



U.S. Department of Energy, Vehicle Technologies Program

Advanced Vehicle Testing Activity (AVTA) – EESTT Update

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Electrochemical Energy Storage Tech Team,
USCAR, Southfield, MI. February 2010

AVTA Description

- **A U.S. DOE activity, the AVTA tests whole vehicle systems and fueling infrastructure that employ:**
 - **Advanced energy storage systems**
 - **Advanced technology control systems**
 - **Electric and/or dual-fuel propulsion systems**
 - **(Some) Alternative fuels**
- **Vehicle technologies tested during 2009:**
 - **Plug-in hybrid electric vehicles (PHEV)**
 - **Hybrid electric vehicles (HEV)**
 - **Hydrogen ICE vehicles (HICEV)**
 - **Neighborhood electric vehicles (NEV)**
 - **Pure battery electric vehicles (BEVs)**
- **INL and eTec conduct the AVTA. ANL provides dynamometer testing support.**

Objectives

- Provide benchmarked advanced technology vehicle data to research and development programs, technology modelers, vehicle manufacturers, and target and goal setters (DOE) via VSATT and other industry venues
- Assist early adaptor government and industry fleet managers, as well as the general public, in making informed vehicle purchase, deployment and operating decisions via Clean Cities Coalitions and other public venues
- Conduct independent testing of emerging technologies
- *Continue to be DOE's independent resource for valid information on emerging and alternative-fuel vehicle technologies employed in whole-vehicle systems*

Approach

- Depending on vehicle technology and capabilities, vehicles are tested via:
 - Closed test tracks
 - Dynamometer testing
 - Laboratory testing (batteries)
 - Accelerated testing, using dedicated drivers and other methods to accumulate miles and cycles
 - Fleet testing
 - Different testing methods are used to balance testing control/repeatability and larger sample sizes
- *Publish testing results in relevant ways to accurately*
 - *Document real-world petroleum reduction potentials*
 - *Document alternative fuel and infrastructure use*
 - *Document life-cycle risks and costs*

PHEV Testing

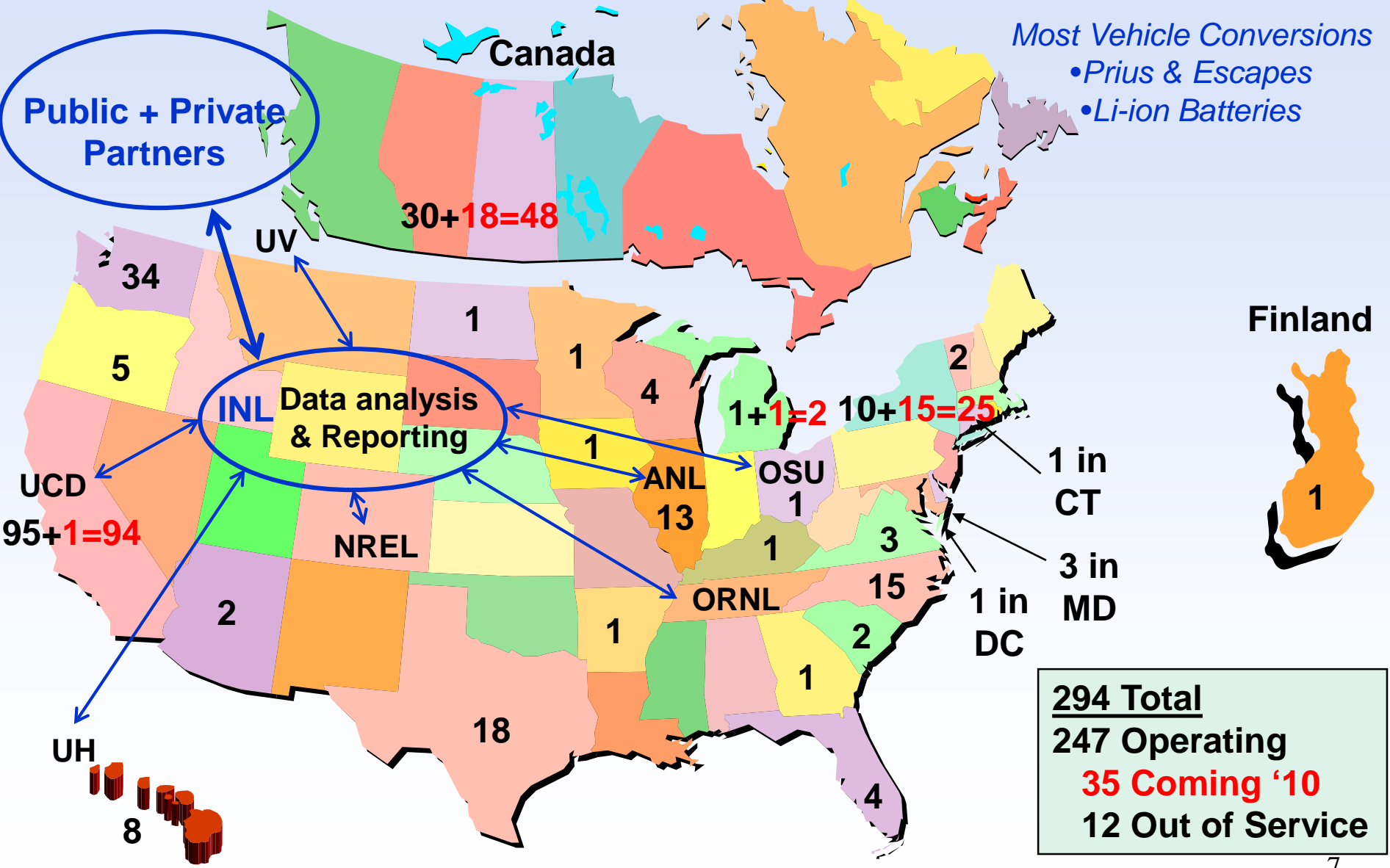
- 12 PHEV models tested to date, 4 PHEV models (red) introduced into testing in 2009. Testing is conducted to test the PHEV concept as well as individual models
 - Hymotion Prius (A123Systems)
 - Hymotion Escape (A123Systems)
 - **Ford E85 Escape (Johnson Controls/Saft)**
 - EnergyCS Prius, 2 models (Valance and **Altair Nano**)
 - Electrovaya Escape (Electrovaya) - done
 - Hybrids Plus Escape, 2 models (Hybrids Plus and **K2 Energy Solutions**)
 - Hybrids Plus Prius (Hybrids Plus)
 - Manzanita Prius (lead acid)
 - Manzanita Prius (**Thunder Sky**)
 - Renault Kangoo (Saft NiCad) - done
 - (Lithium unless noted)



PHEV Testing – cont'd

- Initiated demonstrations of another 105 PHEVs in 2009
- 257 PHEVs in 23 states, Canada and Finland, 1.3 million miles - AVTA only purchased 2 vehicles and 12 conversions
- 93 PHEV testing partners include:
 - 38 Electric utilities
 - 10 County governments
 - 4 State governments
 - 10 Canadian government groups
 - 3 Sea ports and military bases
 - 2 PHEV conversion companies
 - 5 Private companies and advocacy organizations
 - 9 City governments
 - 10 Universities
 - 2 Clean Air Agencies
- 2,000 monthly PHEV 3-page summary reports have been generated and disseminate to testing partners
- Conducted (second) PHEV fire investigation in 2009

PHEVs and Demonstration Locations



Hymotion Prius Gen II – Accelerated Testing

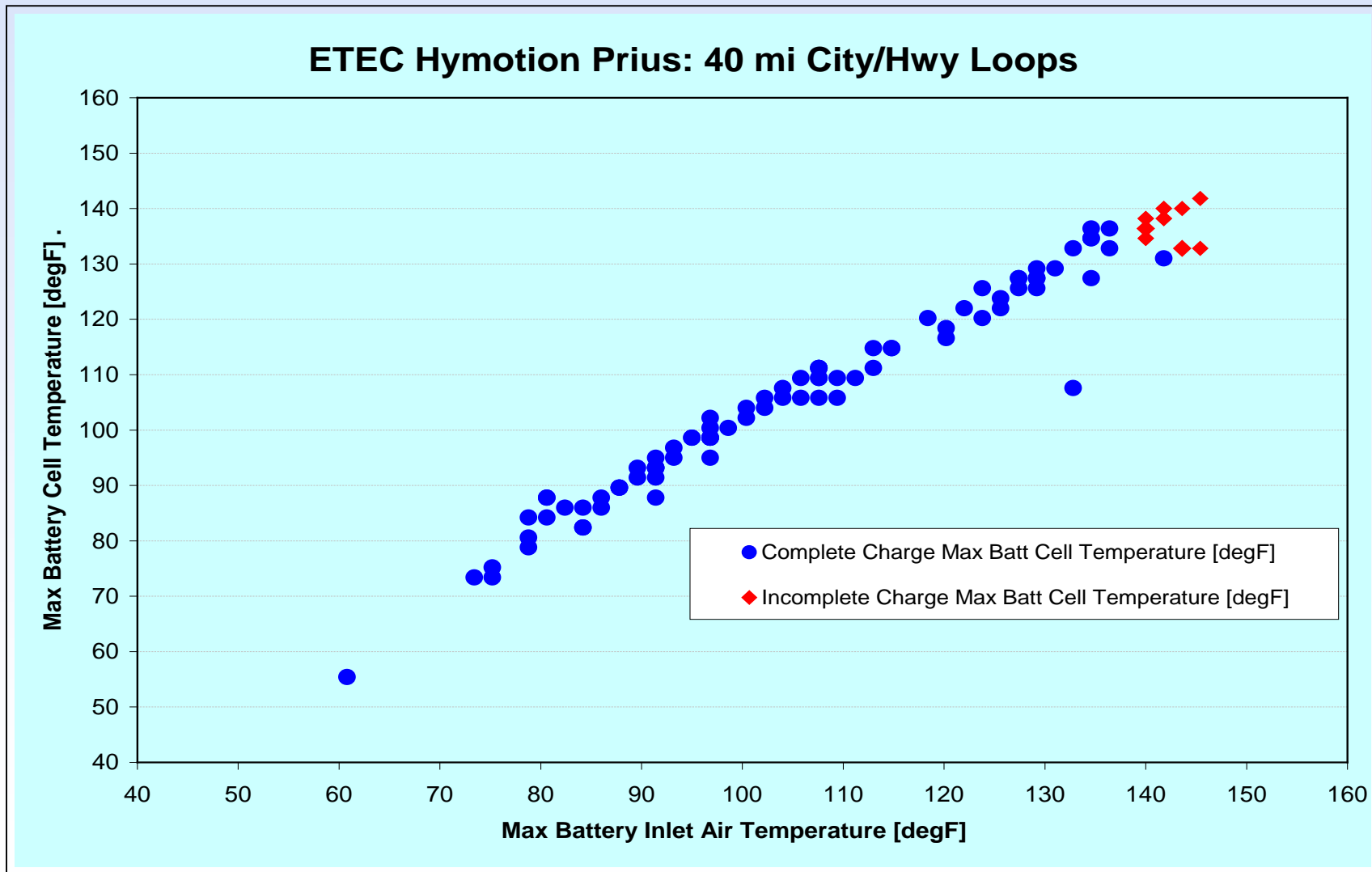
Cycle	Urban (mi)	Highway (10 mi)	Charge (hr)	Reps (N)	Total (mi)	Electricity AC kWh	Gasoline		Recalculated without incomplete charges
							Gals	MPG	
10	1	0	4	60	600	111.43	5.205	117.6 E	
20	1	1	8	30	600	124.50	8.105	80.1 I	
40	4	0	12	15	600	71.28	9.8	62.1 I	64.2
40	4	0	12	15	600	44.97	7.2	84.2 E	135.6
40	2	2	12	15	600	64.36	9.70	64.3 I	65.5
40	2	2	12	15	600	75.14	6.20	99.8 E	101.7
40	2	2	12	15	600	70.98	6.83	90.6 I	98.9
40	0	4	12	15	600	75.18	6.10	103.3 E	100.0
40	0	4	12	15	600	63.46	8.88	70.8 I	92.4
60	2	4	12	10	600	33.38	10.54	58.8 I	
80	2	6	12	8	640	41.38	10.71	61.8 I	
100	2	8	12	6	600	26.48	10.91	56.5 I	
200	2	18	12	3	600	16.01	10.41	57.7 I	
Total	2340	3100	1404	167	7,840	Weighted Average			

Each total distance slightly greater than 600 and 640 miles. HEV version = 44 mpg.

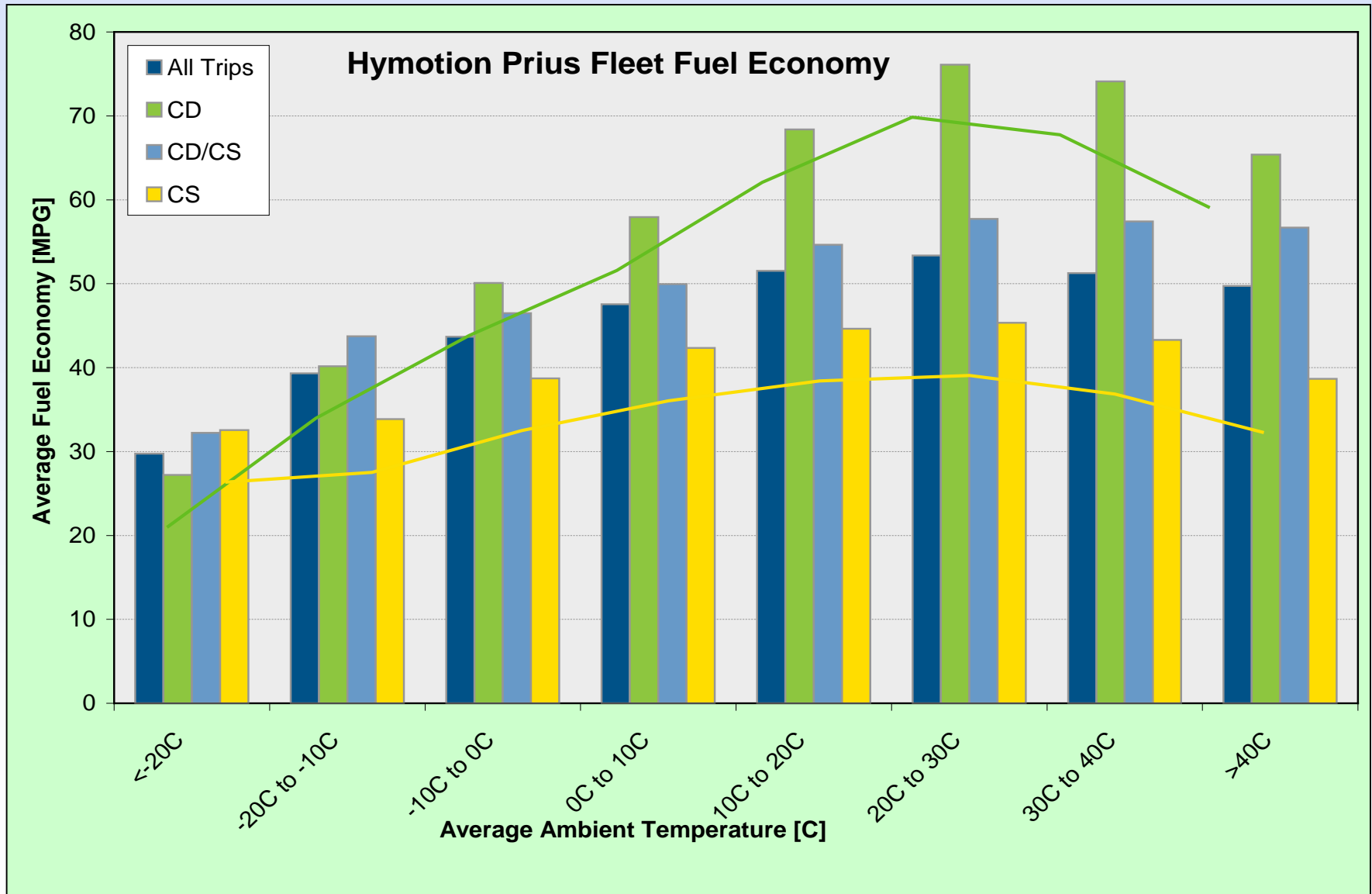
E = experienced HEV driver, I = inexperienced driver

Hymotion Prius Gen II – Accelerated Testing

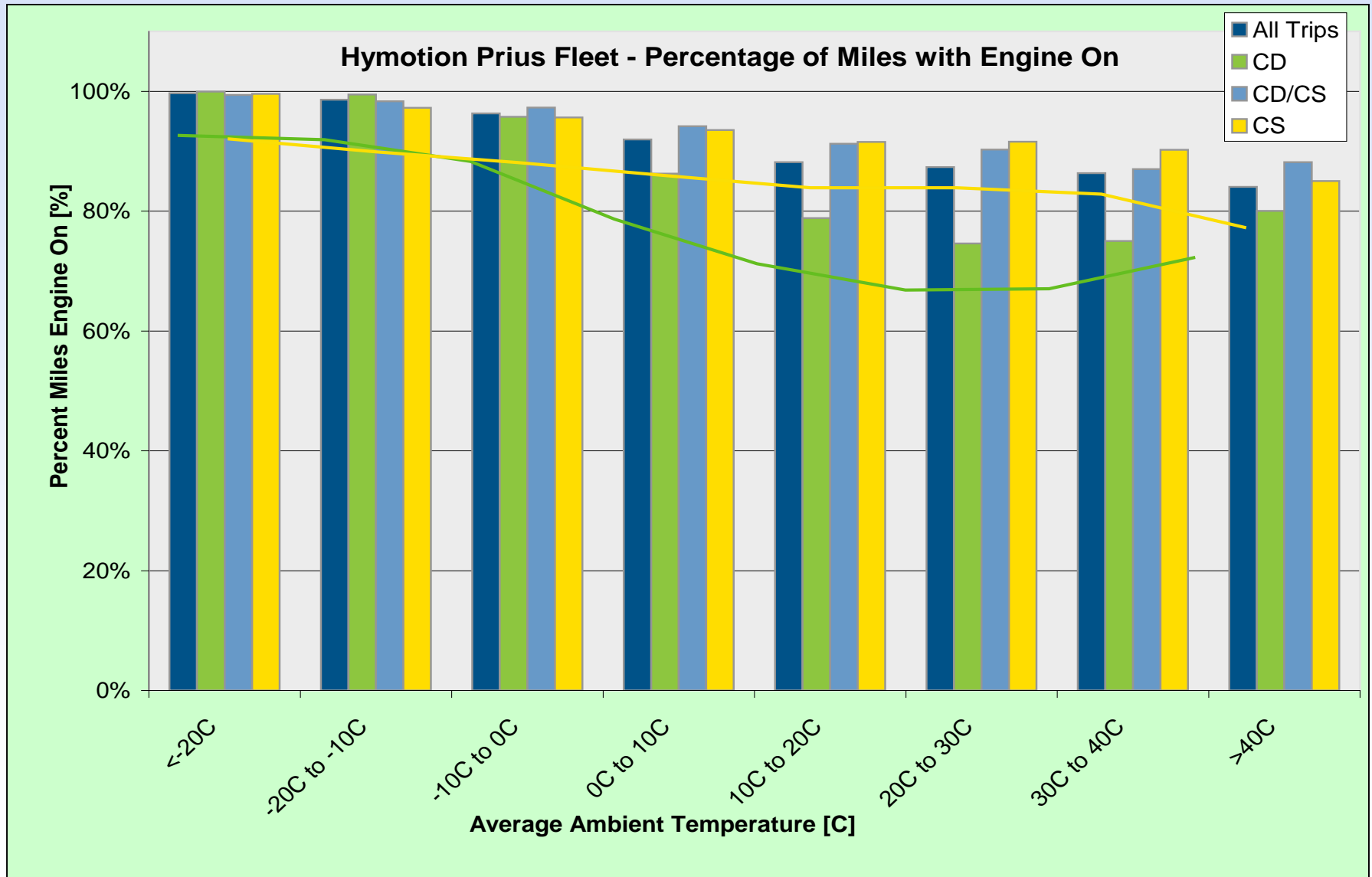
- High ambient temperatures impact charge completion



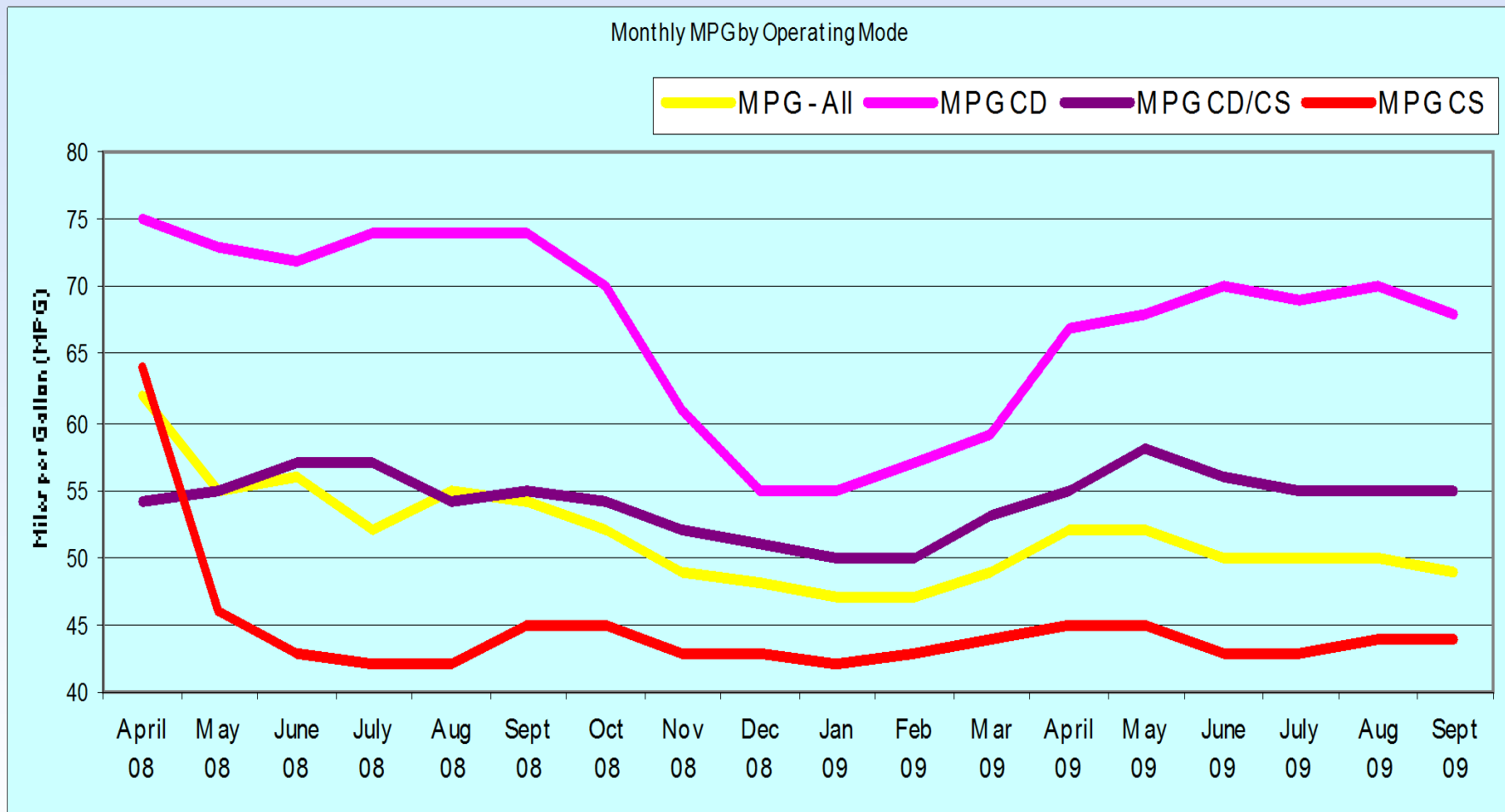
Ambient Temperature MPG Impacts



Engine Operations by Ambient Temperatures



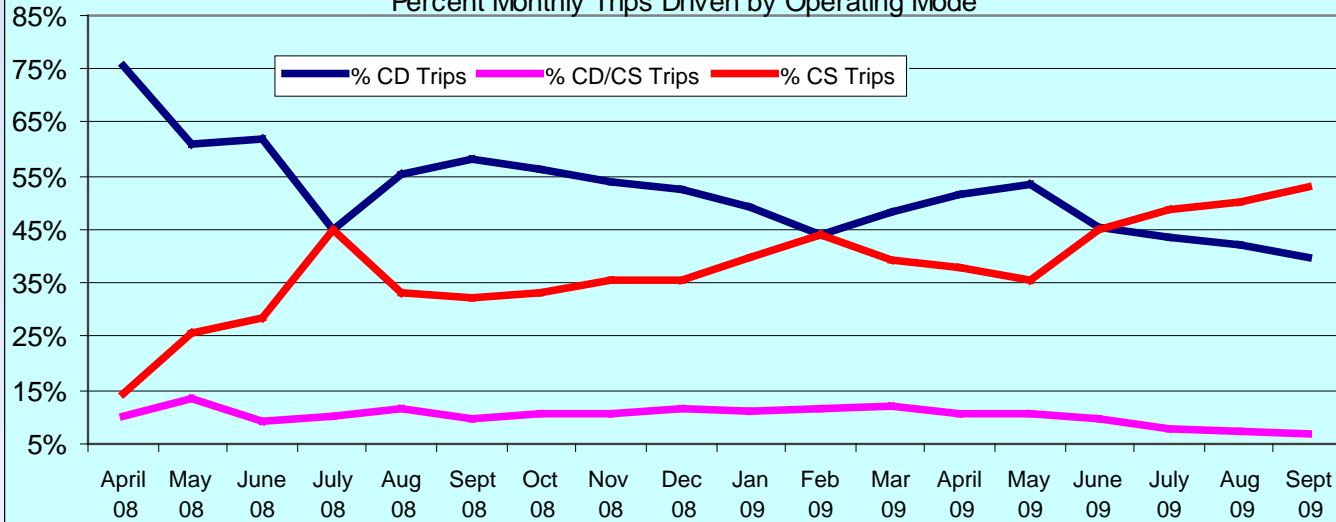
Monthly Fleet Testing MPG Results



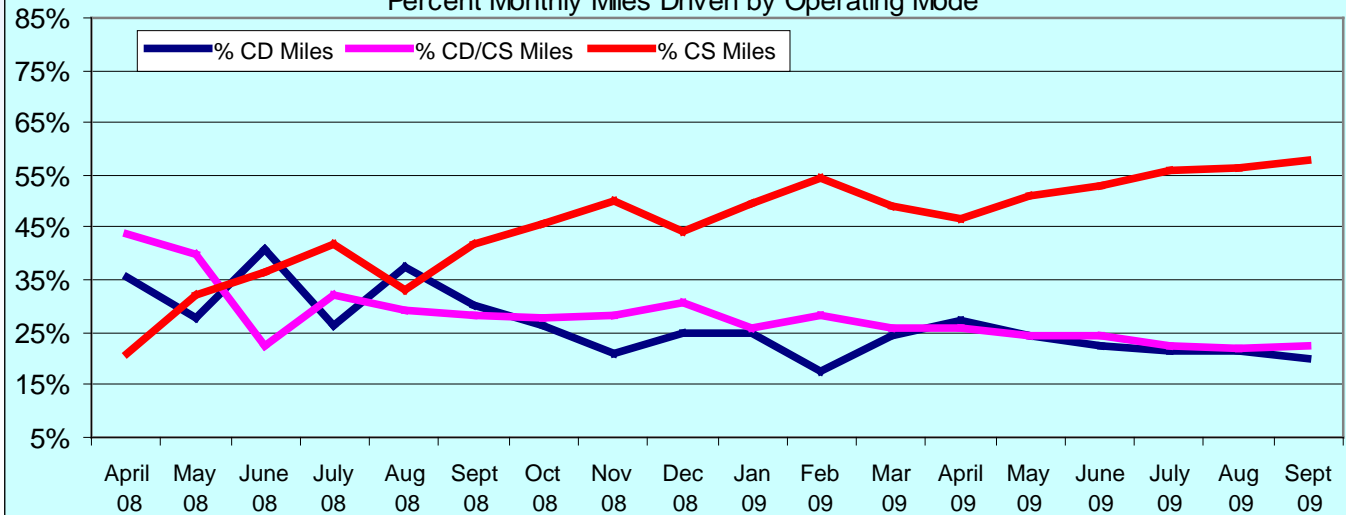
Hymotion Prius PHEVs with GridPoint (V2Green) data loggers – 731,000 miles of data from 108 vehicles (as of September 2009)

Monthly Fleet Testing Drive Modes

Percent Monthly Trips Driven by Operating Mode



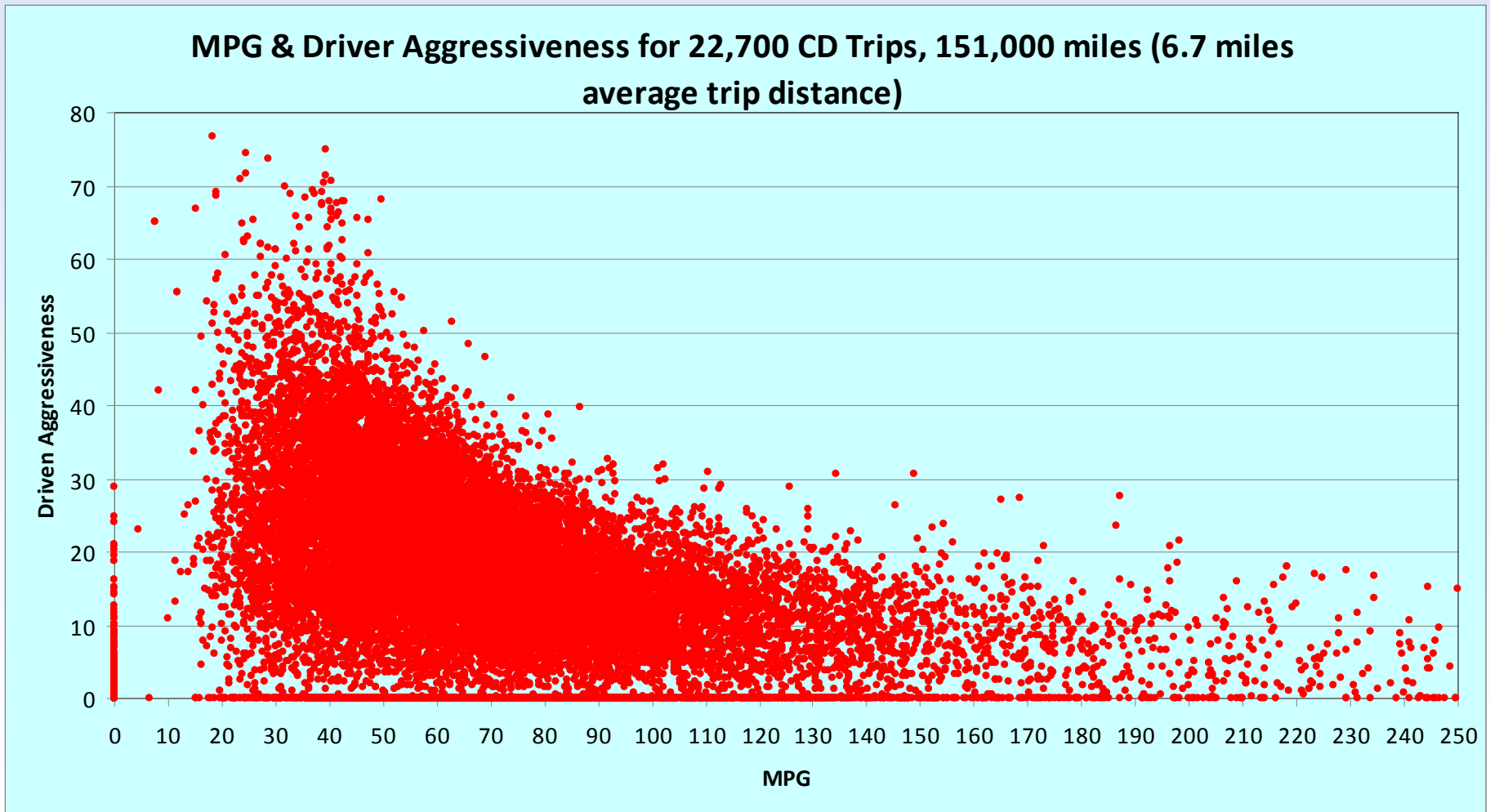
Percent Monthly Miles Driven by Operating Mode



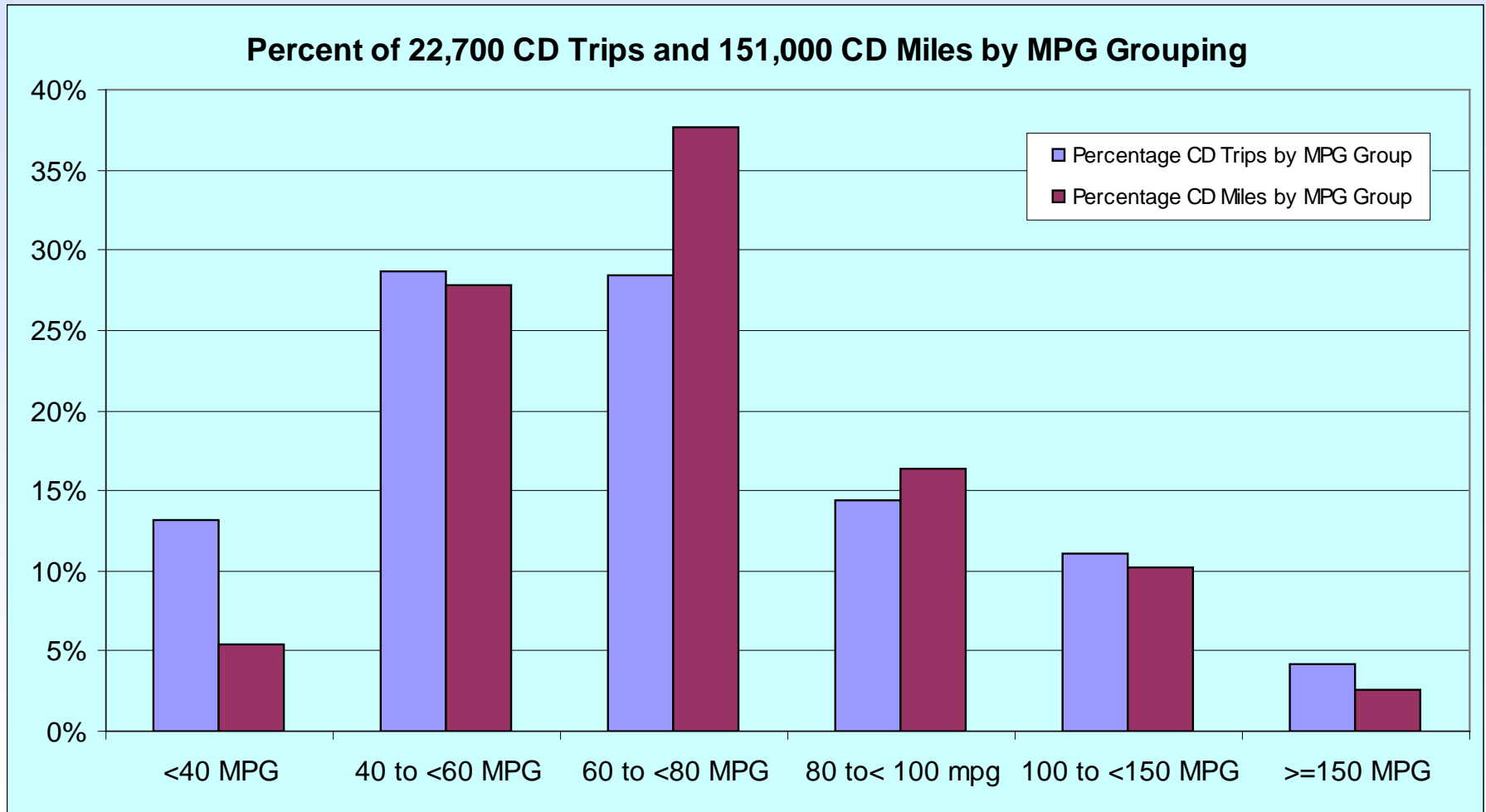
Hymotion Prius PHEVs with GridPoint (V2Green) data loggers – 731,000 miles of data from 108 vehicles (as of September 2009)

Hymotion Prius PHEVs – CD Trips

- MPG and aggressive driving impacts March '08 – May '09



MPG Results - Charge Depleting (CD) Mode



North American PHEV Demonstration

Fleet Summary Report: Hymotion Prius (V2Green data logger)

Number of vehicles: 180

Reporting Period: Apr 08 - Dec 09

All Trips Combined

Overall gasoline fuel economy (mpg)	49
Overall AC electrical energy consumption (AC Wh/mi) ¹	59
Overall DC electrical energy consumption (DC Wh/mi) ²	44
Total number of trips	105,249
Total distance traveled (mi)	971,420

Trips in Charge Depleting (CD) mode ³

Gasoline fuel economy (mpg)	64
DC electrical energy consumption (DC Wh/mi) ⁴	141
Number of trips	48,387
Percent of trips city / highway	86% / 14%
Distance traveled (mi)	220,864
Percent of total distance traveled	23%

Trips in both Charge Depleting and Charge Sustaining (CD/CS) modes ⁵

Gasoline fuel economy (mpg)	53
DC electrical energy consumption (DC Wh/mi) ⁶	49
Number of trips	9,296
Percent of trips city / highway	48% / 53%
Distance traveled (mi)	236,967
Percent of total distance traveled	24%

Trips in Charge Sustaining (CS) mode ⁷

Gasoline fuel economy (mpg)	43
Number of trips	47,566
Percent of trips city / highway	74% / 26%
Distance traveled (mi)	517,076
Percent of total distance traveled	53%

Number of trips when the plug-in battery pack was turned off by the vehicle operator ⁸	2415
Distance traveled with plug-in battery pack turned off by the vehicle operator (mi) ⁹	93,839

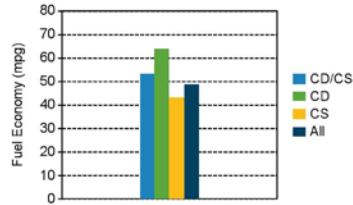
Vehicle Technologies Program

Date range of data received:

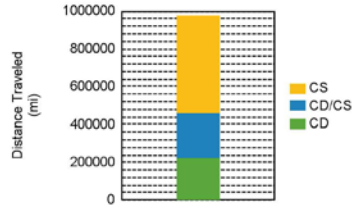
4/18/2008 to 12/31/2009

Number of days the vehicles were driven: 616

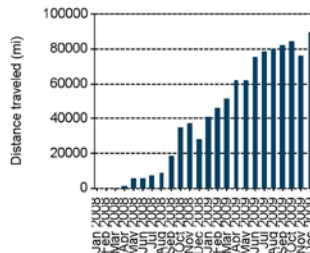
Gasoline Fuel Economy By Trip Type



Distance Traveled By Trip Type



Miles Logged by Month This Year



Notes: 1 - 9. Please see <http://avt.inel.gov/phev/reportnotes> for an explanation of all PHEV Fleet Testing Report notes.

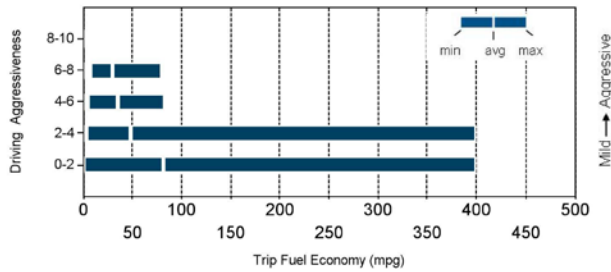
3-Page PHEV Fact Sheets provide AC and DC Wh/mile, and mpg by charge modes

Trips In Charge Depleting (CD) mode		City	Highway
Gasoline fuel economy (mpg)		62	67
DC electrical energy consumption (DC Wh/mi)		167	109
Percent of miles with internal combustion engine off		30%	8%
Average trip aggressiveness (on scale 0 - 10)		1.7	1.7
Average trip distance (mi)		2.9	14.4

Trips in both Charge Depleting and Charge Sustaining (CD/CS) modes			
Gasoline fuel economy (mpg)		55	53
DC electrical energy consumption (DC Wh/mi)		81	43
Percent of miles with internal combustion engine off		23%	5%
Average trip aggressiveness (on scale 0 - 10)		1.8	1.6
Average trip distance (mi)		8.6	40.6

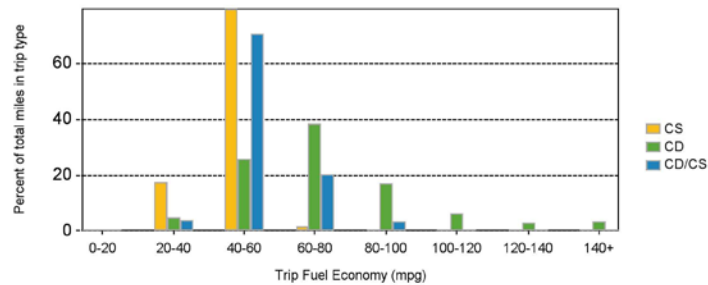
Trips In Charge Sustaining (CS) mode			
Gasoline fuel economy (mpg)		37	46
Percent of miles with internal combustion engine off		21%	4%
Average trip aggressiveness (on scale 0 - 10)		1.8	1.7
Average trip distance (mi)		3.7	31.2

Effect Of Driving Aggressiveness on Fuel Economy This Year



Aggressiveness factor is based on accelerator pedal position. The more time spent during a trip at higher accelerator pedal position, the higher the trip aggressiveness.

Trip Fuel Economy Distribution By Trip Type

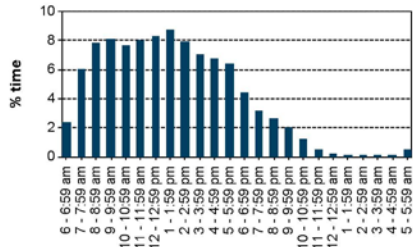


In addition to charge mode, the 3-Page PHEV Fact Sheets provide fuel use by drive cycle and driver style (aggressiveness)

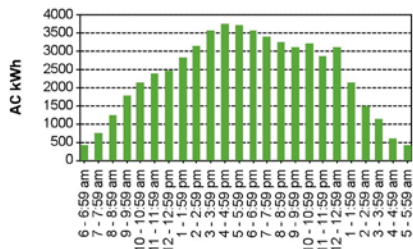
Plug-in charging

Average number of charging events per vehicle per month when driven	15
Average number of charging events per vehicle per day when vehicle driven	1.0
Average distance driven between charging events (mi)	43.8
Average number of trips between charging events	4.7
Average time plugged in per charging event (hr)	20.5
Average time charging per charging event (hr)	2.9
Average energy per charging event (AC kWh)	2.6
Average charging energy per vehicle per month (AC kWh)	38.6
Total number of charging events	22,194
Total charging energy (AC kWh)	57,546

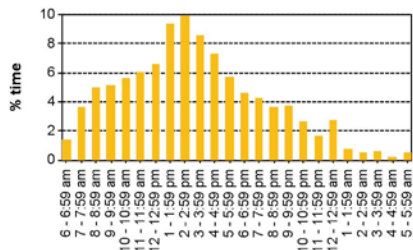
Time of Day When Driving



Time of Day When Charging

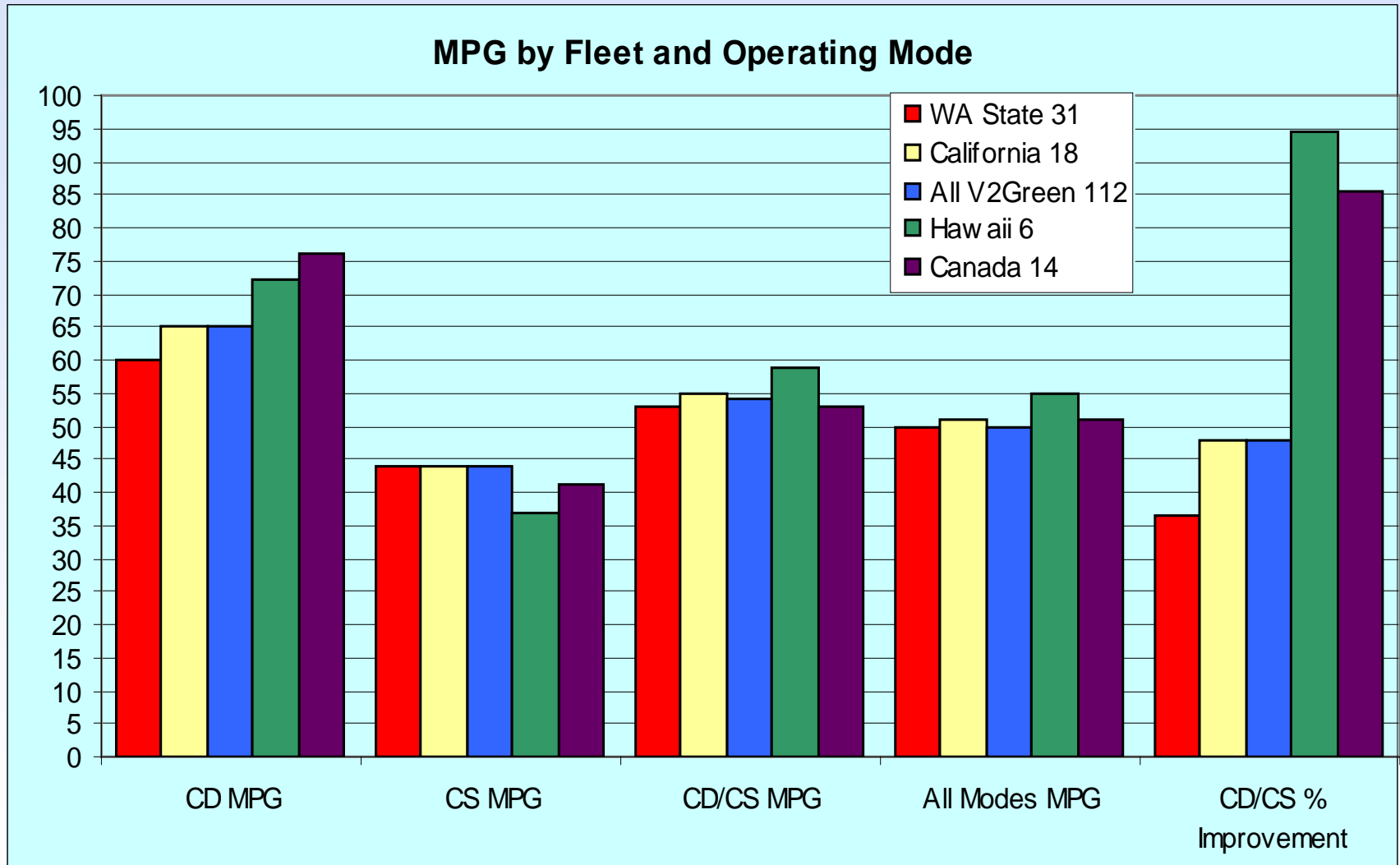


Time of Day When Plugging In



3-Page PHEV Fact Sheets provide charging stats, time of day driving, and charging profiles

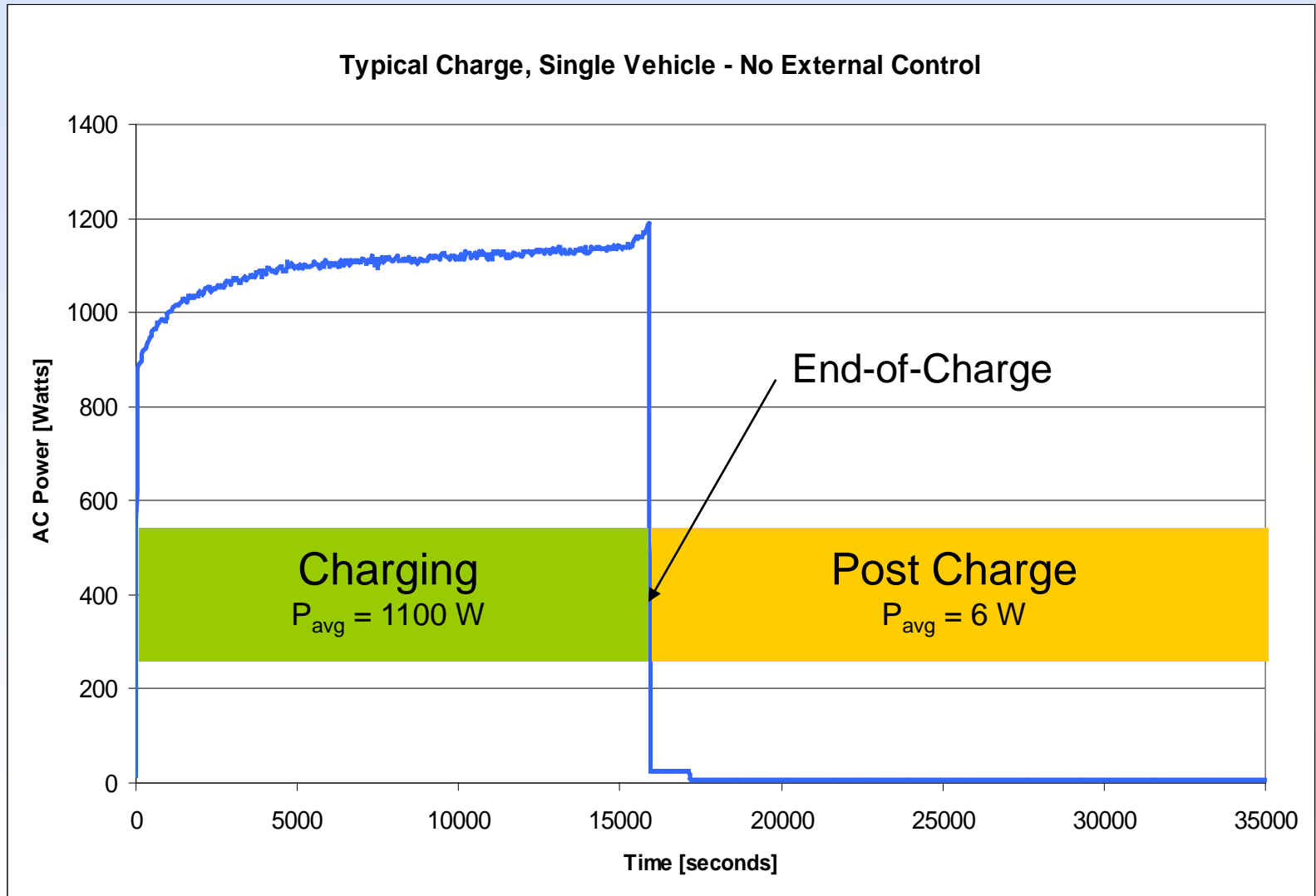
PHEV Testing Results by Fleet



Seattle Area PHEV Smart Charging Trials

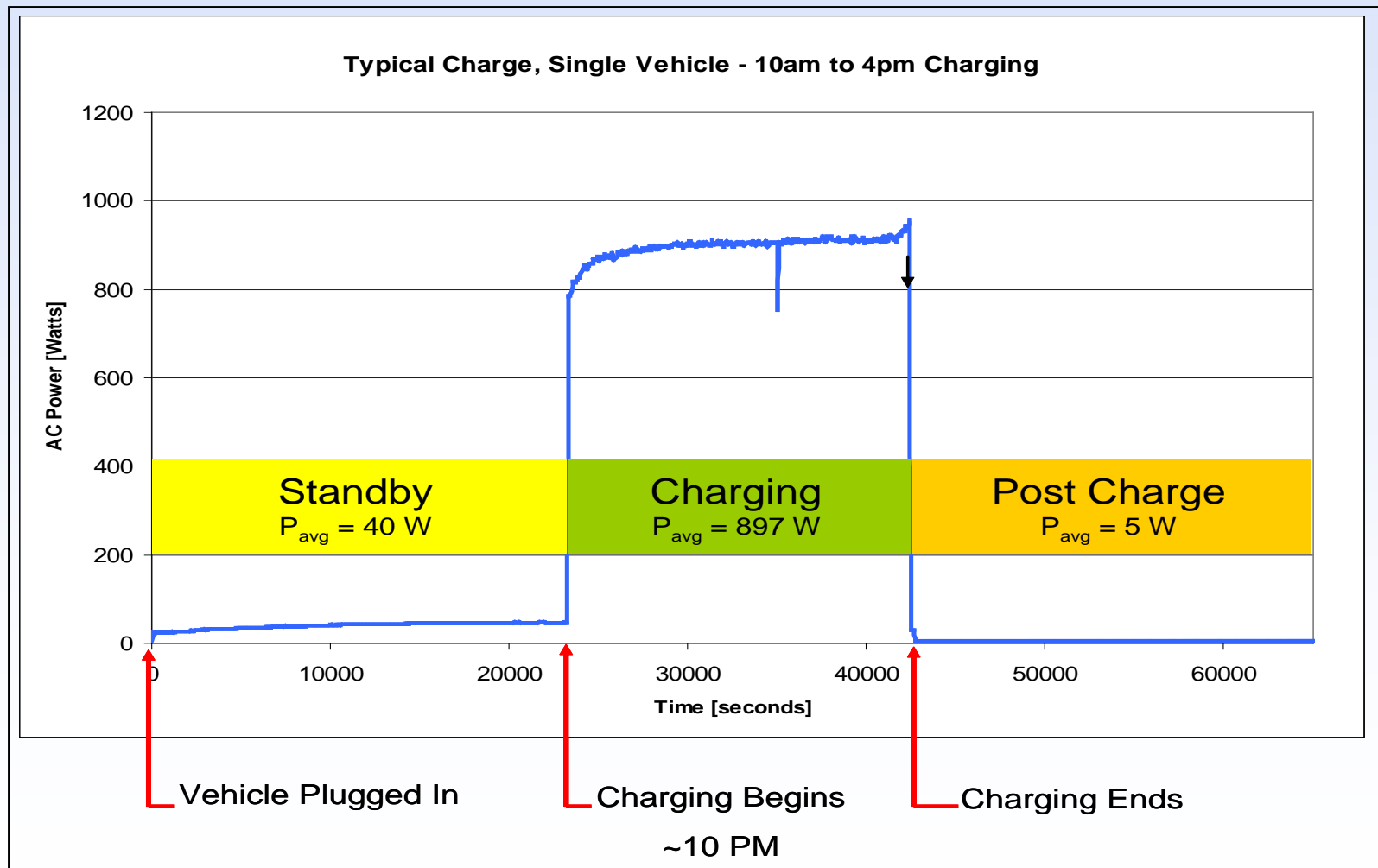
- 13 Hymotion PHEVs using GridPoint's *Electric Vehicle Management Solution*
- Types of Trials:
 - Time of Day Charging – Vehicle charging only allowed during certain hours of the day
 - Goal Based Charging – Normalize power demand for vehicle charging around a kW goal load
 - Economic Charging – Allow vehicle charging only when the price of electricity is below a threshold
- GridPoint Vehicle Connectivity Modules (VCM) used to control charging as directed by GridPoint's server and to log vehicle charging and driving data
- VCM requests the pack to wait to charge or to charge at a specified power level - no physical circuit interruption
- INL analyzed the data collected from the vehicles

Charging – No Control



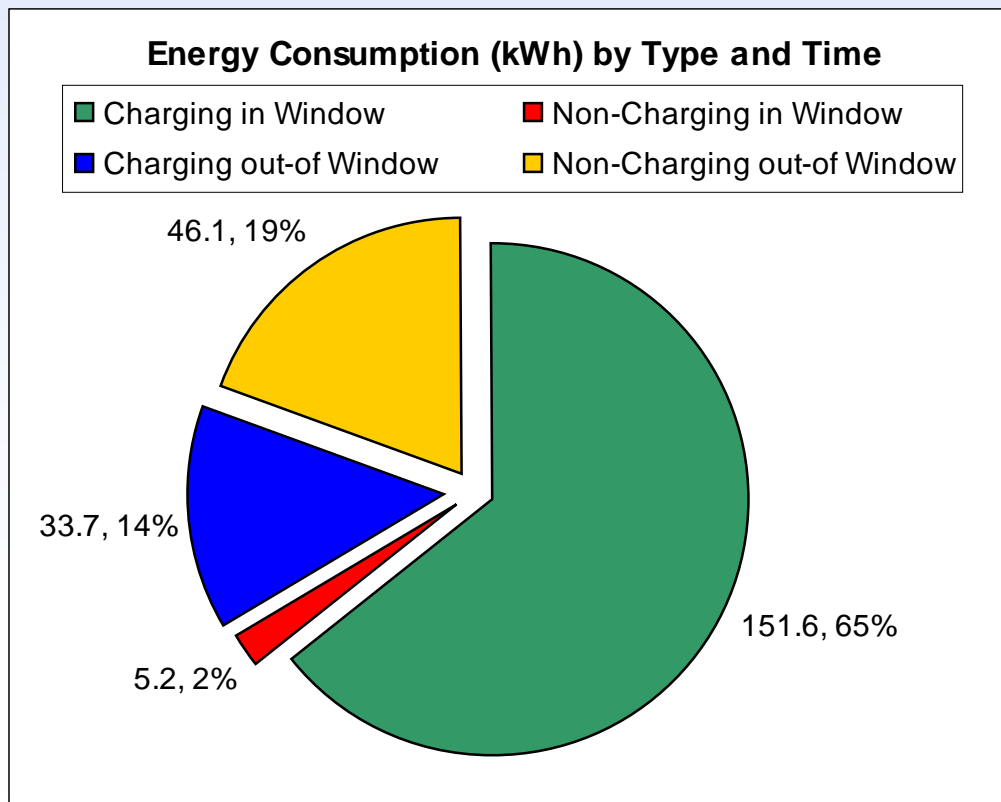
Results of Time of Day Charging Trials

- VCM establishes communication with control server, requests charging only between 10pm & 4am



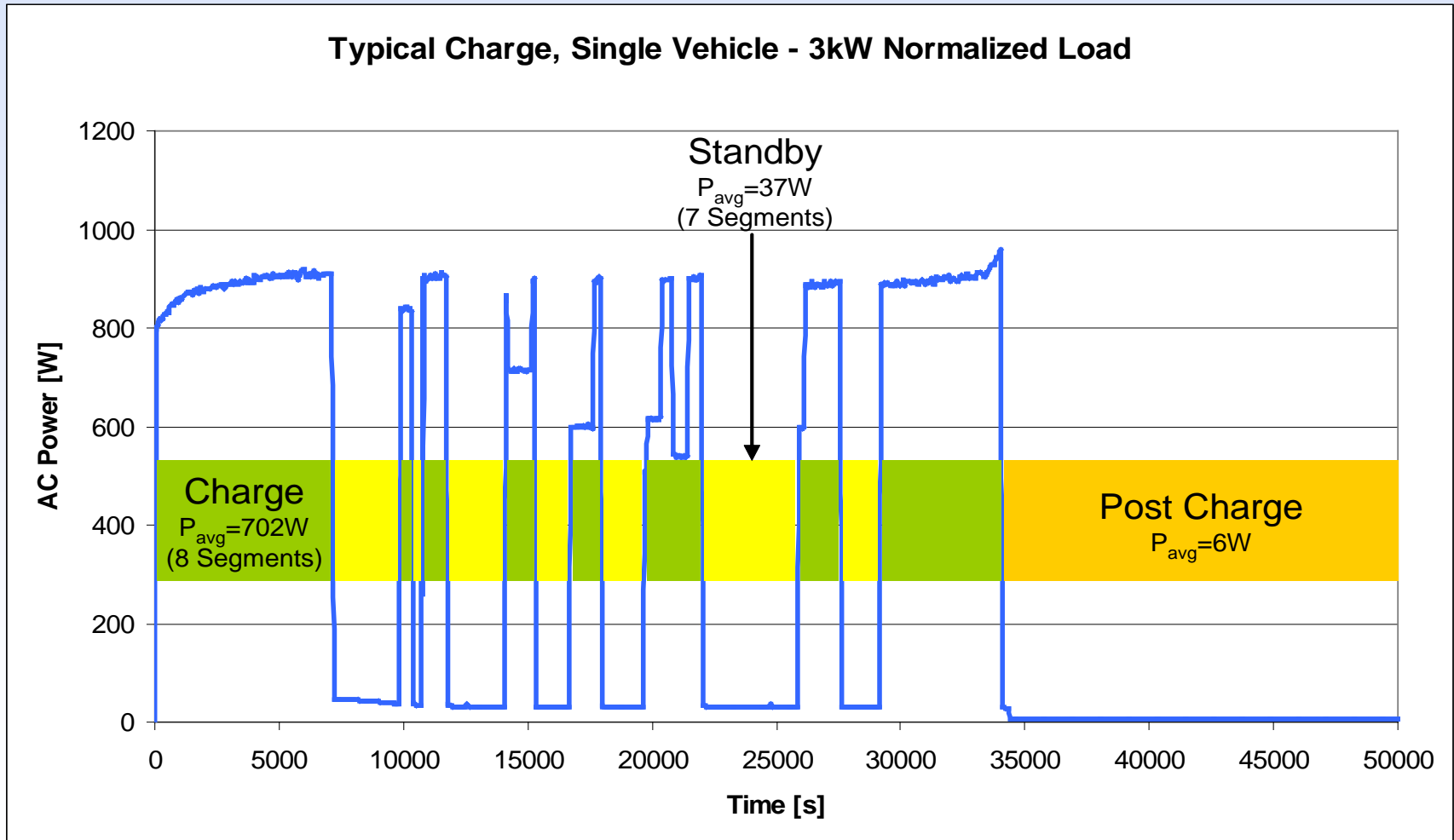
Results of Time of Day Charging Trials

- Rogue AC kWh – energy drawn outside of allowable charging window:
 - Communication not established or lost - charging occurs
 - Cumulative standby energy draw when not charging



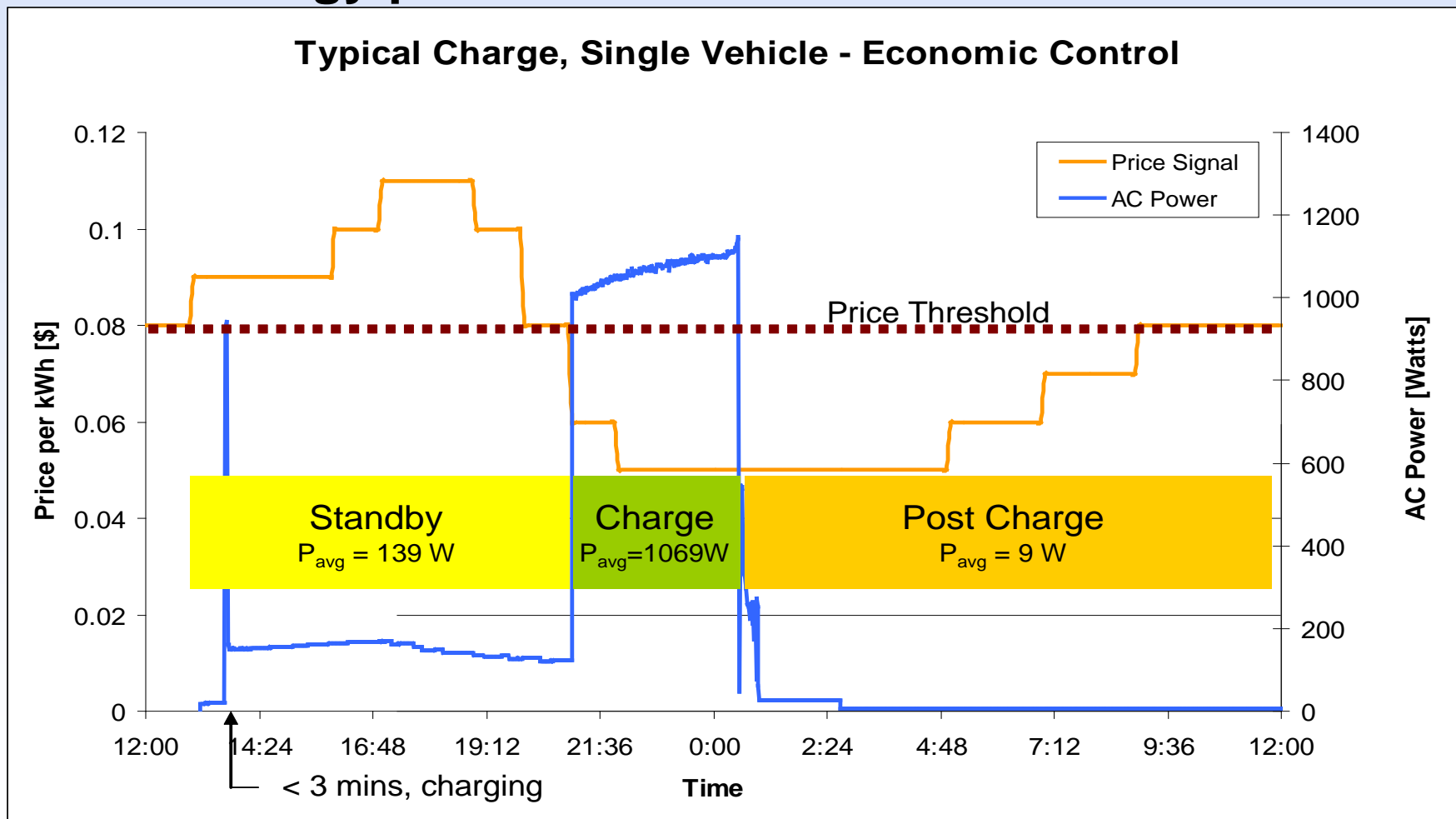
Results of kW Goal Charging Trials

- Vehicle charging controlled to normalize the resource load around 3 kW (Typical 7 Vehicle Max, 13 Possible)



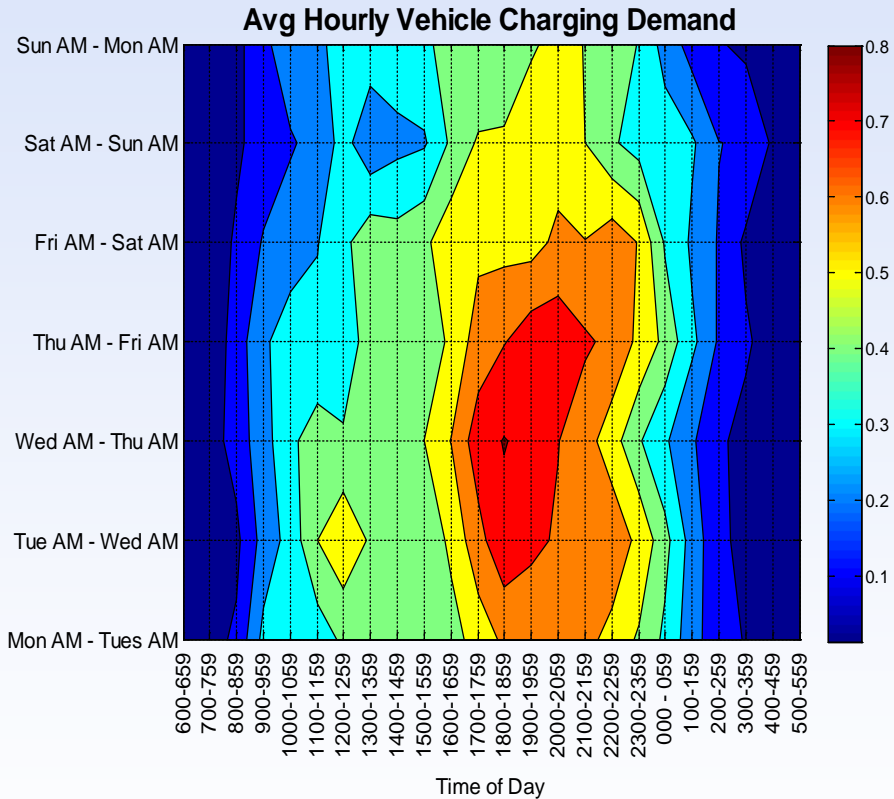
Results of Economic (\$/kWh) Charging Trials

- Artificial price signal supplied and vehicles only charged when energy price < \$.08/kWh

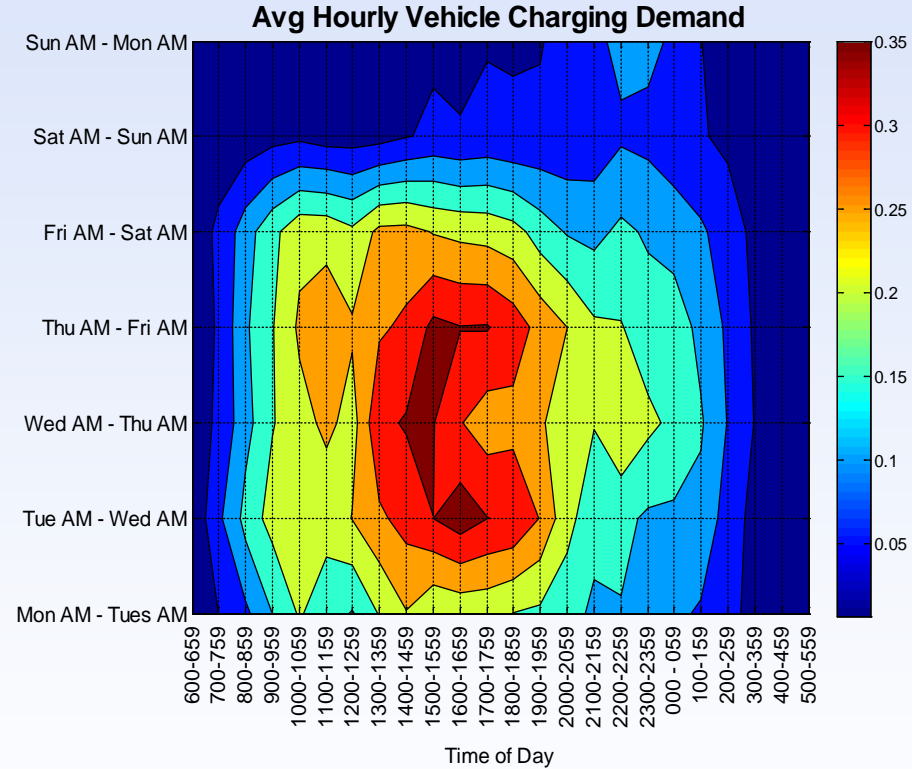


Commercial / Private Fleet Charge Demand

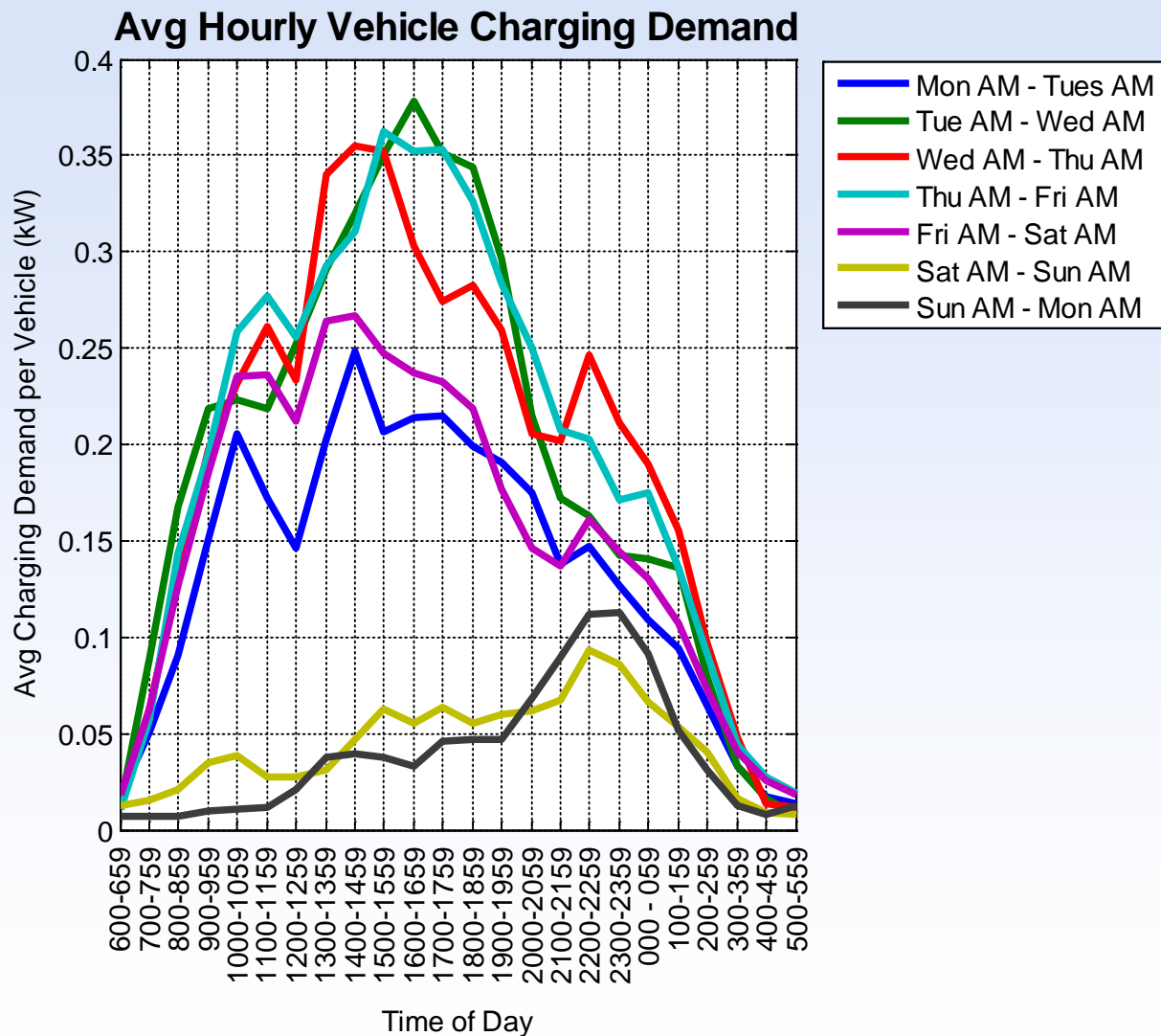
Private fleet



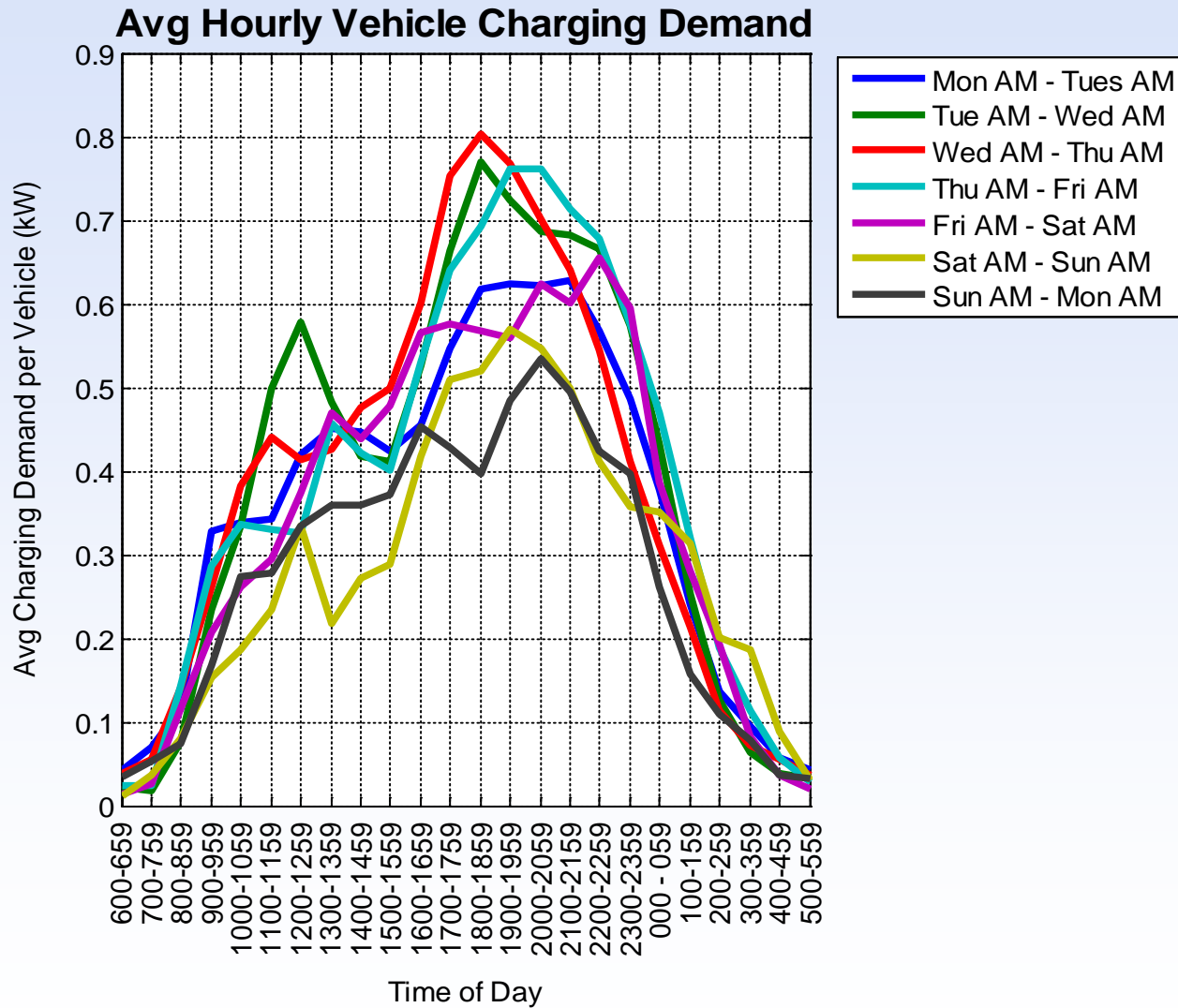
Commercial fleet



Commercial Fleet Average Charge Demand

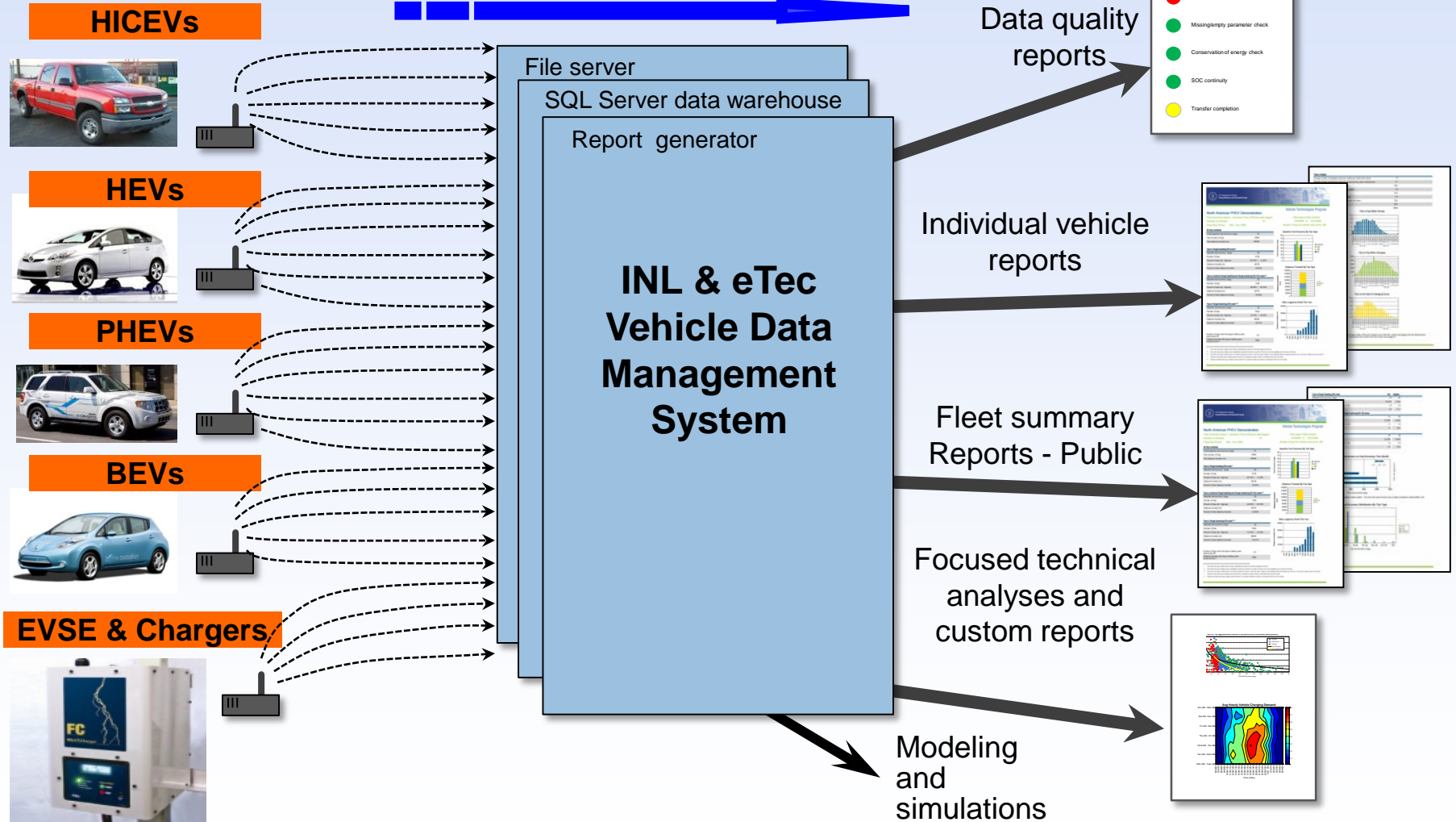


Private Fleet Average Charging Demand



Vehicle Data Management Process

Process Affected by Disclosure Agreements

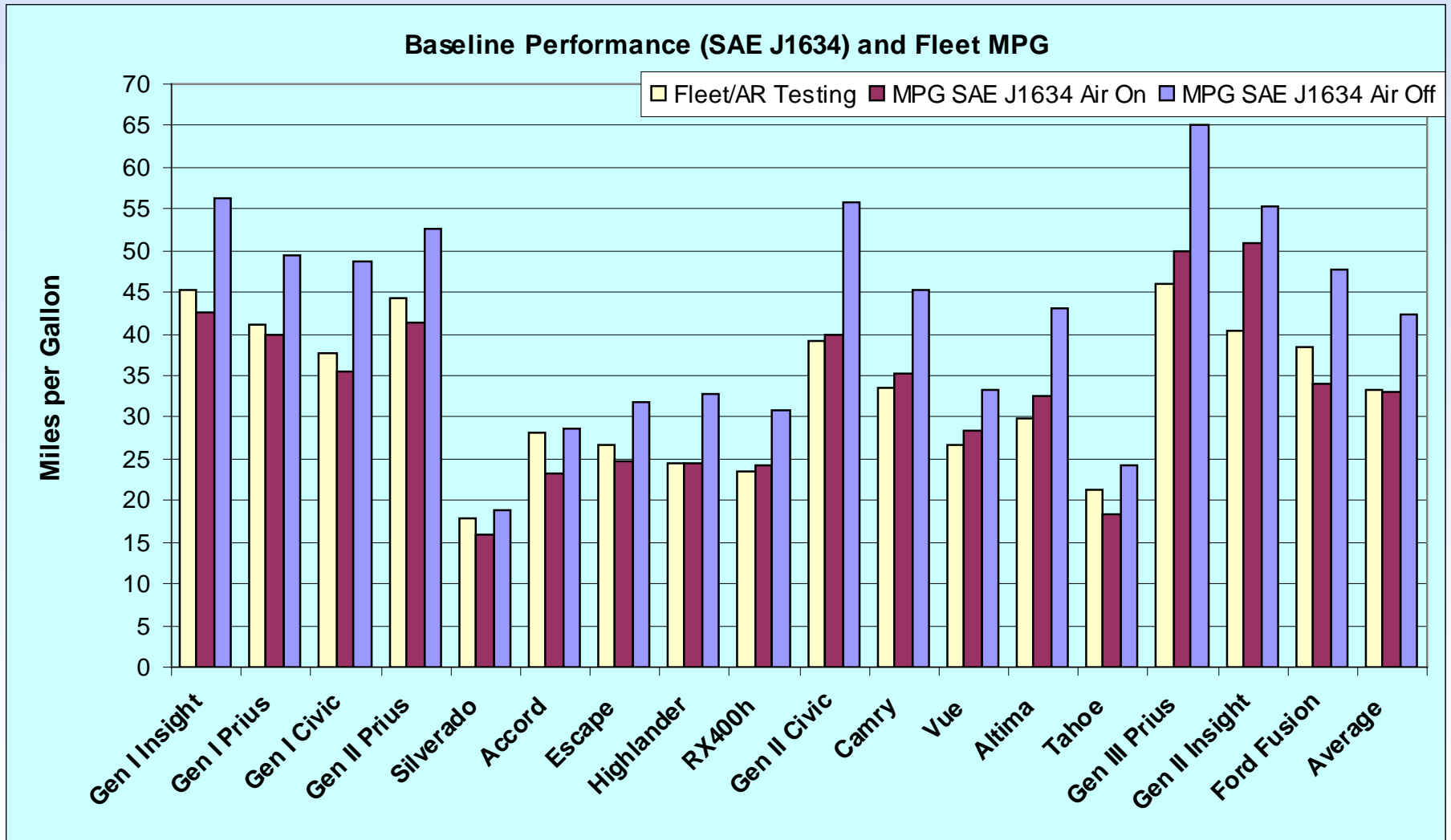


HEV Testing

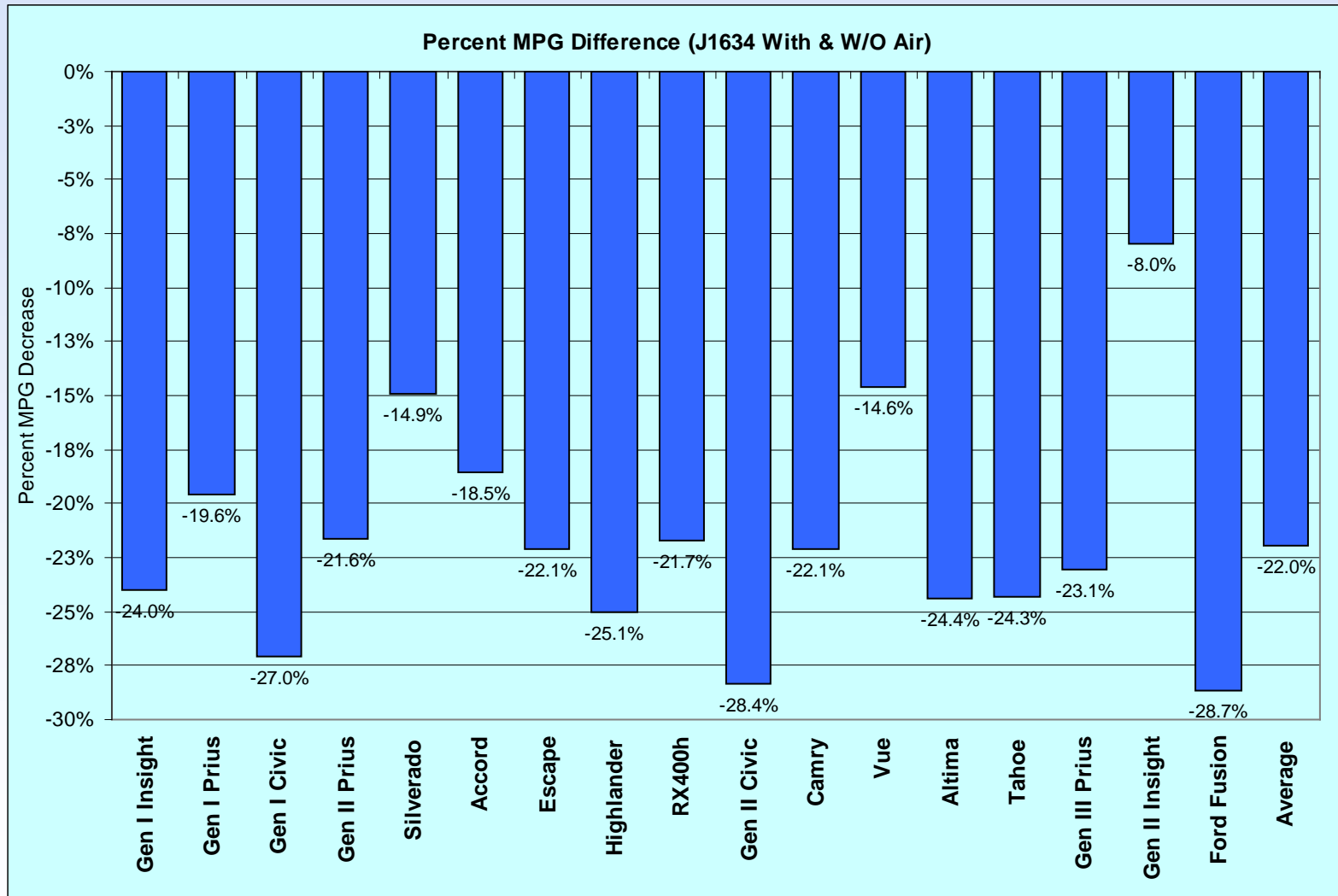


- 4.7 million HEV accelerated testing miles
- Initiated testing on 15th thru 18th HEV test models (in red) during 2009, with 47 HEVs tested / in testing to date:
 - 6, 2001 Honda Insight
 - 6, 2002 Gen I Toyota Prius
 - 4, 2003 Gen I Honda Civic
 - 2, 2004 Chevrolet Silverado
 - 2, 2004 Gen II Toyota Prius
 - 2, 2005 Ford Escape
 - 2, 2005 Honda Accord
 - 3, 2006 Lexus RX 400h
 - 2, 2006 Toyota Highlander
 - 2, 2006 Gen II Honda Civic
 - 2, 2007 Saturn Vue
 - 2, 2007 Toyota Camry
 - 2, 2008 Nissan Altima
 - 2, 2008 GM 2-mode Tahoe
 - 2, 2010 Ford Fusion
 - 2, 2010 Toyota Prius
 - 2, 2010 Honda Insight
 - 2, 2010 Mercedes Benz S400
- Published sixteen HEV battery tests during 2009, with another 8 near completion

HEV Testing – cont'd



HEV Testing – cont'd



HEV Testing – cont'd

HEV Fleet Testing Advanced Vehicle Testing Activity Maintenance Sheet for 2007 Nissan Altima

VIN # 1N4CL21E27C177982

Date	Mileage	Description	Cost
1/31/2008	4,856	Changed oil	\$25.45
2/18/2008	9,817	Changed oil	\$35.84
4/8/2008	18,289	Changed oil and filter	\$27.85
5/27/2008	30,947	Changed oil and filter	\$30.24
7/7/2008	39,387	Changed oil and filter	\$32.58
8/5/2008	48,243	Changed oil and filter, replaced air filter and cabin air filter, exchanged coolant, filled air conditioning coolant, and rotated tires	\$259.08
8/22/2008	52,506	Changed oil and filter	\$28.08
9/9/2008	58,349	Changed oil and filter	\$28.31
9/25/2008	63,648	Changed oil and filter, exchanged coolant, replaced cabin air filter, and purchased tire life preventative maintenance package	\$444.64
10/13/2008	66,826	Changed oil and filter	\$28.08
11/3/2008	72,156	Changed oil and replaced, balanced, and aligned two front tires	\$207.32
11/7/2008	73,172	Changed oil and filter	\$28.08
12/4/2008	79,464	Changed oil and filter and rotated tires	\$35.10
1/14/2009	91,050	Changed oil and filter	\$28.08
2/11/2009	99,340	Changed oil and air filters and balanced two tires	\$268.34
3/25/2009	111,501	Changed oil and filter, replaced alternator belt and replaced wiper blades	\$125.56
4/17/2009	117,676	Changed oil and filter, replaced front and back brake pads and shoes, and turned rear rotors	\$414.26
5/1/2009	122,141	Changed oil and filter and replaced air filter	\$48.56
6/1/2009	133,892	Changed oil and filter and installed and balanced two tires	\$321.34
6/19/2009	142,317	Changed oil and filter	\$28.21
7/20/2009	154,225	Changed oil and filter	\$28.21
7/24/2009	154,986	Installed and balanced two tires	\$229.10

eere.energy.gov

HEV Fleet Testing



2006 Toyota Highlander Hybrid

Final Fleet Testing Results

Operating Statistics

Number of Vehicles Tested: 2
Distance Driven¹: 297,852 mi
Average Trip Distance²: 13.8 mi
Stop Time with Engine Idling²: 23%
Trip Type City/Highway²: 74%/26%

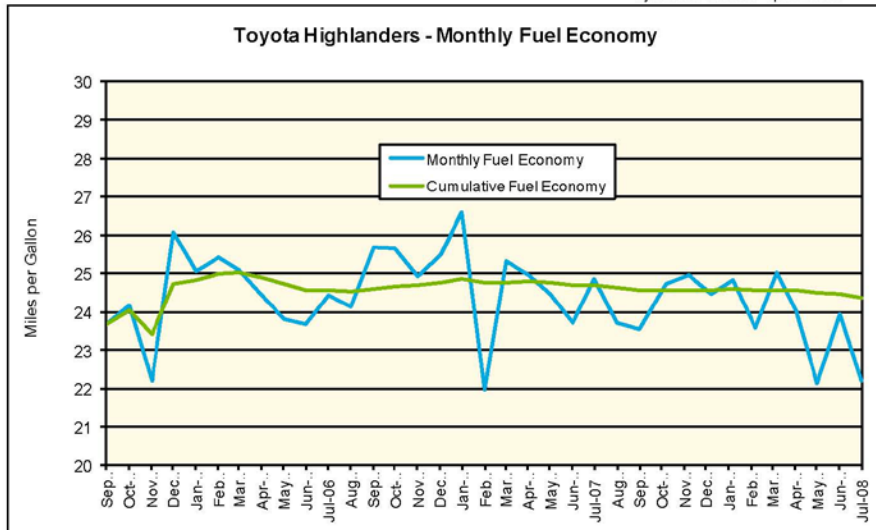
Operating Performance

Cumulative MPG³: 24.4

See HEV America Baseline Performance and Fleet Testing Fuel Economy fact sheets for more information on vehicle specifications and fuel usage reporting, available at <http://avt.inl.gov/>

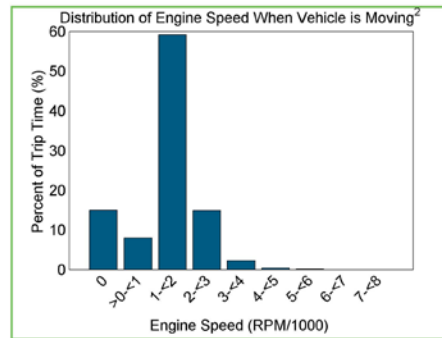
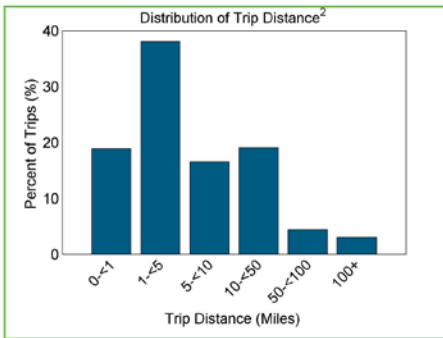
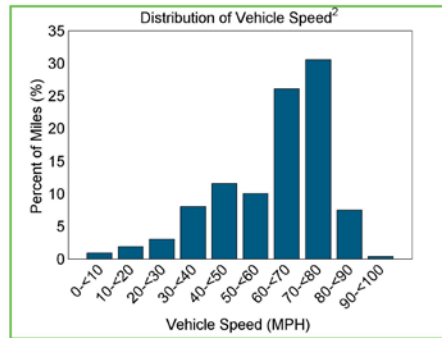
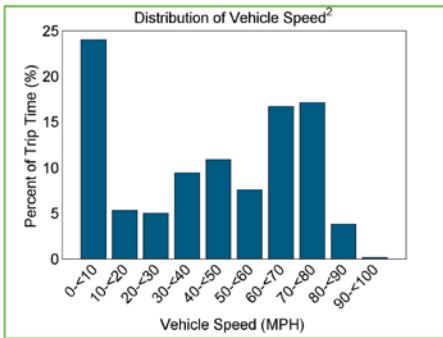
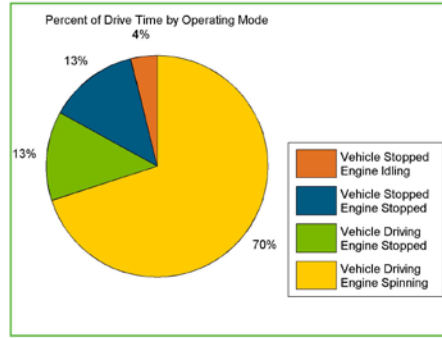
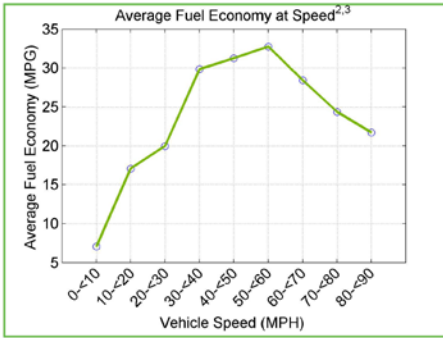
Test Notes

1. Calculated over the life of the vehicle based on odometer reading and fuel logs. More information available in Fleet Testing Fuel Economy sheet.
2. Calculated from electronic data logged over a subset of total miles traveled equal to 118,838 miles.
3. Fuel economy calculated for this figure using mass air flow over dynamic vehicle operation.



continued >

2-Page HEV Fleet Testing Fact Sheets



2-Page HEV Fleet Testing Fact Sheets – cont'd



HEV Fleet Testing

Advanced Vehicle Testing Activity



**2005 Chevrolet
 Silverado
 1500HD
 Hydrogen ICE¹
 Conversion**

**North American
 Fleet Testing
 Results to Date
 June, 2009**

Fleet Performance

Operating Statistics²:

Vehicles in Fleet: 12
 Total Miles: 55,255
 Total Number of Trips: 9271
 Average Trip Distance (miles): 6.0
 Percent Idle Time: 16%³
 Percent Air Conditioner Run Time: 8.5%³

Operating Performance²:

Cumulative MPGGE⁴: 13.2
 Total Fuel Consumed (kg H₂): 4229
 Total Engine Run Time (hours): 2339
 Total Engine Idle Time (hours): 385

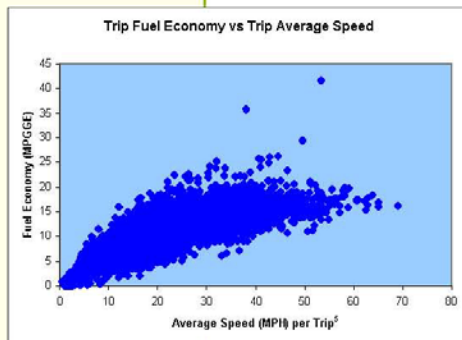
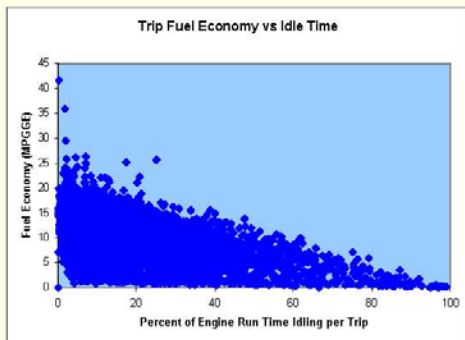
Vehicle Specifications

Engine: 6.0L V8
Fuel Capacity: 10.5 GGE
Nominal Tank Pressure: 5000 psi
Seatbelt Positions: Five
Payload: 2775 lbs
Features: 4 Speed Automatic
 Transmission

*See HICEV America Baseline Performance
 Fact Sheet for more information.*

**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.

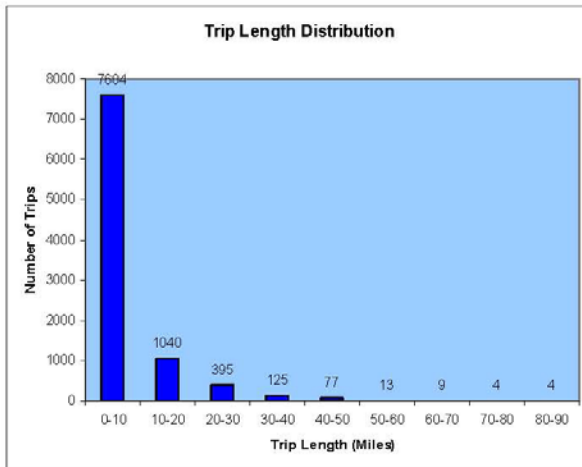
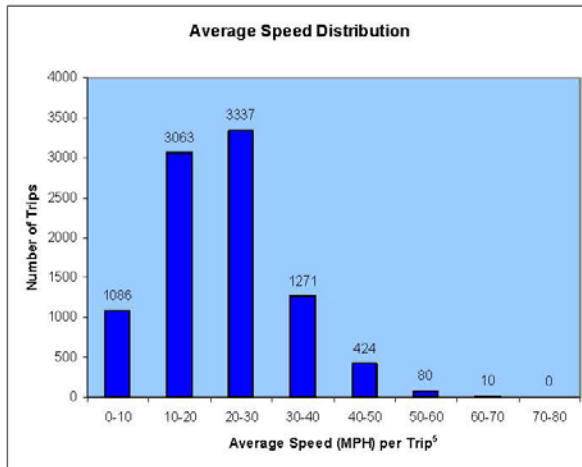
For more information contact:
 EERE Information Center
 1-877-EERE-INF (1-877-337-3483)
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Hydrogen Internal Combustion Engine Fact Sheet

- Twelve 2005 Chevrolet Silverado 1500HD pickups
- Operating in Canada and the U.S.
- Onboard data logger generated results
- 10.5 GGE ~100% H₂ onboard storage
- Low cost data monitoring activity

Hydrogen Internal Combustion Engine Fact Sheet – cont'd



Notes:

1. Internal Combustion Engine
2. Data presented represents all electronically logged data, which is a subset of the overall fleet mileage
3. Percentage of total engine run hours
4. Miles per gallon gasoline equivalent (1 GGE = 1.012 kg H₂)
5. Average speed of vehicle when moving, idle time not included in calculation



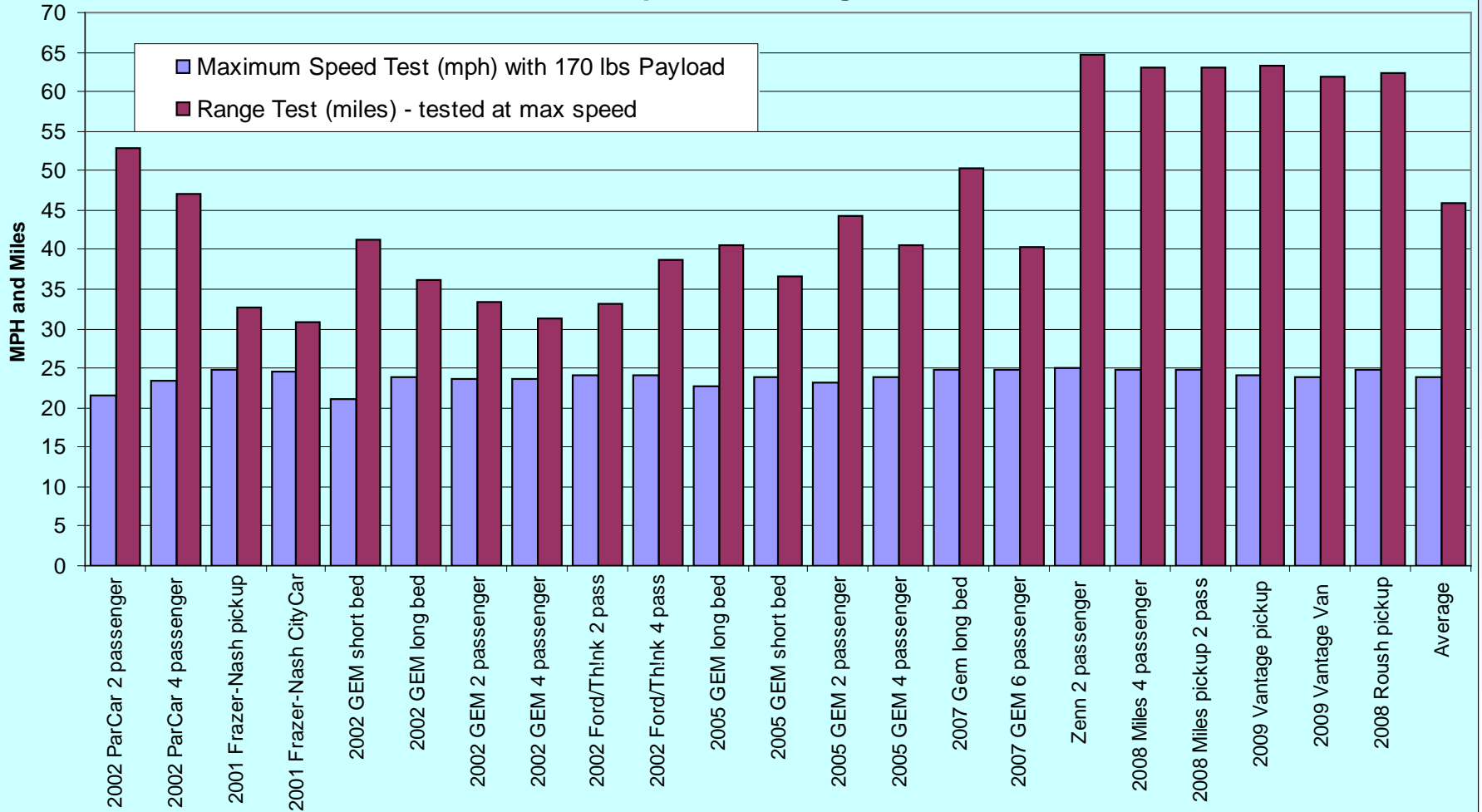
NEV Testing

- **Completed baseline performance testing on 3 new neighborhood electric vehicle models in 2009. 22 NEV models tested to date. 2009 NEVs tested:**
 - Vantage (China) pickup
 - Vantage (China) van
 - Roush pickup, including battery test report
- **NEV baseline performance testing methods and results continue to be used by California Air Resource Board to determine NEV eligibility for:**
 - **CARB alternative fuel incentives program (\$950 to \$1500 per NEV)**
 - **CARB ZEV credits (0.30 credits per NEV)**



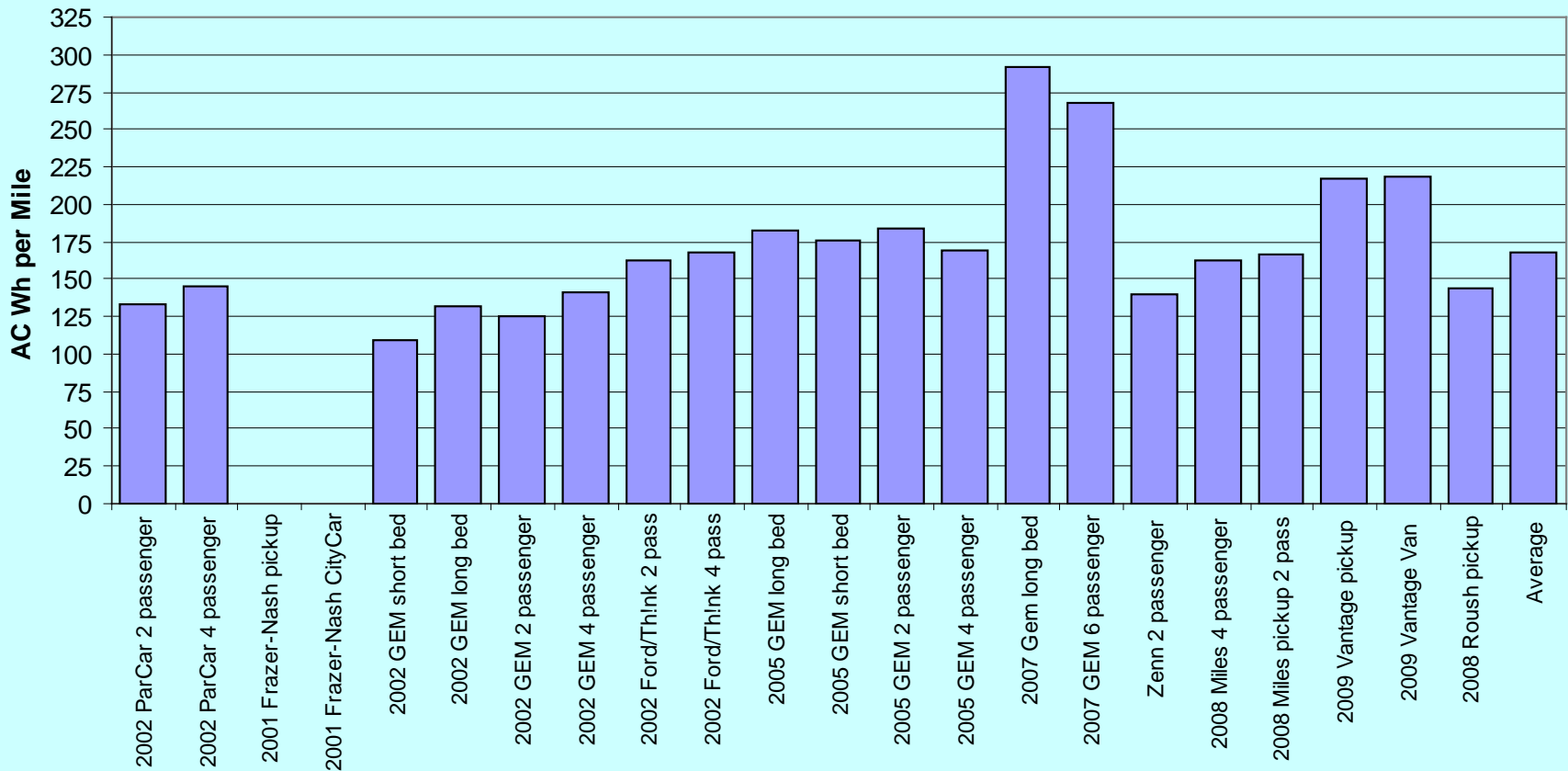
NEV Testing – cont'd

NEV Maximum Speed and Range Test Results



NEV Testing – cont'd

Charging Efficiency - AC Wh per Mile



Governmental Collaborations

- All vehicles requiring dynamometer testing are coordinated and shared with ANL
- High-mileage HEV components shared with ORNL
- High-mileage HEVs shared with EPA
- PHEV and HEV testing results shared with ANL, ORNL and NREL
- PHEV fleet testing includes 38 governmental fleets

Future Plans

- Support the ALABC and DOE/AVTA development, manufacturing and testing of a lead acid battery in a 100,000-mile HEV testing regime (Ultra Battery)
- Initiated battery mule test project, anticipating new battery deliverables via DOE programs
- Continue to support CARB's requirement that all NEVs be tested by the AVTA
- Continue focus on vehicles with advanced electric drive and electric storage technologies
- Incorporate vehicles with new control systems such as gasoline, diesel and compression start/stop
- Continue PHEV data sharing with:
 - University of California at Davis
 - Ohio State University
 - University of Hawaii
 - University of Victoria

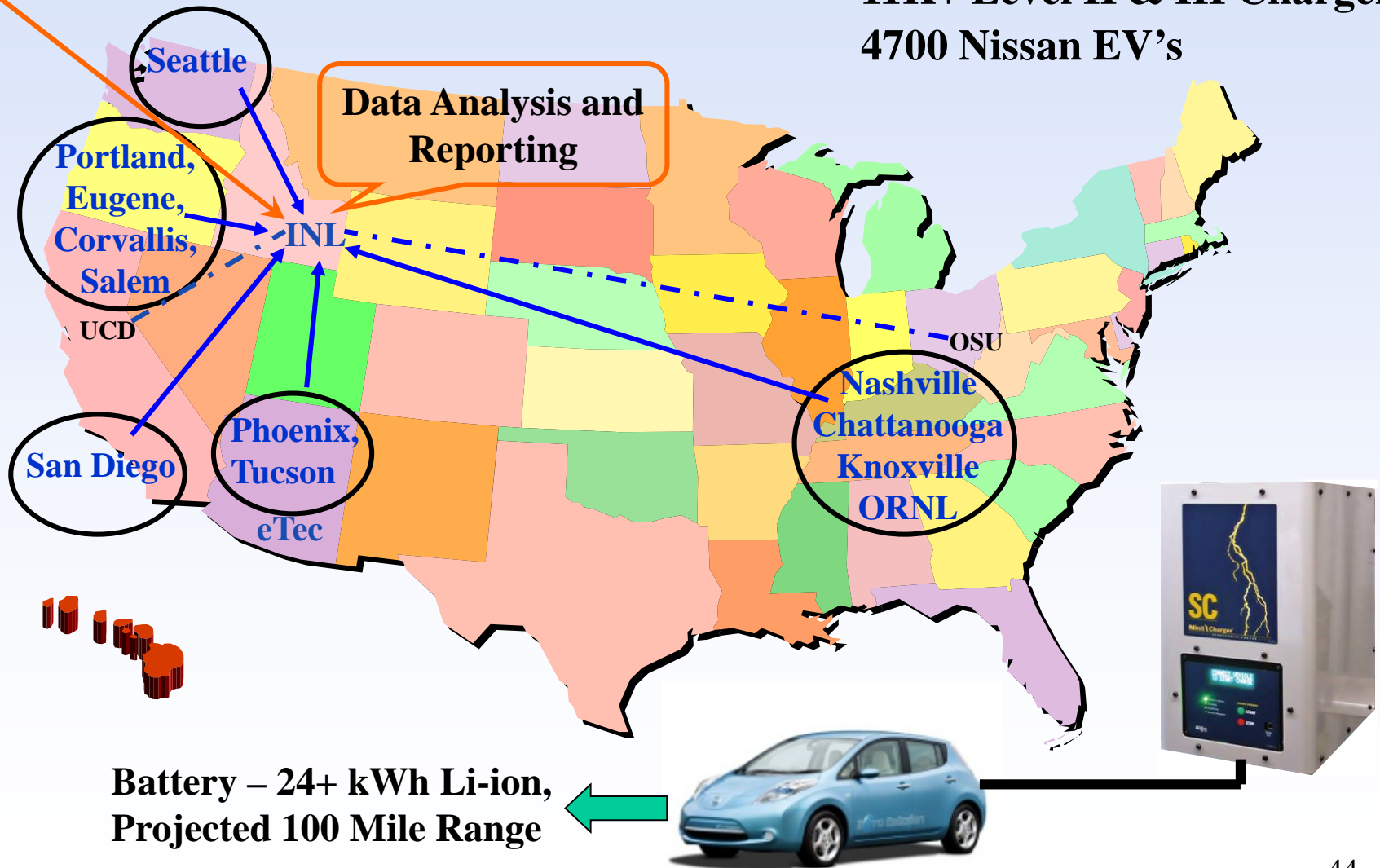
eTec/Nissan/INL EV Infrastructure Project

- INL is a principle participant with eTec and Nissan in the deployment of 4,700 battery electric Nissan Leaf vehicles in 5 states:
 - Oregon, Washington, California, Arizona and Tennessee
- Charging and vehicle data will be collected via data streams from eTec and Nissan
- INL will analyze and report on charging infrastructure utilization for ~11,000 Level II electric vehicle supply equipment (EVSE), ~300 Level III chargers, and 4,700 Leafs
- INL will report on vehicle charging patterns and charging infrastructure utilization patterns
- Many of the 42 project partners are electric utilities with high interest in demand / smart charging controls

eTec/Nissan/INL EV Infrastructure Project

eTec/Nissan/Regional Partners

11K+ Level II & III Chargers
4700 Nissan EV's



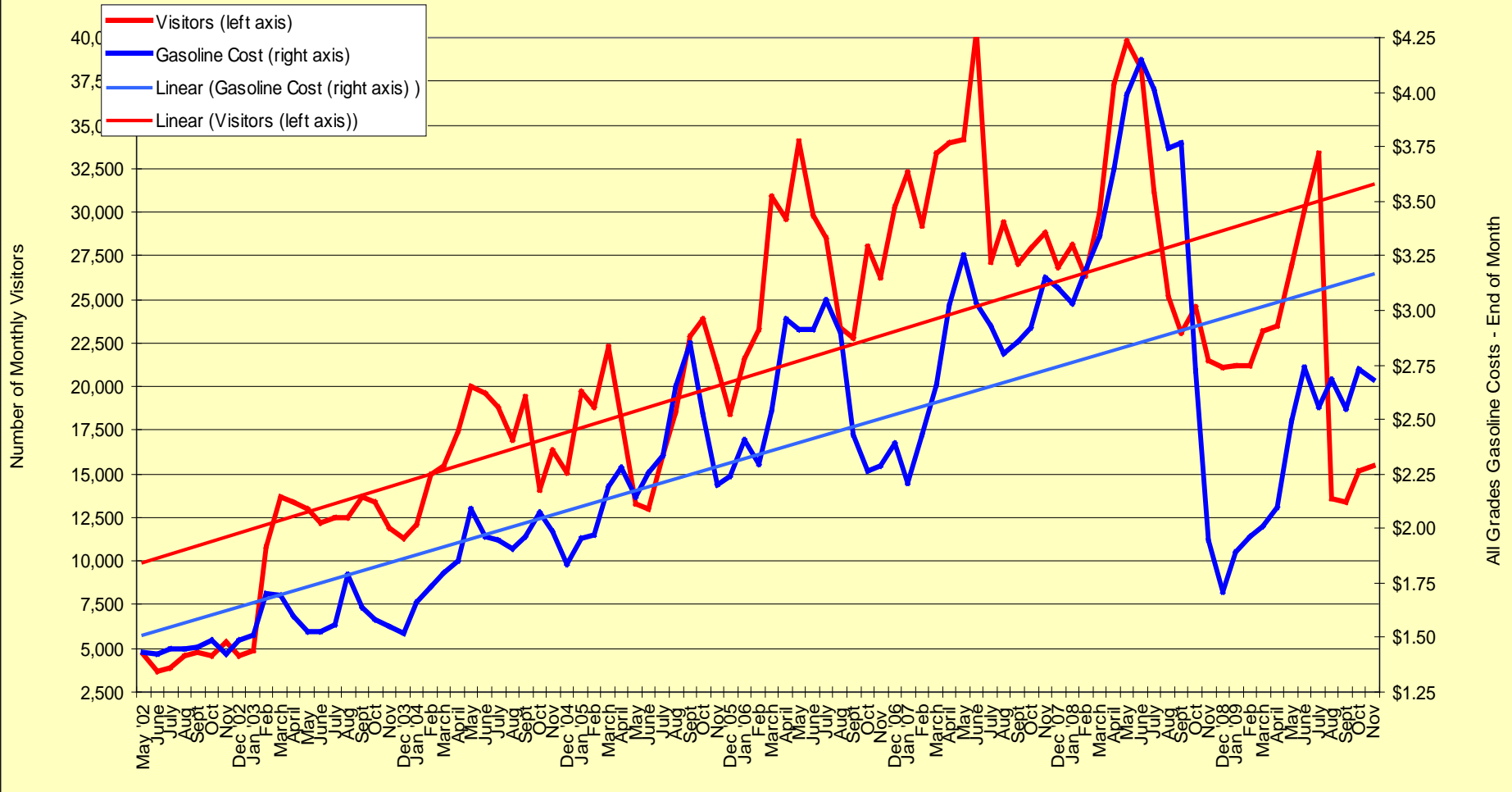
Battery – 24+ kWh Li-ion,
Projected 100 Mile Range

Summary

- **PHEV Demonstration - 1.3 million miles, 136,000 trips and 21,000 charging events of data**
- **Driver behavior, charging frequency, and environmental conditions have significant impacts on electric drive vehicles' 80-85% energy efficiencies and mpg results**
- **PHEV drive patterns suggest shorter distances per day driving patterns than previously documented**
- **PHEV operations often occur with minimal pre-trip charge events – “they run even if not plugged in”**
- **Non-charging energy use (hotel loads) may be significant**
- **HEV data demonstrated real “real-world” mpg results and life cycle costs**
- **The eTec/Nissan/INL project will document more than 70 million miles of electric drive vehicle operations and more than 3 million charging events**

AVTA Webpage Use and Gasoline Costs

INL WWW Visitors & Gasoline Costs (all formulations, areas, and grades)



Acknowledgement

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Additional Information

<http://avt.inl.gov>

or

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

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