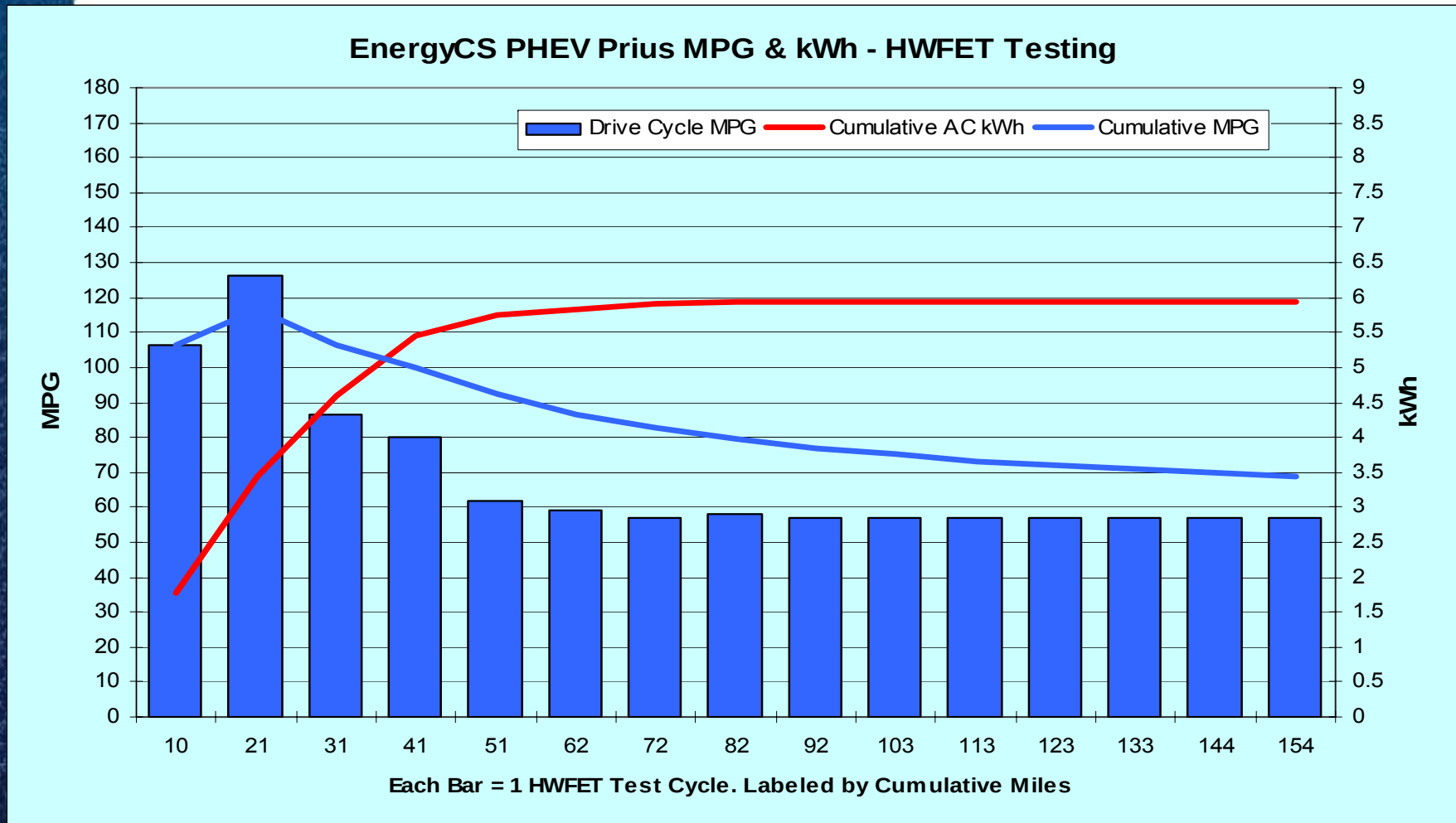


Plug-in Hybrid Electric Vehicle (PHEV) Testing

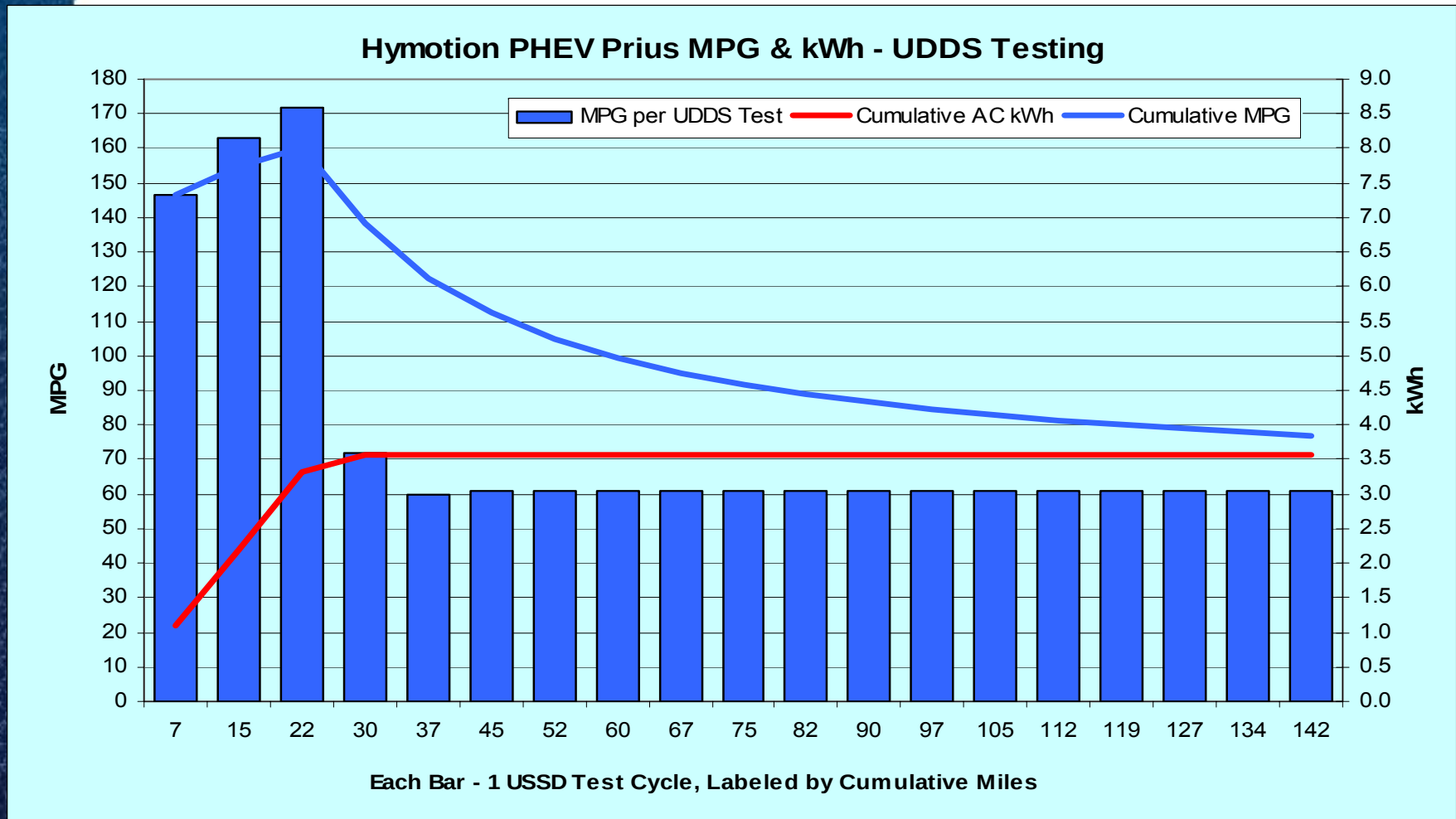
EnergyCS Prius – UDDS



EnergyCS Prius – HWFET

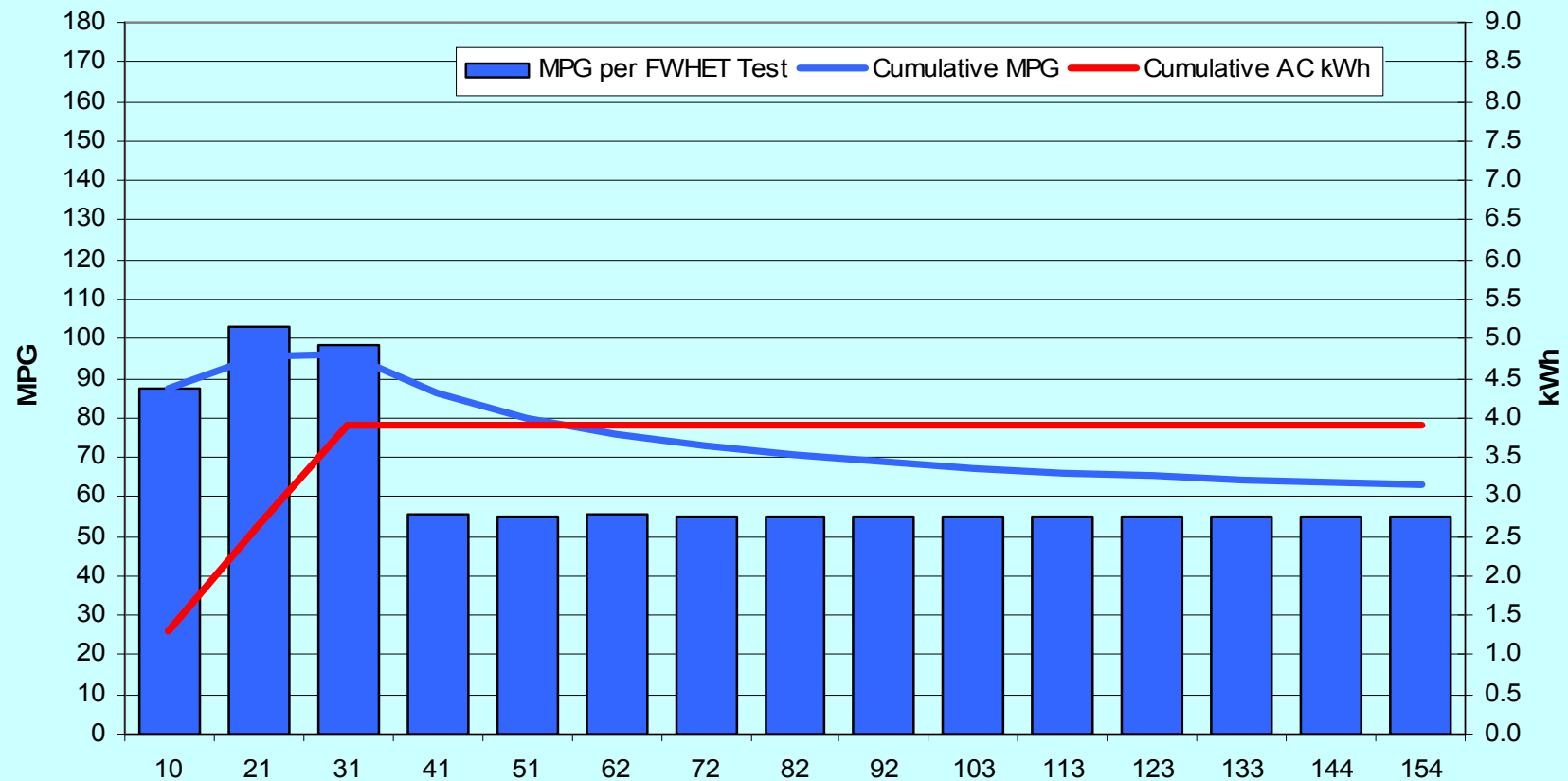


Hymotion Prius – UDDS



Hymotion Prius – HWFET

Hymotion PHEV Prius MPG & kWh - HWFET Testing



Each Bar - 1 HWFET Test Cycle, Labeled by Cumulative Miles

Accelerated PHEV Onroad Testing

- **Uses dedicated drivers**
- **Predetermined and repeatable drive cycles**
- **Combinations of urban and highway loops**
- **5,440 total onroad test miles per PHEV model**
- **162 drive and charging cycles that include 1,344 hours of charging - can not economically be performed on a dynamometer**
- **Not as controlled as dynamometer, but compliments controlled dynamometer testing by allowing a broader view of fuel use over many more miles and charging events**

Accelerated PHEV Onroad Testing

Cycle (mi)	Urban (10 mi)	Highway (10 mi)	Charge (hr)	Reps (N)	Total (mi)	Reps (%)	Miles (%)
10	1	0	4	60	600	37%	11%
20	1	1	8	30	600	19%	11%
40	4	0	12	15	600	9%	11%
40	2	2	12	15	600	9%	11%
40	0	4	12	15	600	9%	11%
60	2	4	12	10	600	6%	11%
80	2	6	12	8	640	5%	12%
100	2	8	12	6	600	4%	11%
200	2	18	12	3	600	2%	11%
Total	2,340	3,100	1,344	162	5,440		
Average	43%	57%	8.3	18			

EnergyCS Prius – Accelerated Testing

Cycle	Urban	Highway	Charge	Reps	Total	Electricity	Gasoline	
(mi)	(10 mi)	(10 mi)	(hr)	(N)	(mi)	kWh	Gals	MPG
10	1	0	4	60	600	115.58	4.78	125.6
20	1	1	8	30	600	86.21	7.95	77.9
40	4	0	12	5	200*	17.37	1.61	126.4
40	2	2	12	5	200*	29.00	1.42	145.1
40	0	4	12	5	200*	30.00	2.43	85.5
60	2	4	12	10	600	65.00	5.90	103.7
80	2	6	12	8	640	39.04	10.09	65.8
100	2	8	12	6	600	22.67	8.81	70.8
200	2	18	12	3	600	12.98	10.46	57.8
Total	1740	2500	984	132	4240	Weighted Ave		88.4

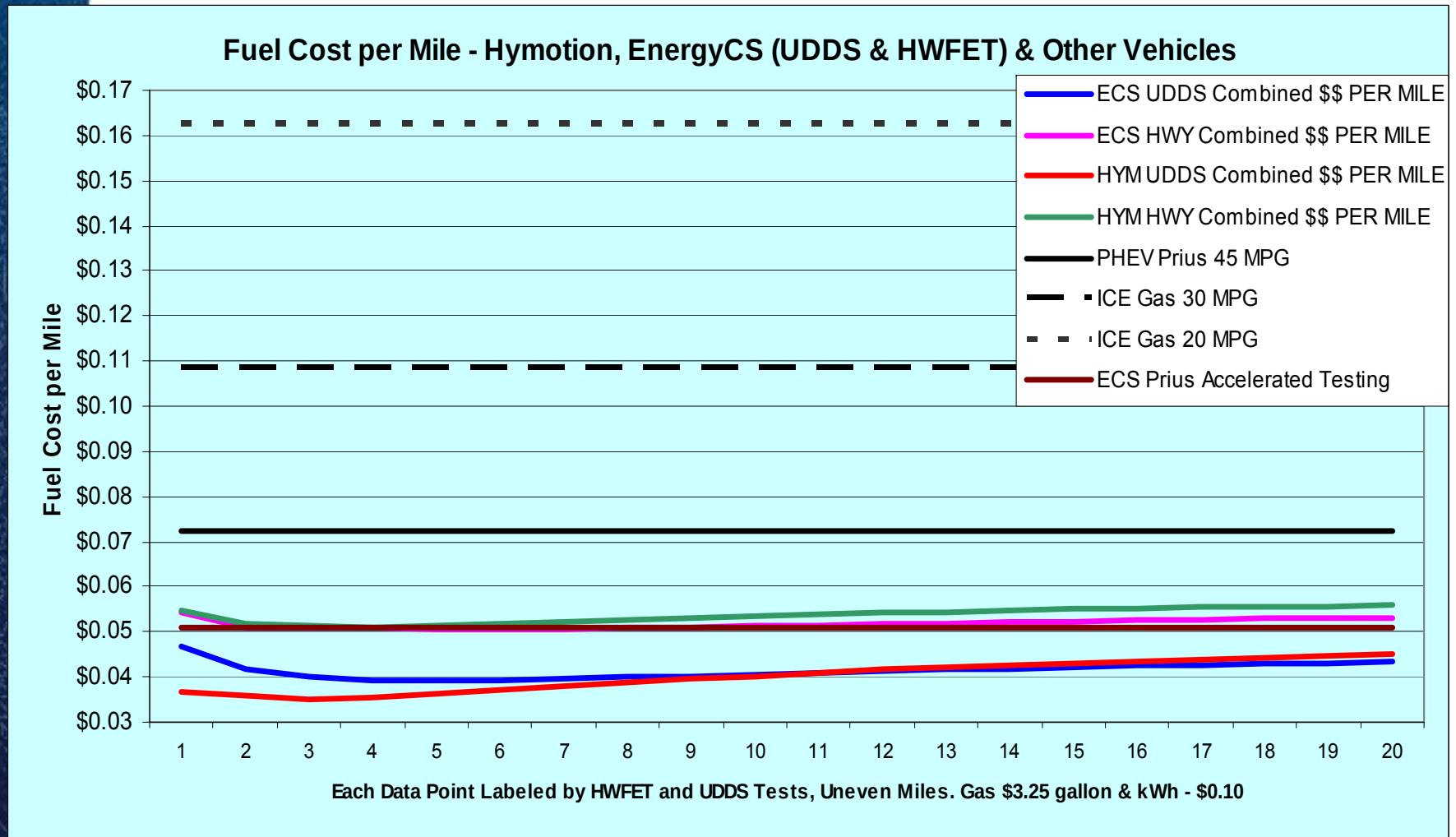
* Being rerun to 600 miles

Hymotion Prius – Accelerated Testing

Cycle	Urban	Highway	Charge	Reps	Total	Electricity	Gasoline	
(mi)	(10 mi)	(10 mi)	(hr)	(N)	(mi)	kWh	Gals	MPG
10	1	0	4	60	600			
20	1	1	8	30	600	122.02	5.37	115.9
40	4	0	12	5	200*	29.84	1.87	108.9
40	2	2	12	5	600			
40	0	4	12	5	600			
60	2	4	12	10	600			
80	2	6	12	8	640			
100	2	8	12	6	600	35.98	8.43	73.23
200	2	18	12	3	600			
Total	1740	2500	984	132	4240	Weighted Ave		

* Being rerun to 600 miles

EnergyCS & Hymotion Fuel Costs/Mile

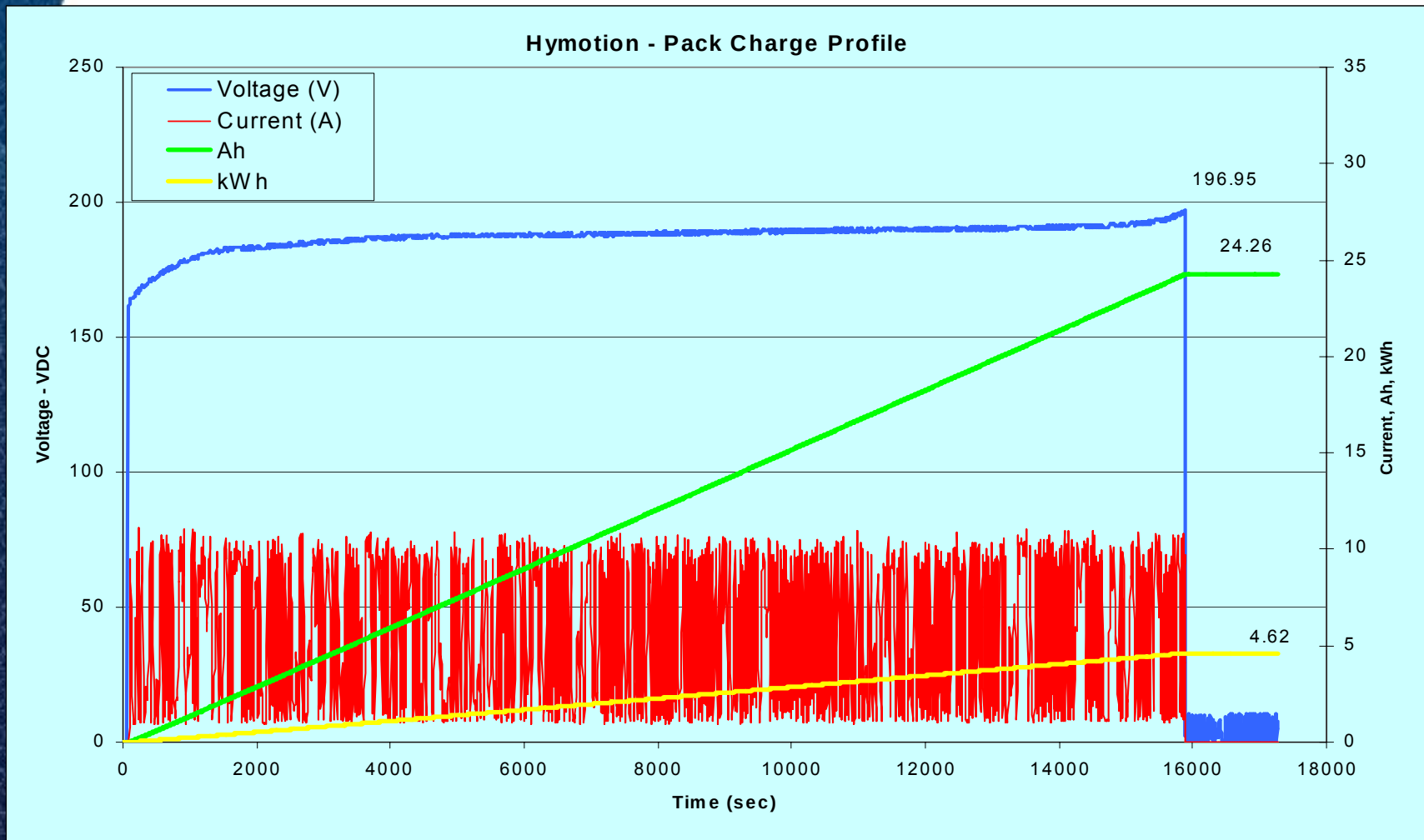


Renault Kangoo – Series hybrid

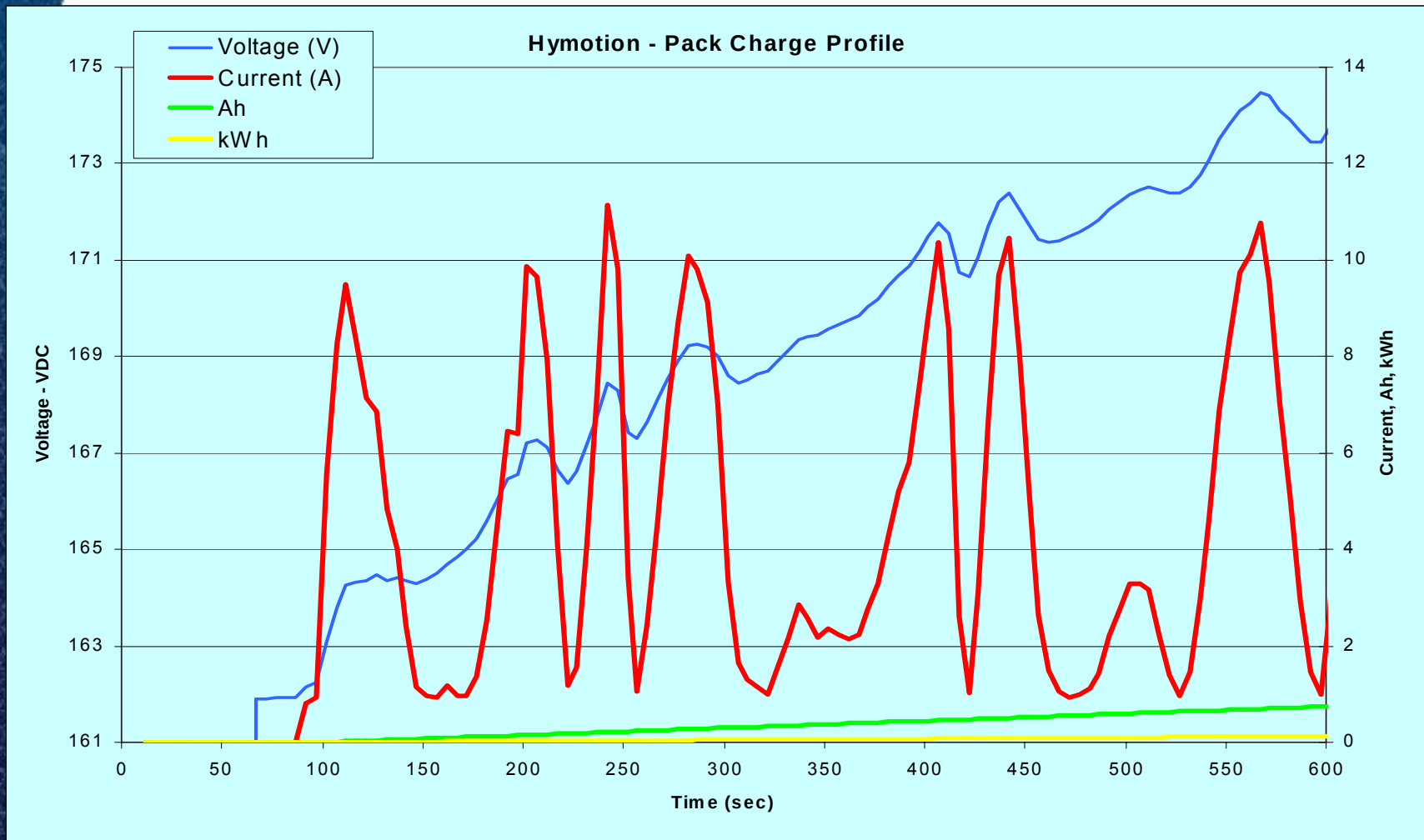
Test Cycle	A/C kWh per Mile	Miles per Gallon
Battery Only - UDDS	0.268	
Battery Only - HWFET	0.155	
Battery Only @ Constant 45 mpg	0.271	
Battery & Gas Cold UDDS	0.144	42.3
Battery & Gas Hot UDDS	0.110	39.4
Battery & Gas Hot HWFET	0.042	40.9
60 Battery Only 10-mile Accelerated Cycles	0.481	



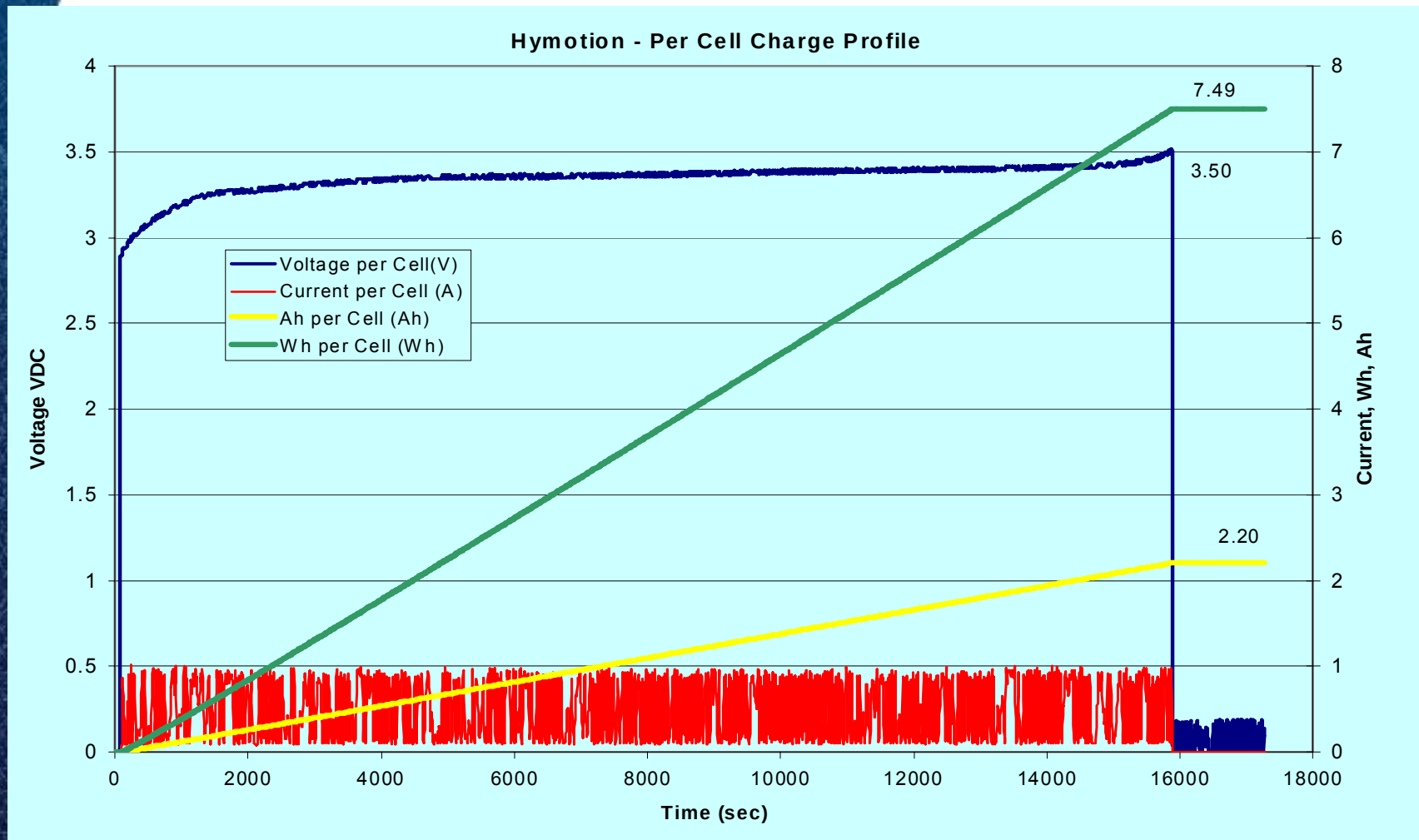
Hymotion Charger Profile



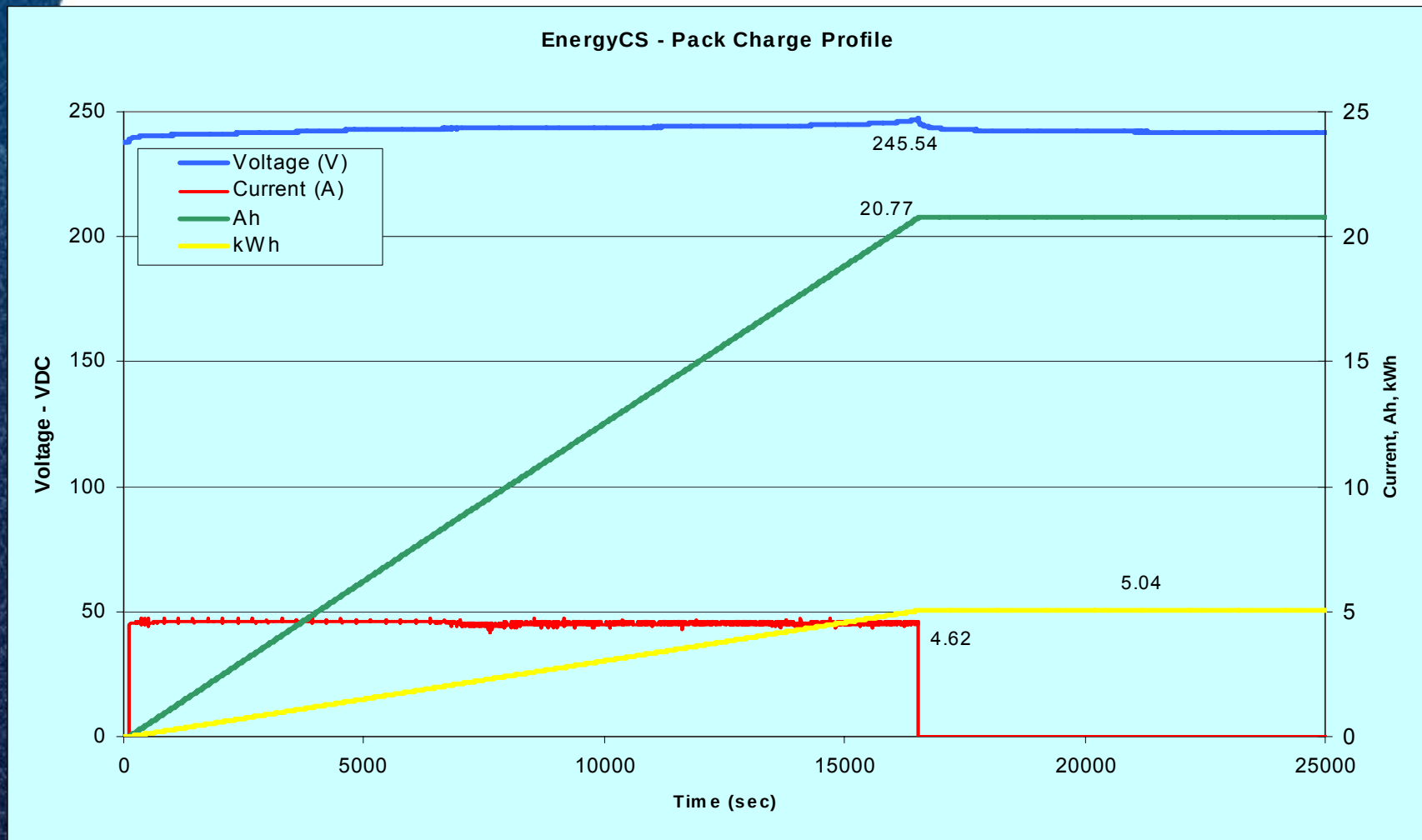
Hymotion Charger Profile



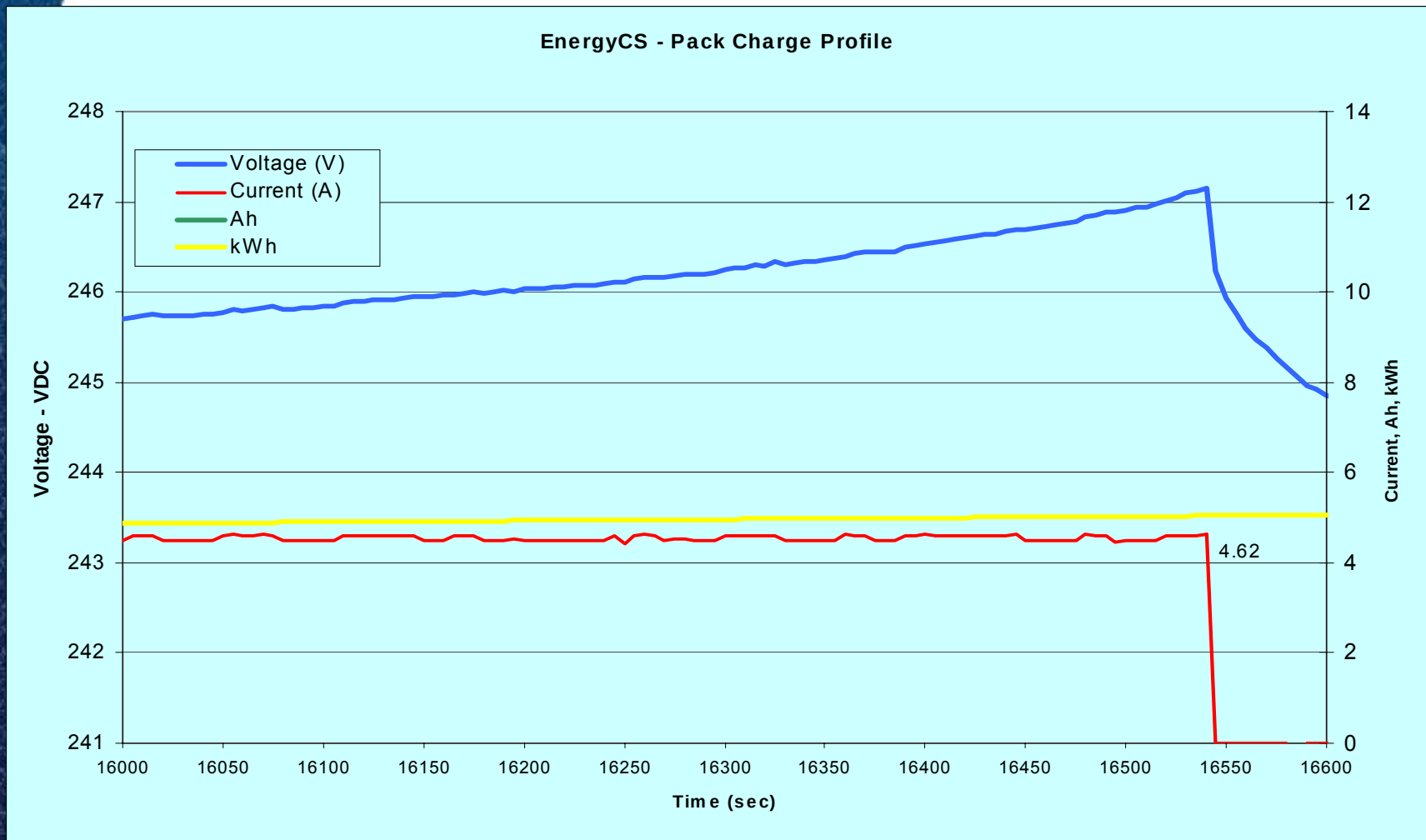
Hymotion Charger Profile – Per Cell



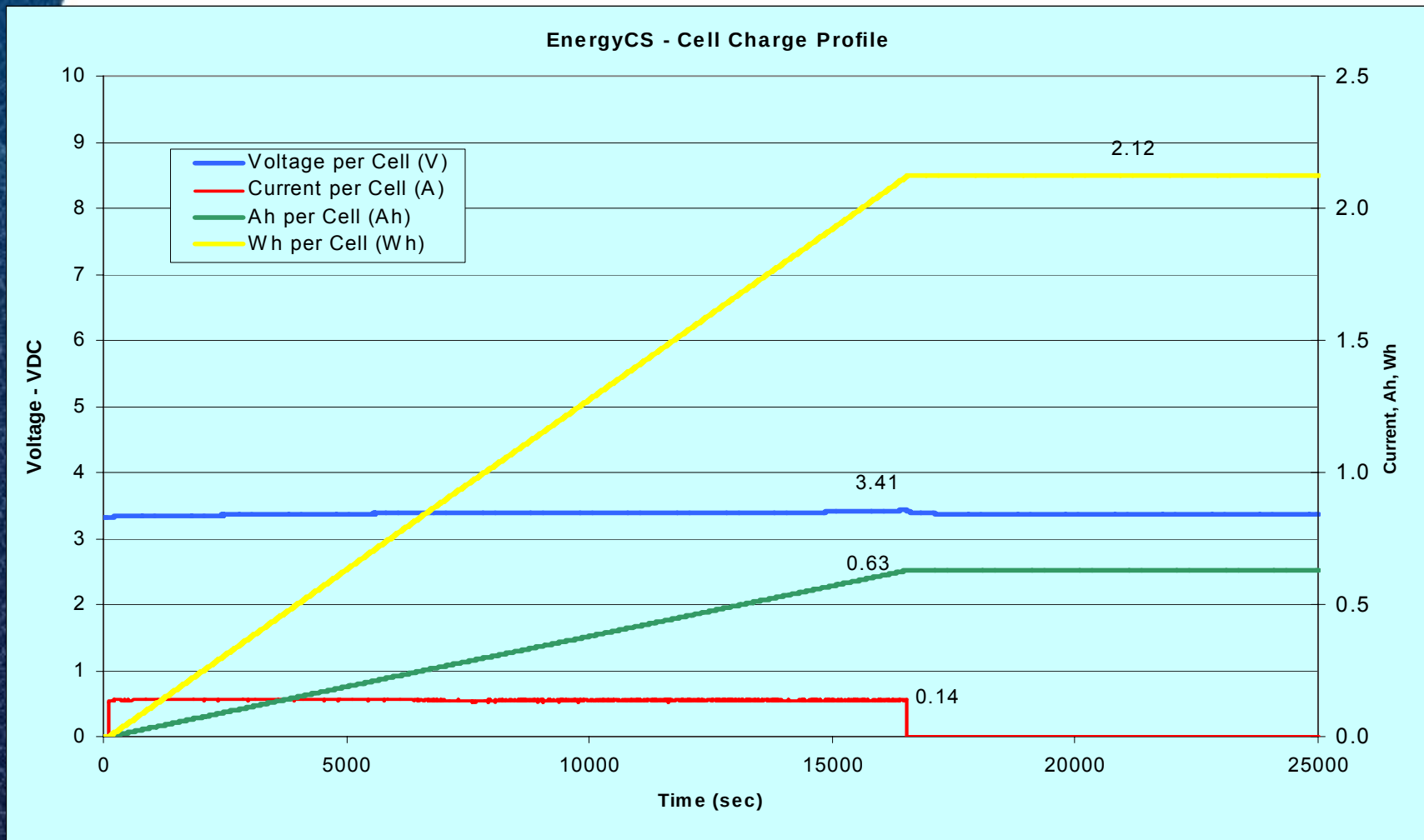
EnergyCS Charger Profile



EnergyCS Charger Profile



EnergyCS Charger Profile – Per Cell



NYSERDA

- **The AVTA is testing New York State Energy Research and Development Agency's PHEVs**

Model	Baseline	Accelerated	Delivery Status
EnergyCS Prius	Completed	Near completion	Delivered
Hymotion Prius	Completed	ongoing	Delivered
Hymotion Civic			Not yet delivered
Hymotion Escape			Delivered Albany, NY
Electovaya Escape	Starting	After baseline	4 deliveries required
HybridsPlus Escape			Delivered once, sent back

Seattle-Area Demonstration

- **13 Hymotion Prius PHEV demonstration with:**
 - ▶ The City of Seattle (4)
 - ▶ King County (4)
 - ▶ Port of Seattle (2)
 - ▶ Puget Sound Clean Air Agency (3)
- **Testing will include charging and driving profiles as well as charging infrastructure analysis**
- **Start late 1st quarter CY2008**

City of Tacoma

- **The City of Tacoma has obtained 1 lead acid battery Prius PHEV from the Green Car Company with 1 more on order, and 1 Hymotion Prius is on order**
- **Tacoma and the AVTA to conduct cooperative testing of vehicles and charging infrastructure**
 - ▶ Tacoma is following the NEC for PHEV charging
 - ▶ Each branch circuit is metered
- **Testing will include charging and driving profiles as well as charging infrastructure analysis**
- **Started 4th quarter CY2007**

NRECA

- **Developing PHEV data collection effort with National Rural Electric Cooperative Association**
- **Total of 7 Prius and Escape PHEVs from Hymotion, EnergyCS, and HybridsPlus will be operated by rural electric coop utilities in Florida, Georgia, Indiana, Minnesota, North Carolina, Oregon, and South Carolina**
- **The AVTA will collection and process onboard data from the fleets, and provide individual vehicle and fleet operations data**
- **Testing will include charging and driving profiles as well as charging infrastructure analysis**

Hymotion

- Data loggers installed on most of 50 PHEVs in 25 North America locations, with plans to actively collect data on 100 vehicles during 2008
- New battery version available in 1st quarter 2008, is in crash testing and will have SULEV certification
- Testing will include charging and driving profiles as well as charging infrastructure analysis
- The AVTA signed agreement with Hymotion and is initiating Hymotion fleet testing support

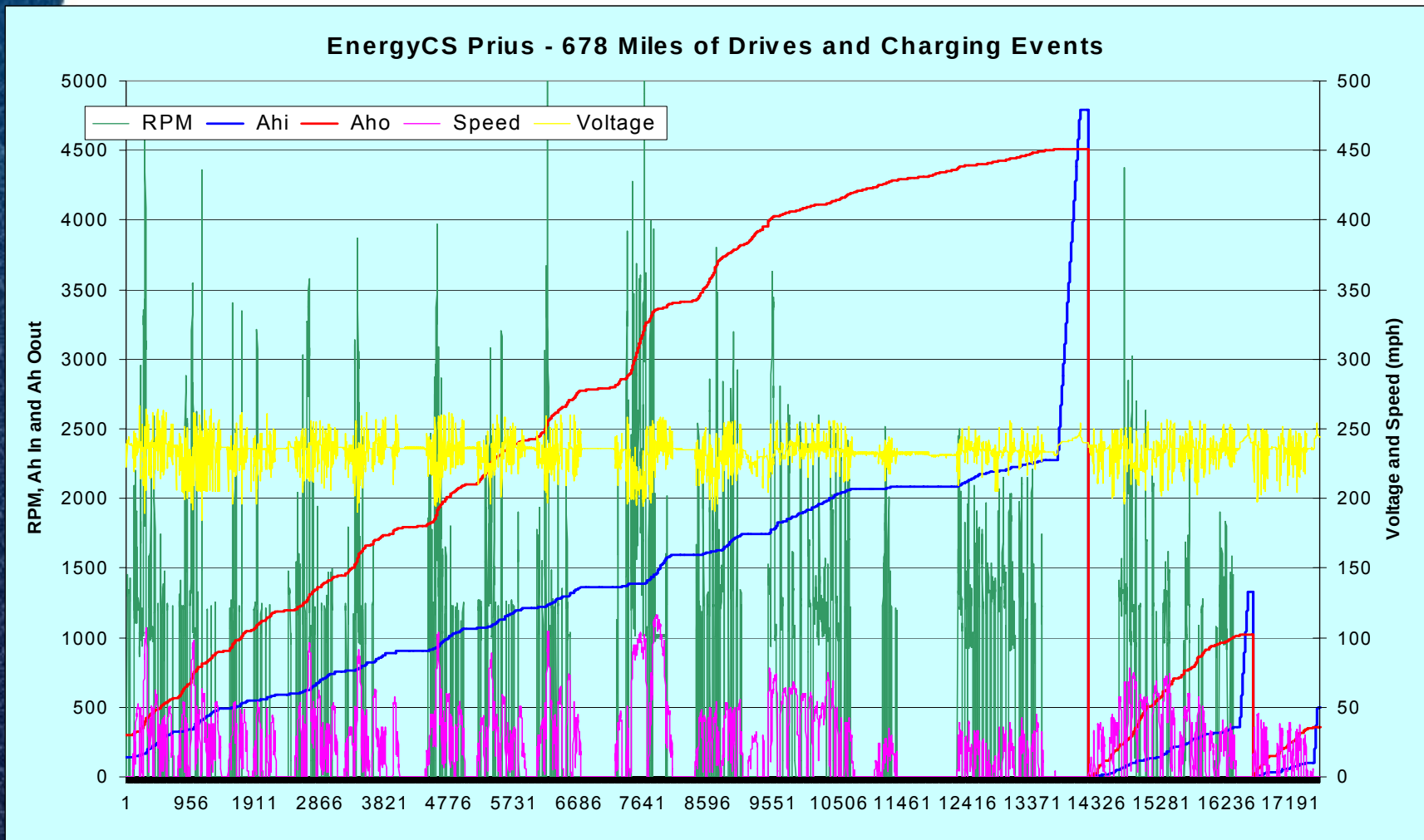


EnergyCS

- The AVTA and EnergyCS have signed and initiated a data collection, dissemination and reporting agreement
- EnergyCS has provided historical PHEV operations onboard data for 7 vehicles operating in fleets in Canada, Arizona, and California



EnergyCS Onboard Data



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ANAHEIM, CALIFORNIA USA

**This work is supported by DOE's
Office of Vehicle Technologies
- Vehicle Systems Team Leader, Tien Duong
- AVTA DOE Lead, Lee Slezak**

**<http://avt.inl.gov>
or
<http://www1.eere.energy.gov/vehiclesandfuels/avta/>**

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