U.S. Department of Energy, Vehicle Technologies Program

AVTA Electric Drive Vehicle Testing Activities & Infrastructure Requirements – NAFA (March 2010)

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Seattle, WA. March 2010

This presentation does not contain any proprietary or sensitive information

AVTA Description

- AVTA background
- BEVs, HEVs, PHEVs, NEVs, HICEs, and EREVs
  - How they work
  - Advantages / disadvantages
  - Testing results / performance
- Charging infrastructure
  - Terms
  - Safety
  - Levels
  - Smart Charging
- eTec/Nissan/INL charging infrastructure project
- Future vehicle announcements
- Vehicle deployment considerations

AVTA Description

- The Idaho National Laboratory (INL) and Electric Transportation Engineering Corporation (eTec) conduct the AVTA for DOE's Vehicle Technologies Program
- The AVTA tests light-duty whole vehicle systems and fueling infrastructures that employ / support:
  - 100% Electric and dual-fuel electric drive systems
  - Advanced energy storage systems
  - Some ICE 100% Hydrogen and HCNG blended fuels
  - Advanced control systems (i.e., start/stop hybrids)
- Provide benchmarked vehicle data to R&D programs, modelers, manufacturers, and target/goal setters (DOE)
- Assist early adaptor fleet managers and the general public in making informed vehicle purchase, deployment and operating decisions
  - Reports, fact sheets, and presentations

AVTA Testing by Technology

- Plug-in hybrid electric vehicles (PHEVs)
  - 12 models, 259 vehicles, 1.5 million test miles
- Hybrid electric vehicles (HEVs)
  - 18 models, 47 vehicles, 5 million test miles
- Neighborhood electric vehicles (NEVs)
  - 23 models, 200,000 test miles

- Hydrogen internal combustion engine (ICE) vehicles
  - 7 models, 500,000 test miles

- Full-size battery electric vehicles (BEVs)
  - 41 EV models, 5+ million test miles
- Urban electric vehicles (UEVs)
  - 3 models, 1 million test miles
- 13 million test miles have been accumulated on 1,600 electric drive vehicles representing 97 different electric drive models

AVTA Vehicle Testing 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, uses unstructured vehicle utilization
  - Different testing methods are used to balance testing control/repeatability, sample size, and costs
- Publish testing results in relevant ways to accurately
  - Document real-world petroleum reduction potentials
  - Document fuel and infrastructure use
  - Document life-cycle risks and costs

Battery Electric Vehicle (BEVs) Technology

- BEVs only have a battery onboard the vehicle for storing energy – no other onboard energy source
- Energy from the battery is used to power one or more electric motors
- Must be charged from an off-board electricity source, mostly from power plants via the electric grid
- Also captures energy during regenerative braking: electric motor(s) acts as a generator to slow the BEV
- There are no emissions from the vehicle. However, depending on the power plant, there maybe be offboard related emissions unless renewables are used
- Examples include the Nissan Leaf, Mitsubishi iMiEV, BMW Mini-E, and Tesla Roadster

BEV Advantages and Disadvantages

- **BEV advantages**
  - No vehicle-based emissions
  - Domestically produced fuel
  - May lower overall electricity costs via higher power plant utilization rates
  - Lower fuel and operating costs
- **BEV Disadvantages**
  - Need to understand and install public charging infrastructure
  - Limited range per charge = "Range anxiety"
  - Battery improvements still needed
  - Long-term battery performance unknown
  - No large scale domestic battery industry
  - No large scale component industry

Hybrid EV (HEVs) Technology

- Usually uses both a small onboard battery and an ICE as energy sources
- Generally uses parallel design, but may include other designs
- Most HEV batteries last 150,000+ miles and hundreds of thousands of cycles due to narrow battery charge / discharge range. Only 20 to 30% maximum SOC swing
- No offboard charging required
- HEV battery charged from the ICE and regenerative braking
- Hydraulic hybrids used by some medium duty trucks such as refuse haulers
- Most OEMs offer HEVs or plan to in near-term

HEV Advantages and Disadvantages

- **HEV advantages**
  - Reduced gasoline fuel use and vehicle emissions
  - Recovers regenerative braking energy (up to ~80%)
  - Uses existing gas station infrastructure
  - Optimized use of electric propulsion
  - No need to connect to the electric grid for battery charging
  - No range anxiety
- **HEV Disadvantages**
  - Complexity and cost of two powertrains
  - Components such as batteries, powertrains and power electronics are still not produced in very large numbers
  - Generally higher initial costs

Plug-in HEV (PHEV) Technology

- **Uses both an onboard battery and an ICE as energy sources**
- **Can have a series or parallel design**
- **In parallel mode, both the ICE and the battery/electric motor power the vehicle, usually through the transmission. The ICE may also recharge the battery**
- **Uses the electric grid to recharge and balance the propulsion battery and accepts regenerative braking energy**
- **Original equipment manufacturer (OEM) designs are anticipated to have a single PHEV propulsion battery**
- **Some conversions (Hymotion) keep the original HEV battery and add a second "mule" PHEV battery. The mule battery can only be recharged from the grid**
- **Includes buses, trucks, and light-duty vehicles**
- **Most OEMs have PHEV plans. Ford built a limited number of Escape PHEVs**

PHEV Advantages and Disadvantages

- **PHEV Advantages**
  - Reduced petroleum consumption and vehicle emissions
  - Smaller battery pack (versus BEV) to buy and manage
  - Gas fueling infrastructure portion exists
  - Minimal electric grid changes needed - add connector and electric vehicle supply equipment (EVSE)
  - At home battery charging, well below cost of gasoline
  - Potential for off-peak charging
- **PHEV Disadvantages**
  - Cost, complexity and added weight of two powertrains
  - Higher initial cost
  - Drivers adapting to dual-fueling scenario
  - Component availability: batteries, powertrains, power electronics

PHEV Operating Modes

- Charge sustaining (CS) mode: from start to finish of a single trip, there is no energy available for electric drive propulsion in the PHEV battery. The battery state-of-charge (SOC) is sustained
- Charge depleting (CD) mode – from start to finish of a single trip, there is energy available for partial or full electric drive propulsion in the PHEV battery. The battery SOC is being depleted during the entire trip
- Mixed CD/CS mode – there is energy in the battery pack at the start of a single trip, but the PHEV battery is fully depleted before the trip ends
- Electric propulsion is either in the form of all-electric or electric-assist (the ICE provides propulsion power)
- Some PHEV designs have as many as eight operating modes, making fuel use measurement and reporting uniformly very difficult

Extended Range EVs (EREVs)

- EREVs have an onboard battery and an ICE as the second energy source
- Operates in series mode: ICE charges the battery and the battery powers the electric motor(s)
- Normally will operate in all-electric mode until battery is discharged, then ICE turns on to charge the battery. No propulsion energy goes directly from the ICE to the vehicle wheels
- Must be plugged into the electric grid to fully recharge and balance its propulsion battery
- Captures energy during regenerative braking
- Examples include the Chevrolet Volt and Renault Kangoo (2003 model)
- Similar advantages and challenges as PHEVs

Purchase and Fuel Costs per Mile

	MSRP ($$$$)	MPG Gas	kWh / Mile	Gas Cost / Mile (Cents)	Electricity Cost / Mile (Cents)	Capital Cost / Mile (Cents)	Total Cost / Mile (Cents)
ICEV	21,825	25		11.0		14.6	25.6
HEV	22,800	45		6.1		15.2	21.3
BEV	35,000		0.290		2.9	23.3	26.2
PHEV Conversion	34,800	70	0.125	3.9	1.25	23.3	28.45

Notes

- ICEV, HEV, and PHEV conversion capital costs are based on known costs. BEV capital cost is an educated guess. PHEV conversion cost includes base vehicle capital cost.
- All capital costs per mile are based on 150,000 miles of straight depreciation, with zero financing costs assumed.
- Gasoline cost of $2.75 / gallon and electricity cost of 10 cents / kWh used.
- Battery life is unknown. Other maintenance costs are not included. BEV maintenance costs should be lower, but no documentation currently exits.

Battery Chemistries

- **Lead Acid** used for applications where weight and space limitations are outweighed by cost considerations. BEV battery of choice in early to mid 1990's. Historically, limited cycle life of 600 to 1,000 cycles
- **Advanced Lead Acid** R&D activities are suggesting a possible revival of lead chemistries due to new production processes, materials, and cost advantages
- **Nickel Metal Hybrid** is used primarily as power battery in HEVs, with 300,000 to 500,000+ cycle life. HEVs are an accepted technology due to NiMH durability
- **Lithium** is viewed as the most commercially viable future energy storage option due to its potential for much higher energy and power densities. Economically viable demonstration successes are needed before a large penetration of PHEVs and a full transition to BEVs can take place

Charging Levels

- **<u>Level I</u> – 110 / 120 VAC, 15 amp (12 amp continuous). Maximum 1.44 kW continuous. Onboard charger. Currently NEMA5-15R receptacle, with GFCI is used. However by NEC code, SAE J1722 connector should be used**
- **<u>Level II</u> – greater than Level I, with 208-240 VAC and up to 40 amp (32 amp continuous). Maximum 9.6 kW (7.68 kW continuous). Generally onboard charger. Electric vehicle supply equipment (EVSE), mated to AC input and SAE J1722 connector should be used per code**
- **<u>Level III</u> – greater than Level II, generally off-board charger supporting more than one vehicle. Energy to vehicle can be 440 VDC or higher**

Charging Terms / Considerations

- <u>Fast Charge</u> – Not definitively defined. Generally returns 50% of a battery's capacity in ~10 minutes. Large batteries require Level III charging
- <u>SAE J1722</u> – Defines standard connector up to ~70 amps
- <u>EVSE</u> - Some "chargers" are not chargers at all, but electric vehicle supply equipment (EVSE). If a charger is onboard the vehicle, the EVSE houses the connector (plug) and cord set offboard, and hopefully some intelligence, communication, and metering capability. EVSE bridges the gap between the vehicle charge post and the electric grid
- A vehicle can have an onboard Level II charger and also be capable of being fast charged from an offboard charger via the same or a second charge port

Smart Charging

- **Ranges from simple “lamp timer” to electric utility controlled charging events**
- **Charging interruption similar to interrupting hot water heaters, air conditioners, other electric loads**
- **Goal is to push charging to off-peak periods, with excess generation capacity, such as at night**
- **Studies indicate night time generation capacity for charging 10’s of millions of vehicles. With increased plant utilitization, may result in lower overall kWh costs**
- **Most sophisticated smart charging devices require the EVSE / charger to have bidirectional communications via PLC, zigbee, cellular or WiFi; and the ability to turn on/off remotely; and hopefully have a utility-grade meter**

Safety / Standards

- **SAE standards are used to insure all OEMs equip their vehicles with the same on-vehicle charge port and communications, so they can be connected and charged at any SAE compliant charger. SAE standards are not a prerequisite for market sales**
- **“UL Listing” by Underwriters Laboratory certifies an offboard charger or EVSE as compliant to a set of standards. Only UL Listed charging infrastructure should be installed for safety and legal reasons. Other U.S. certification companies also provide similar “UL Listing”**
- **National Electric Code (NEC) or NFPA 70, is the U.S. standard for safe installation of electrical wiring and equipment. It is followed non-uniformly by thousands of local and regional building inspectors. When installing charging infrastructure, the NEC should be followed for safety and legal reasons**

Installing Charging Infrastructure

- If specific EVSE requirements are unknown during new building construction, install service panels and conduit in anticipation of 240 Volt, Level II charging
- If charging requirements are known
  – Install SAE J1722 compliant connectors and UL Listed EVSE and offboard chargers
  – Follow the local NEC requirements for electrical wiring and equipment (EVSE and chargers)
  – Match infrastructure to vehicle requirements
- Level I, 120 Volt may be suitable for small PHEV battery packs
- Level II, 240 volt or higher is required for BEVs due to their large energy storage (kWh) and the time required to charge them
- Public infrastructure should be at least Level II

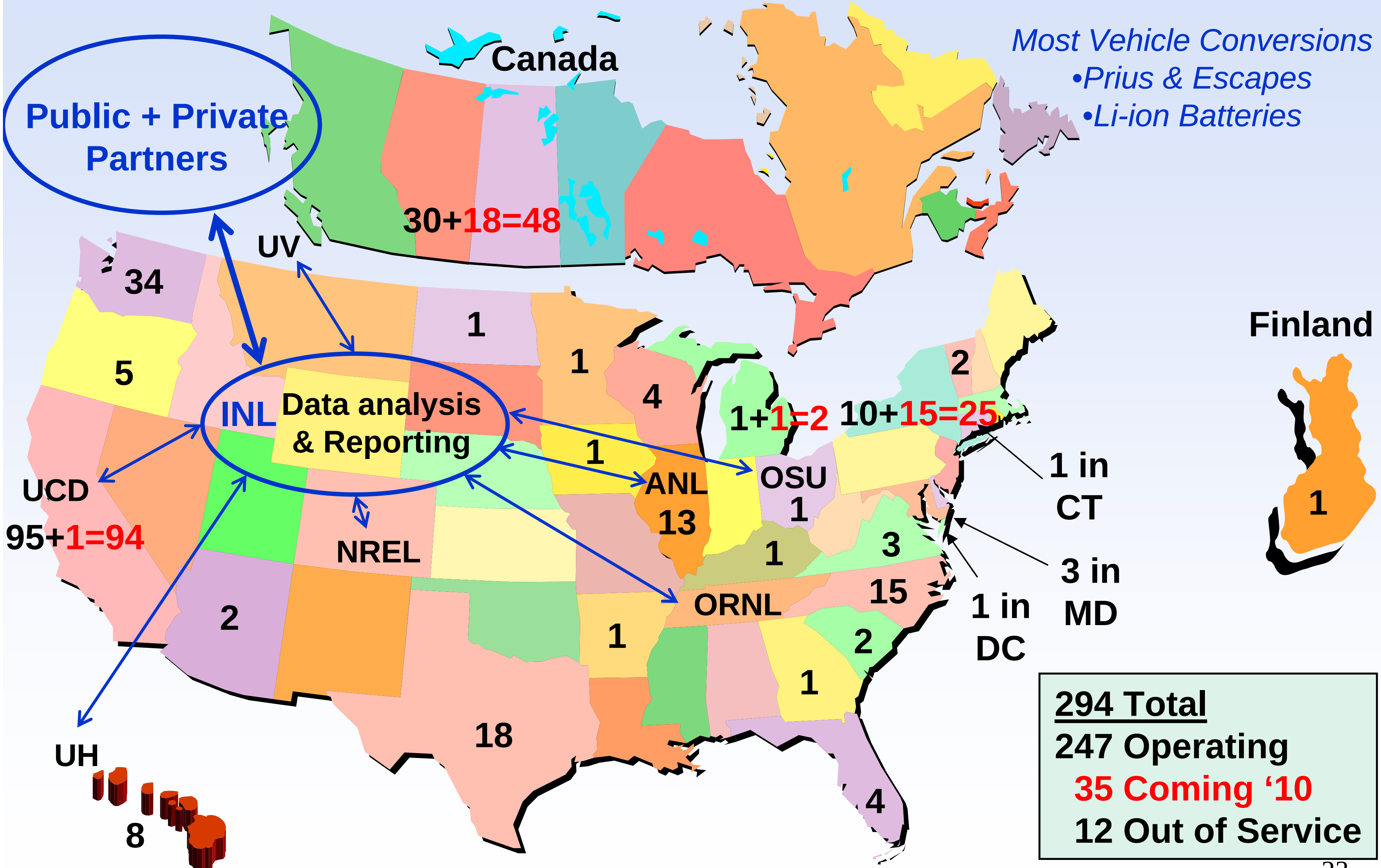
AVTA PHEV Testing

- **12 PHEV models tested to date**
  - **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)**

AVTA PHEV Testing – cont'd

- 259 PHEVs in 23 states, Canada and Finland, 1.5 million miles - AVTA only purchased 2 vehicles and 12 conversions. Highly leveraged testing activity
- 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 disseminated to testing partners

AVTA PHEVs and Demonstration Locations



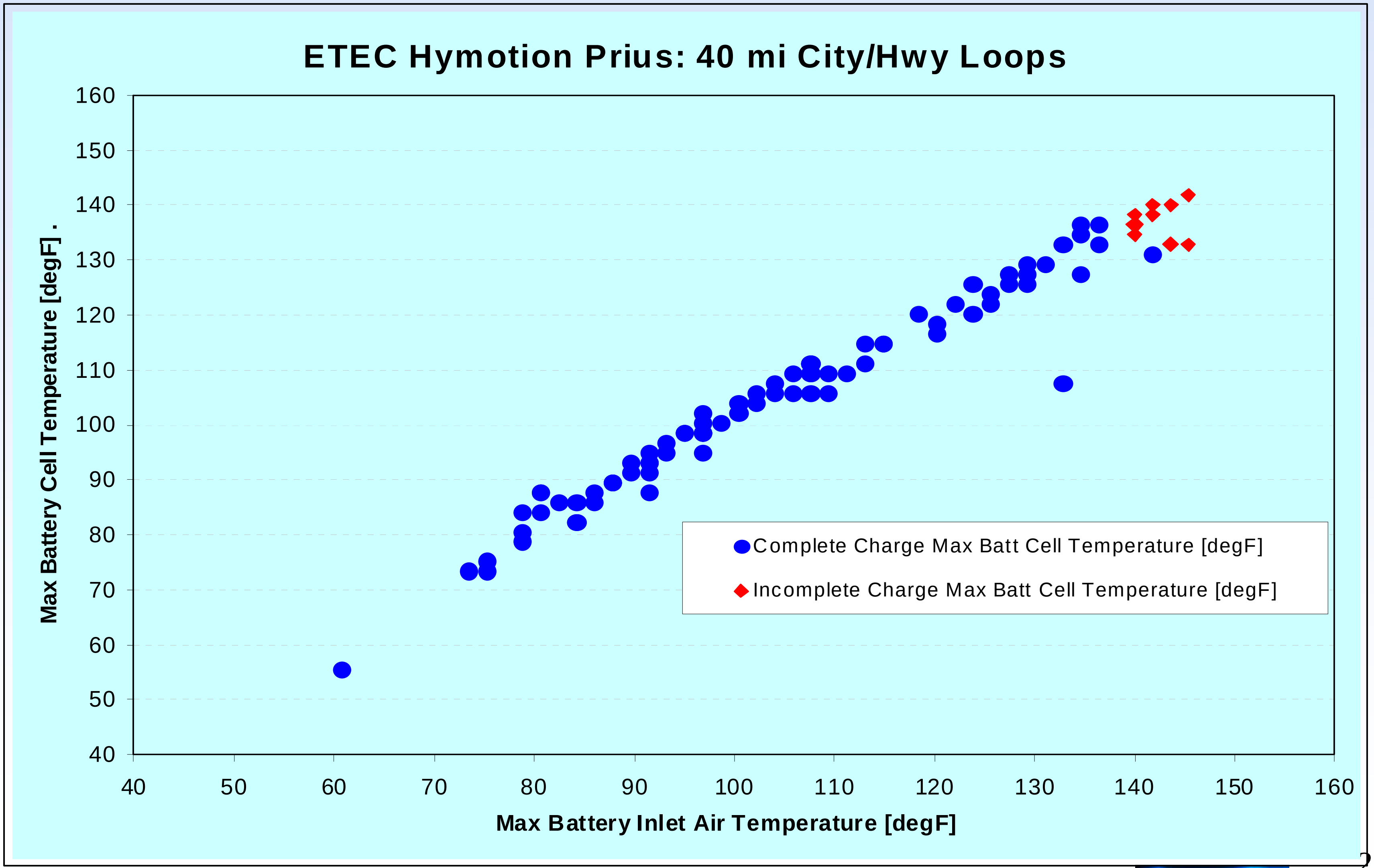
Hymotion Prius PHEV – Accelerated Testing

Cycle (mi)	Urban (10 mi)	Highway (10 mi)	Charge (hr)	Reps (N)	Total (mi)	Electricity AC kWh	Gasoline Gals	Gasoline MPG	Recalculated without incomplete charges
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			

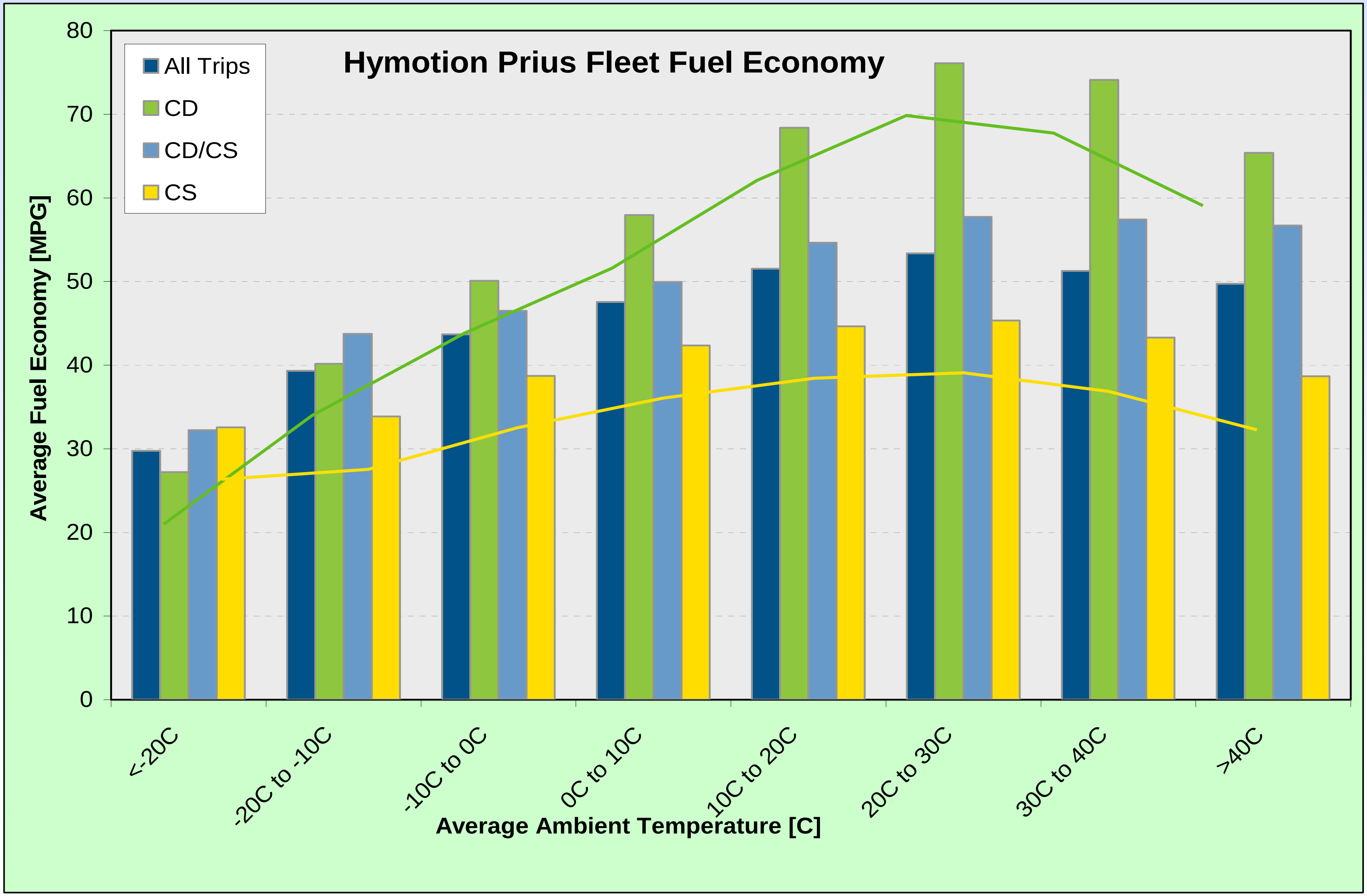
Each total distance slightly greater than 600 and 640 miles. HEV version = 44 mpg.
E = experienced HEV driver, I = inexperienced driver

Hymotion Prius PHEV – Accelerated Testing

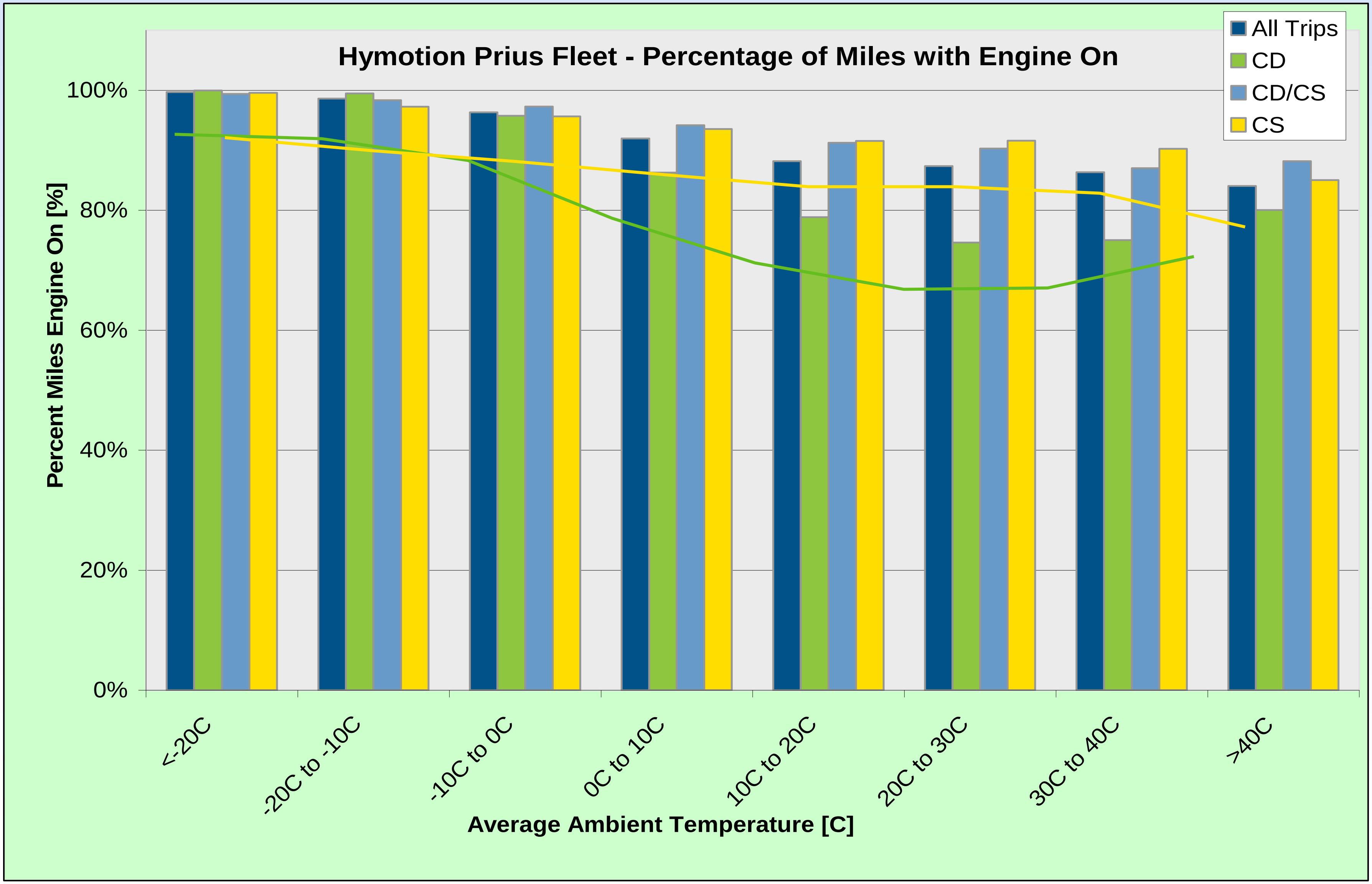
- **High ambient temperatures impact charge completion**



PHEV Ambient Temperature MPG Impacts

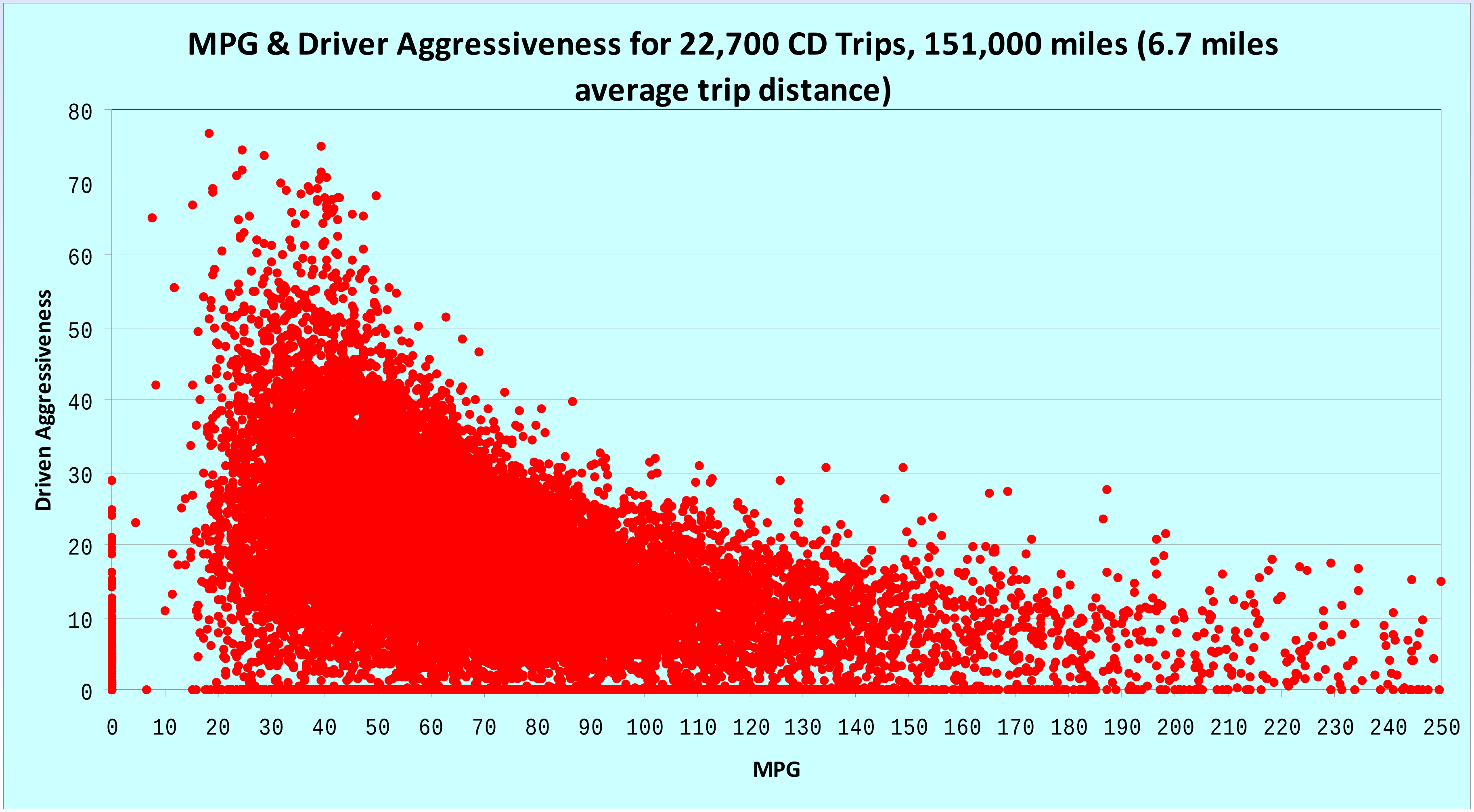


PHEV Engine Ops by Ambient Temperatures

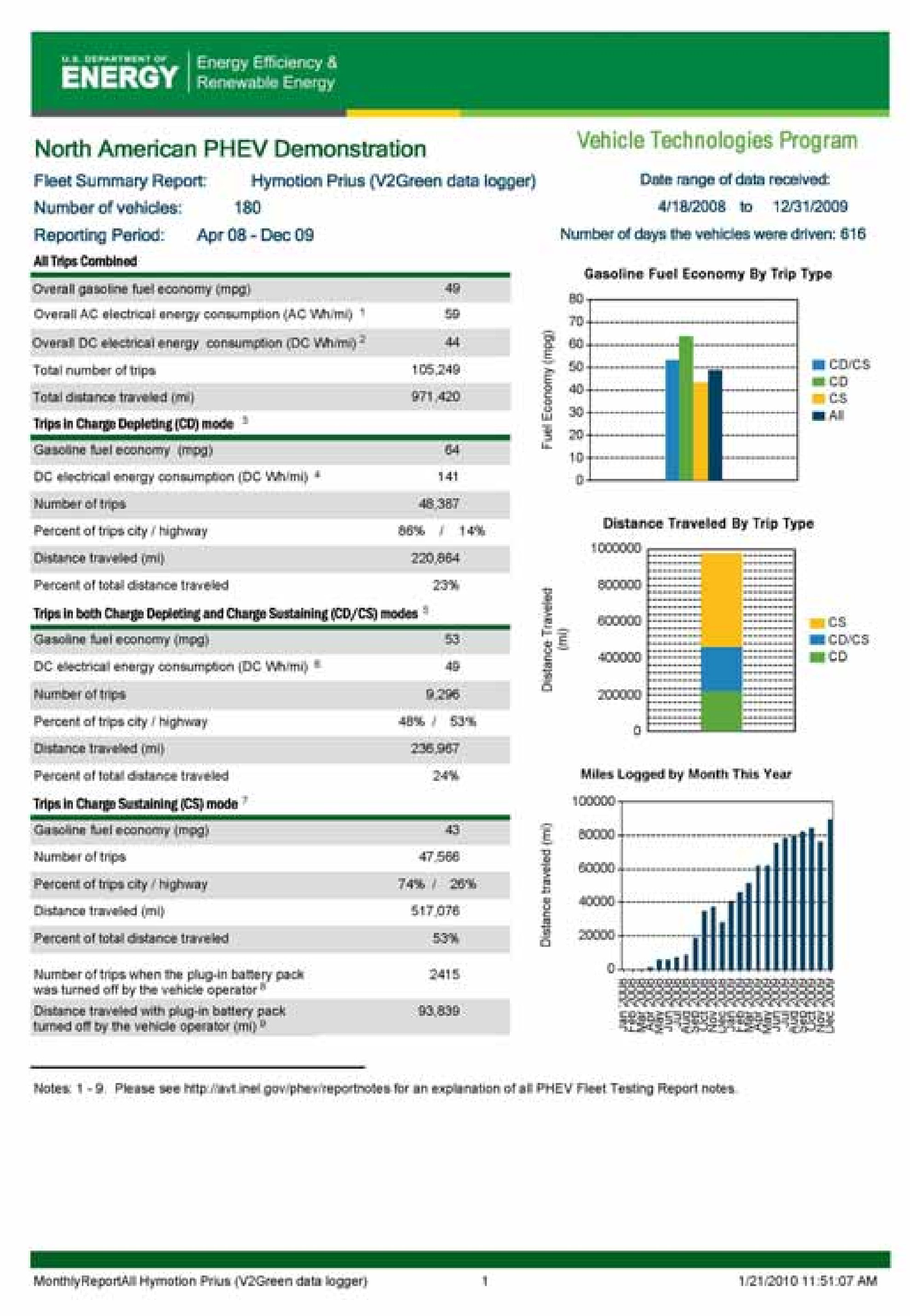


Hymotion Prius PHEVs – CD Trips

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



Data from 150 Hymotion Prius with V2Green and Kvaser loggers



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North American PHEV Demonstration

Vehicle Technologies Program

Fleet Summary Report: Hymotion Prius (V2Green data logger)
Number of vehicles: 180
Reporting Period: Apr 08 - Dec 09

Date range of data received:
4/18/2008 to 12/31/2009
Number of days the vehicles were driven: 616

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

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

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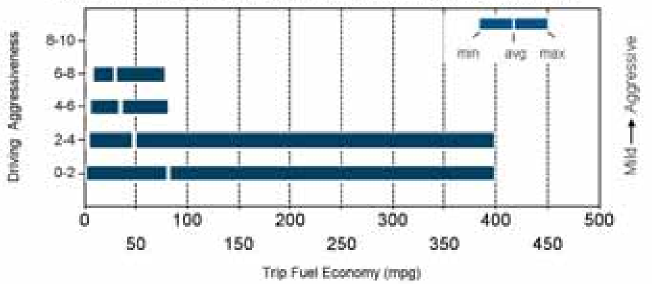
3-Page PHEV Fact Sheets provide AC and DC Wh/mile, and mpg by charge modes

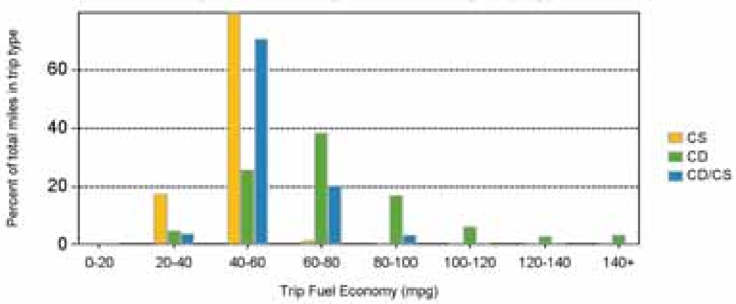
Trips in Charge Depleting (CD) mode	City	Highway
Gasoline fuel economy (mpg)	62	67
DC electrical energy consumption (DC Wh/mi)	167	109
Percent of miles with internal combustion engine off	30%	8%
Average trip aggressiveness (on scale 0 - 10)	1.7	1.7
Average trip distance (mi)	2.9	14.4
Trips in both Charge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



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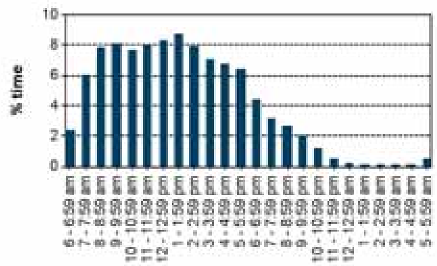
In addition to charge mode, the 3-Page PHEV Fact Sheets provide fuel use by drive cycle and driver style (aggressiveness)

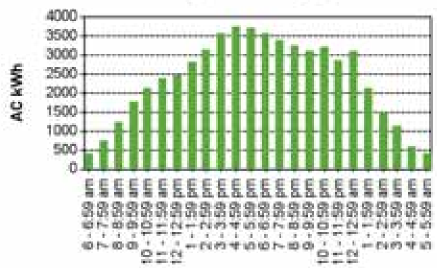
Plug-in charging

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

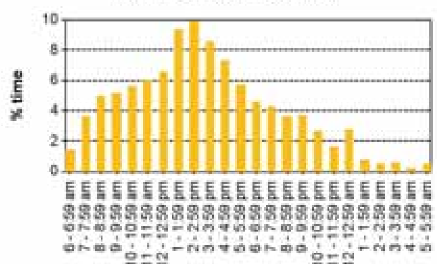
Time of Day When Driving



Time of Day When Charging



Time of Day When Plugging In



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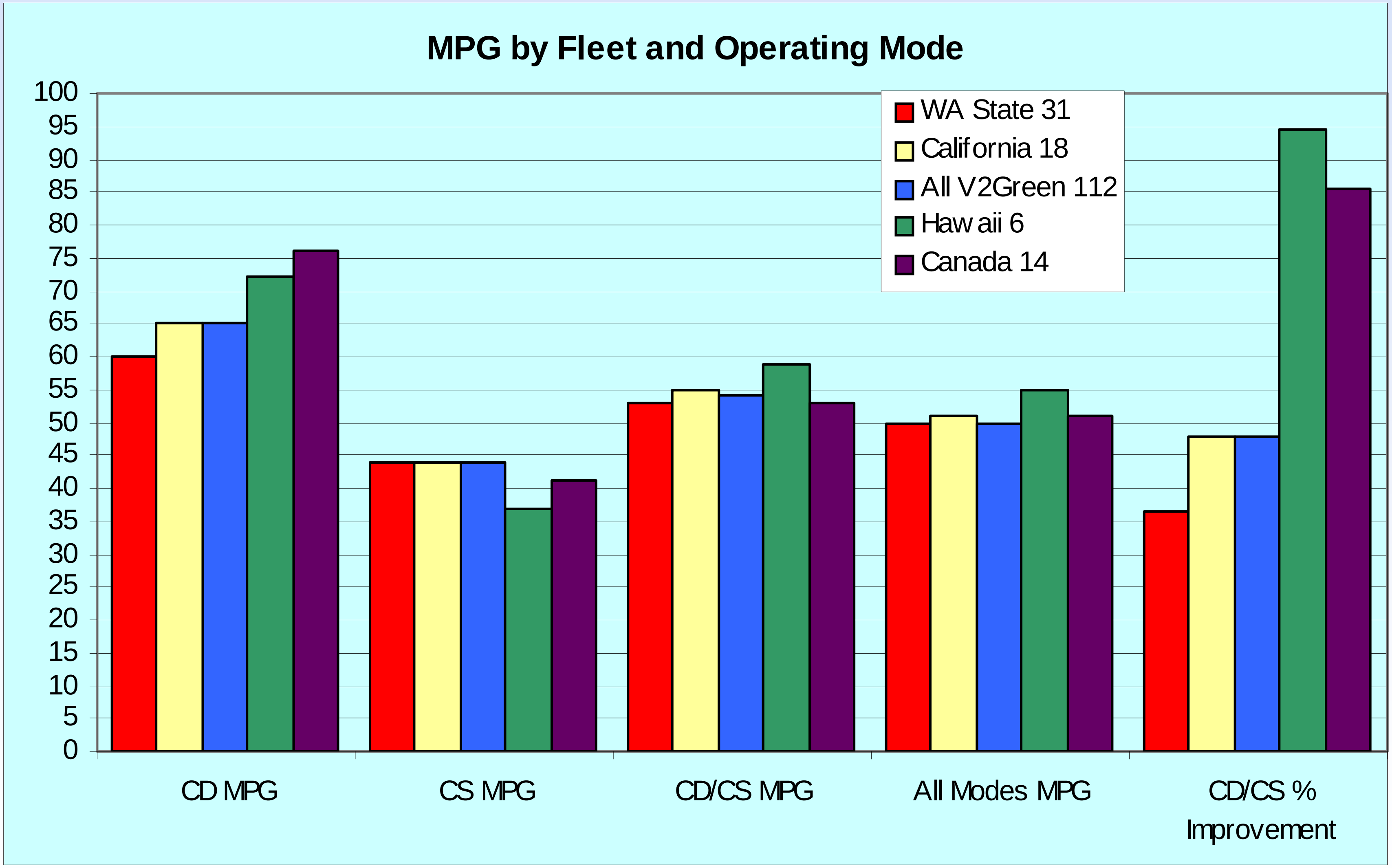
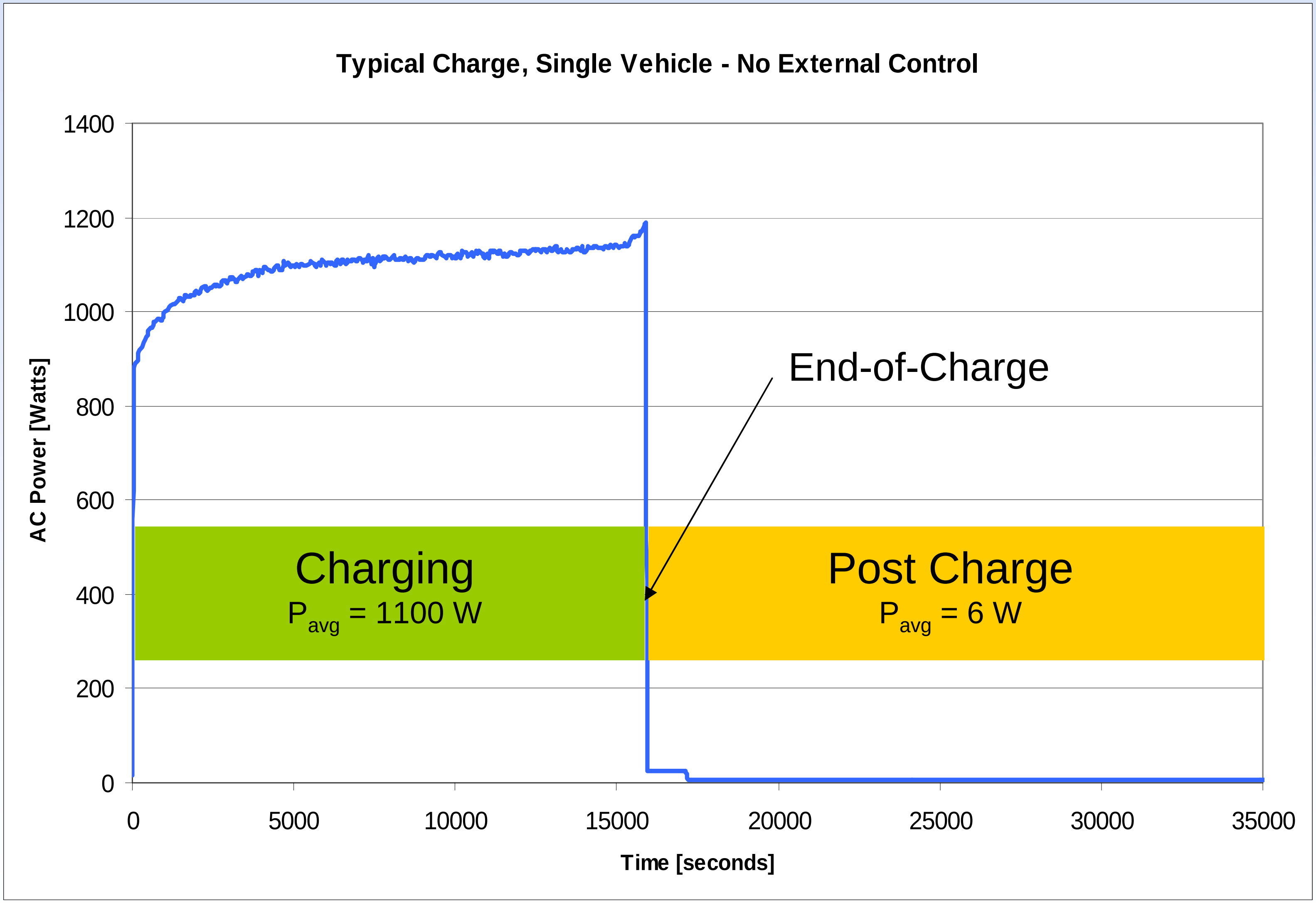
3-Page PHEV Fact Sheets provide charging stats, time of day driving, and charging profiles

PHEV Testing Results by Fleet



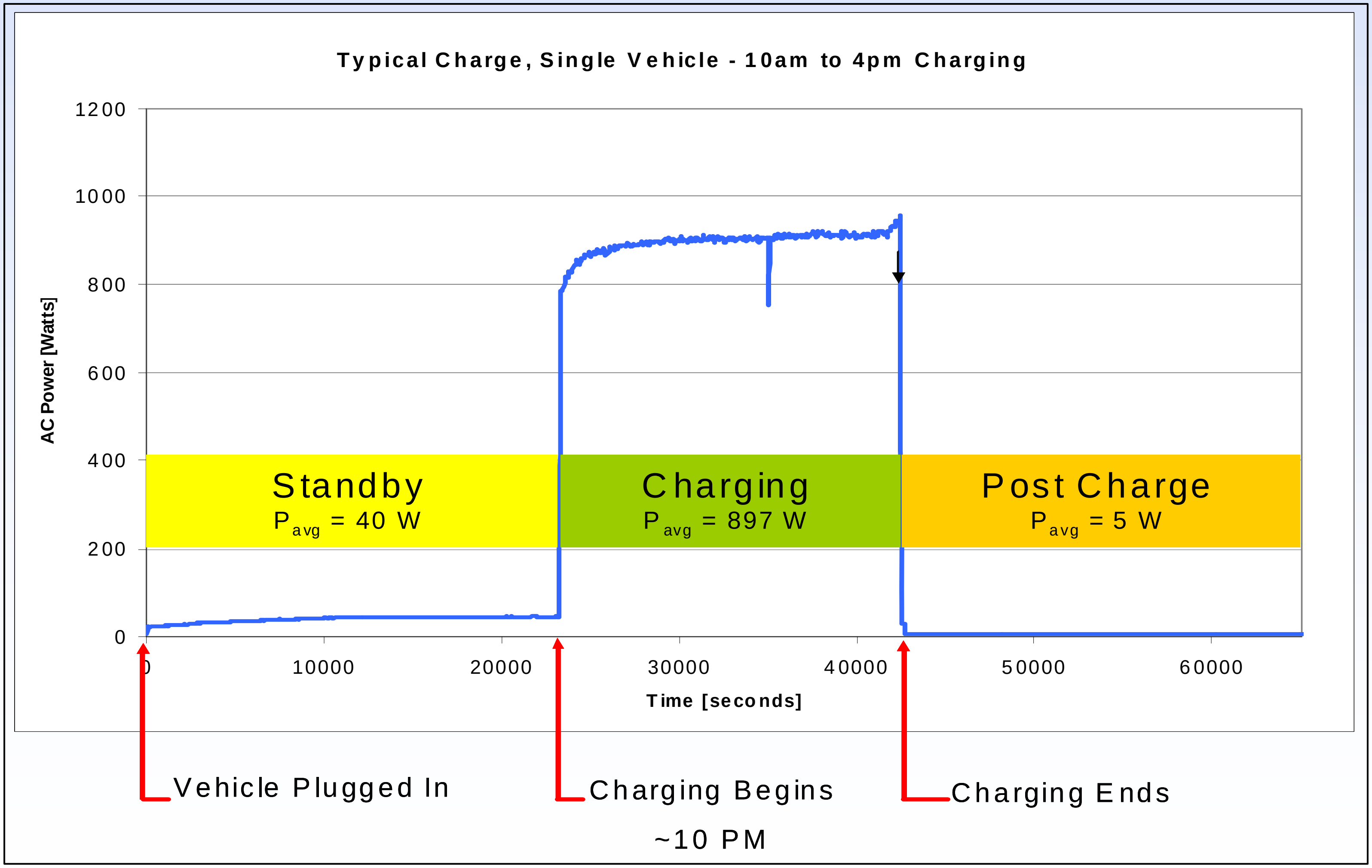
Seattle PHEV Charging – No Control



Hymotion Prius PHEV battery from A123 Systems

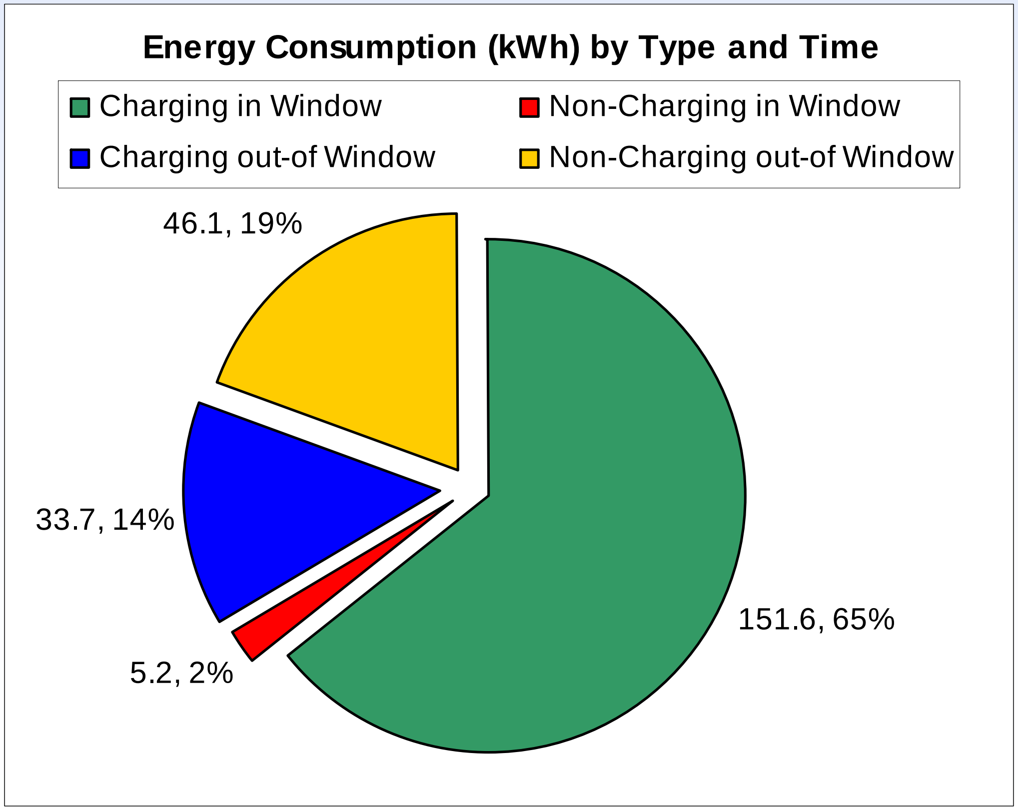
Seattle PHEV Time of Day Charging Trials

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

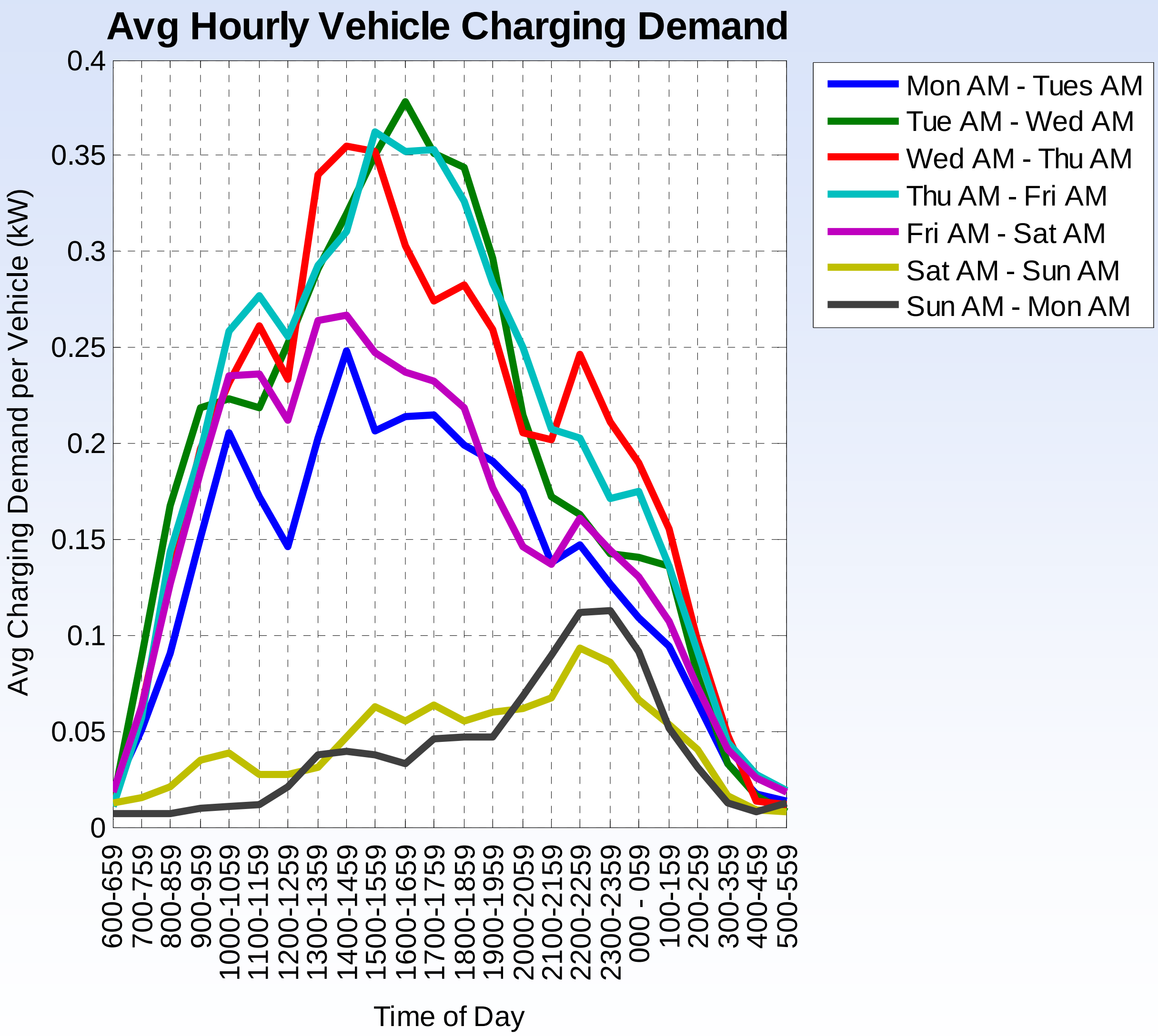


Results of PHEV Time of Day Charging Trials

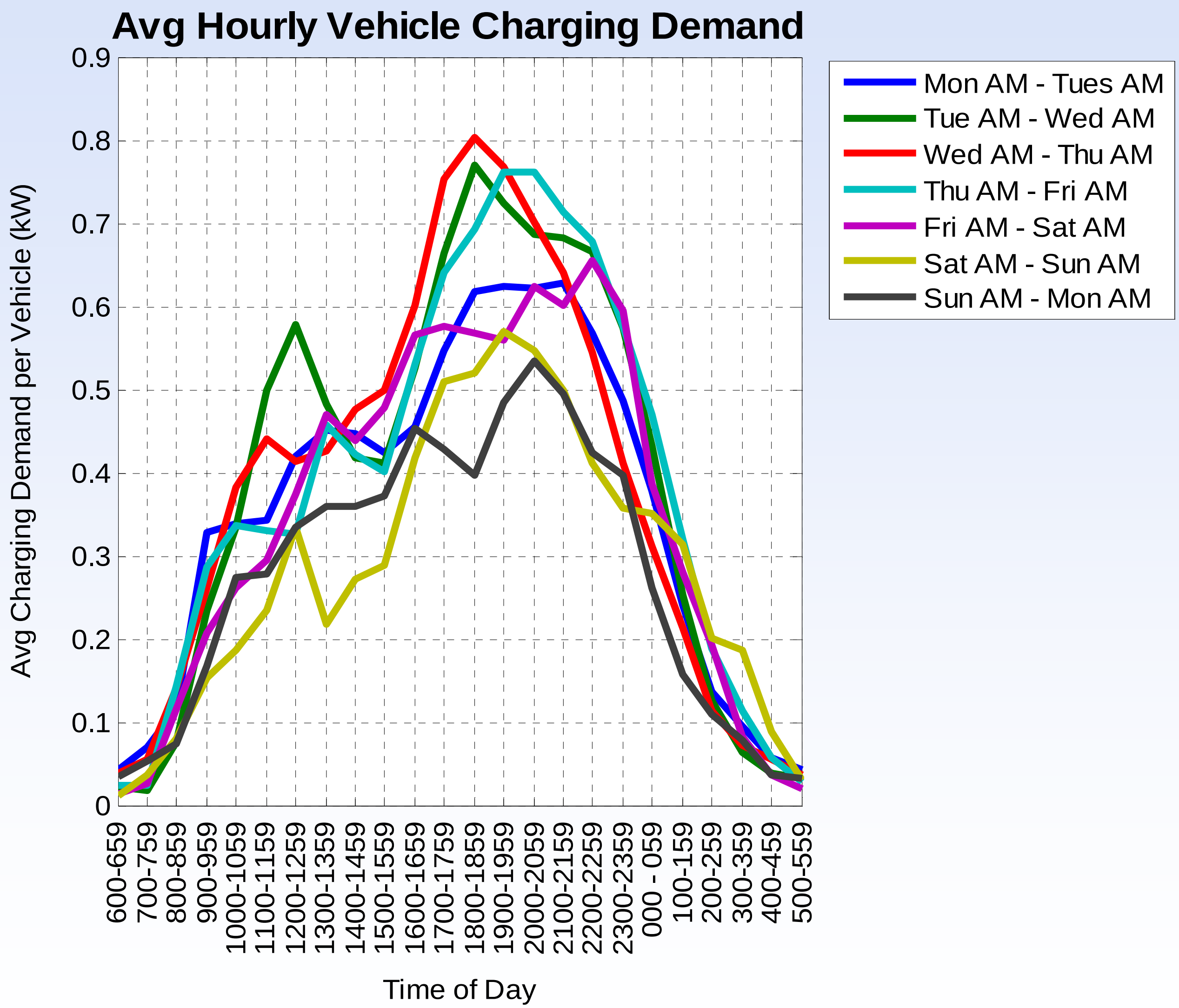
- **Rogue AC kWh – energy drawn outside of allowable charging window:**
  - **Communication not established or lost - charging occurs**
  - **Cumulative standby energy draw when not charging**



PHEV Commercial Fleets Charge Demand



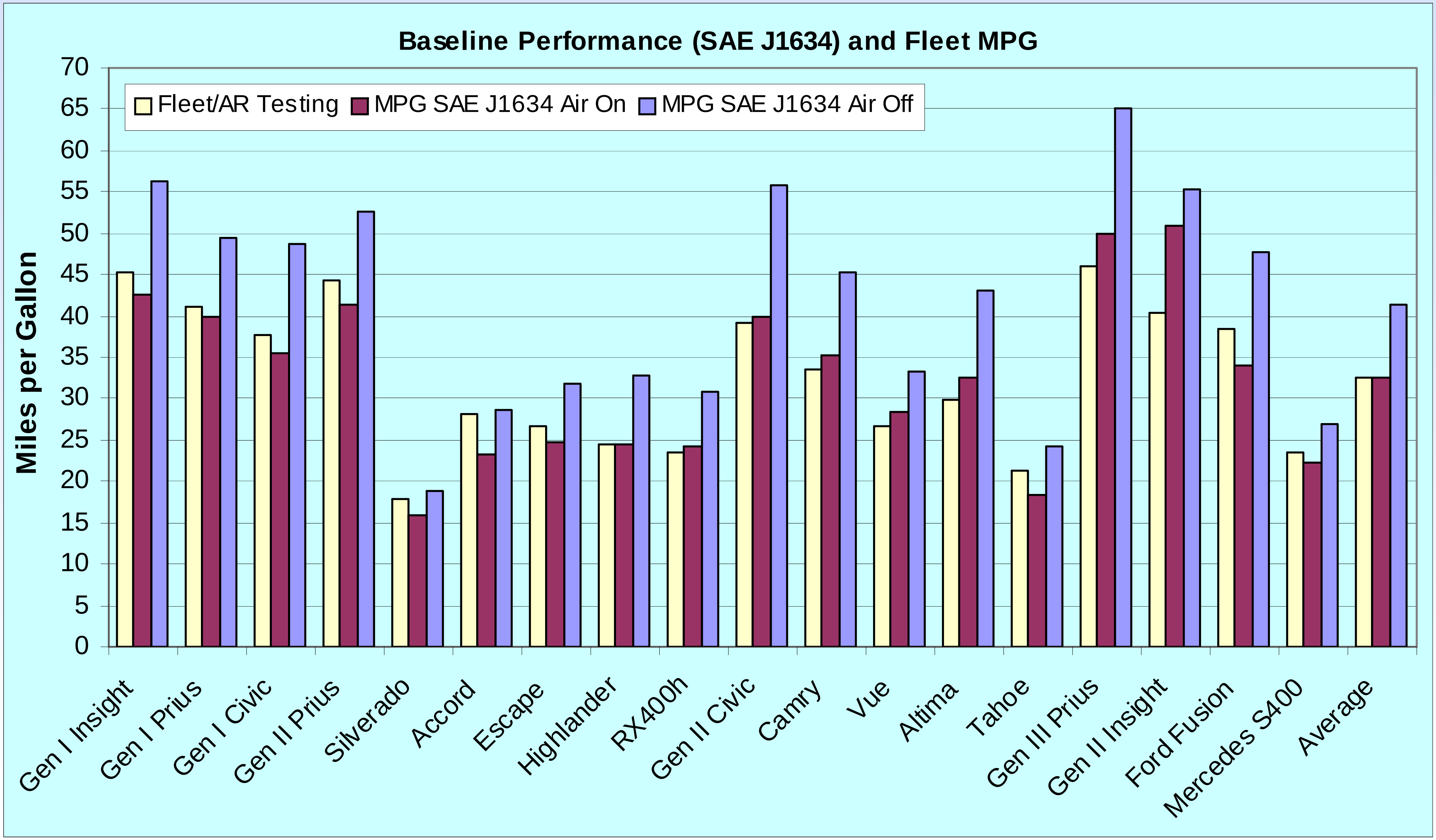
PHEV Private Fleets Charging Demand



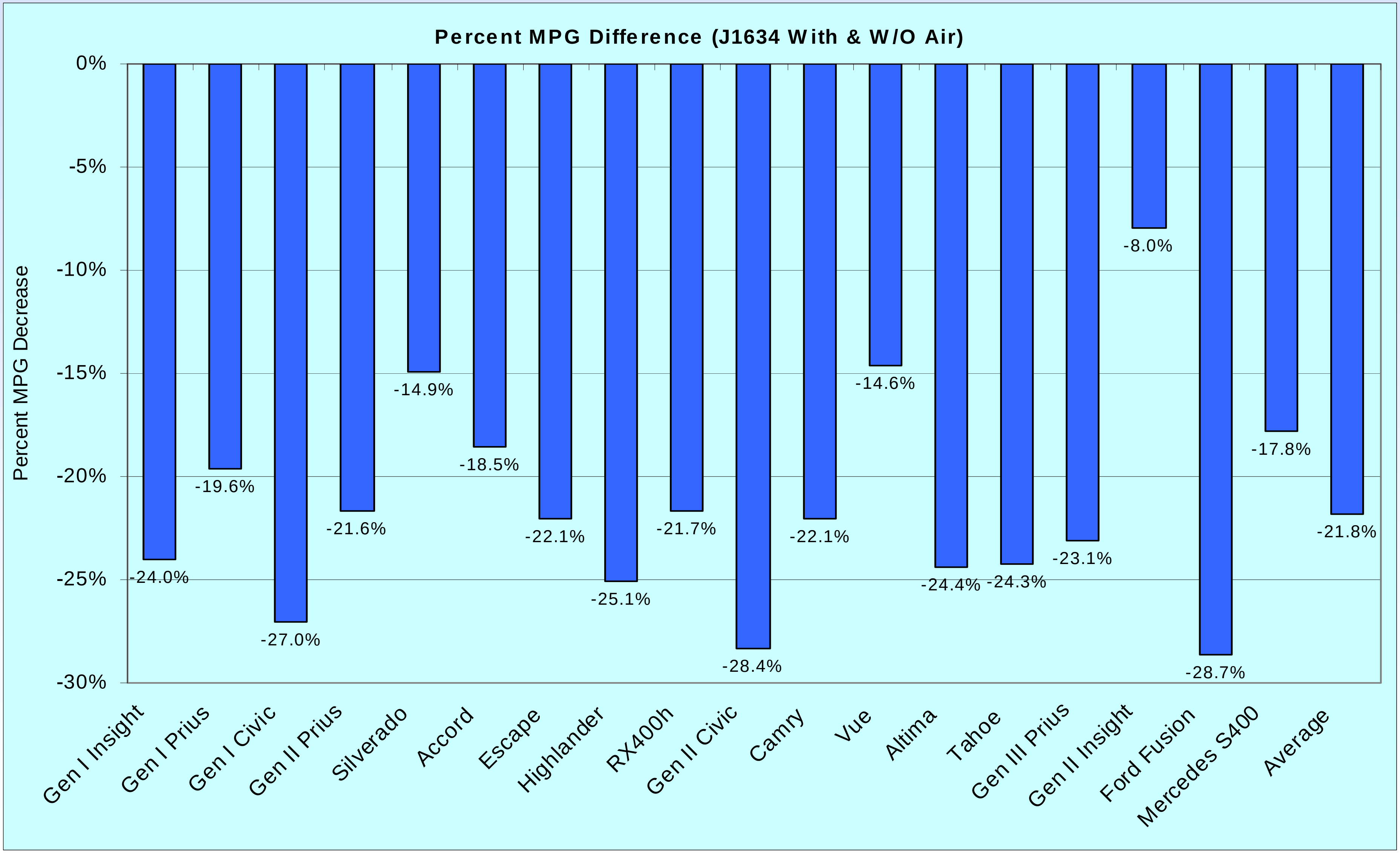
AVTA HEV Testing

- 5 million total HEV testing miles
- 18 HEV models and 47 HEVs tested 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 24 HEV battery testing reports to date

AVTA HEV Testing – cont’d



AVTA HEV Testing – cont'd



AVTA HEV Testing – cont'd

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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

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy   VEHICLE TECHNOLOGIES PROGRAM

HEV Fleet Testing

2006 Toyota Highlander Hybrid

Final Fleet Testing Results

Operating Statistics

Number of Vehicles Tested: 2

Distance Driven[1]: 297,852 mi

Average Trip Distance[2]: 13.8 mi

Stop Time with Engine Idling[3]: 23%

Trip Type City/Highway[2]: 74%/26%

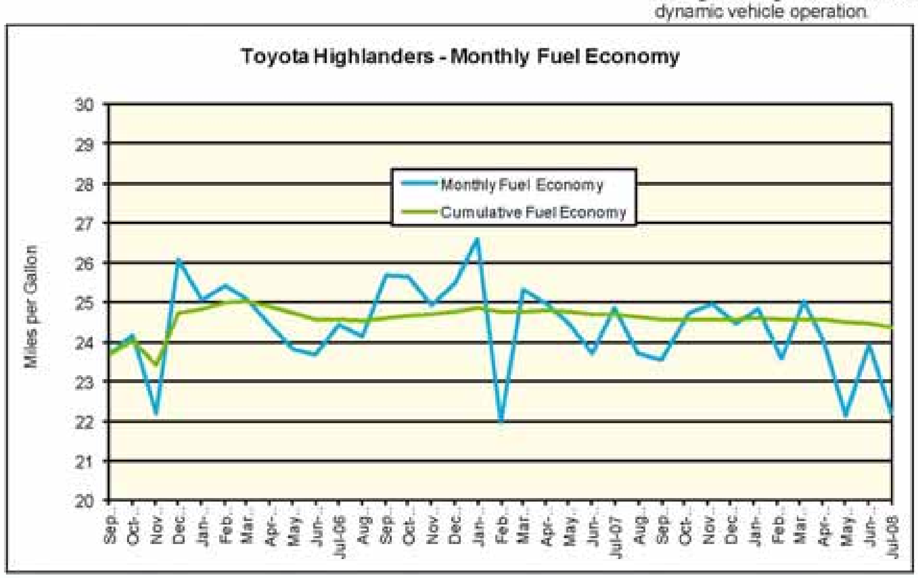
Operating Performance

Cumulative MPG[1]: 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.



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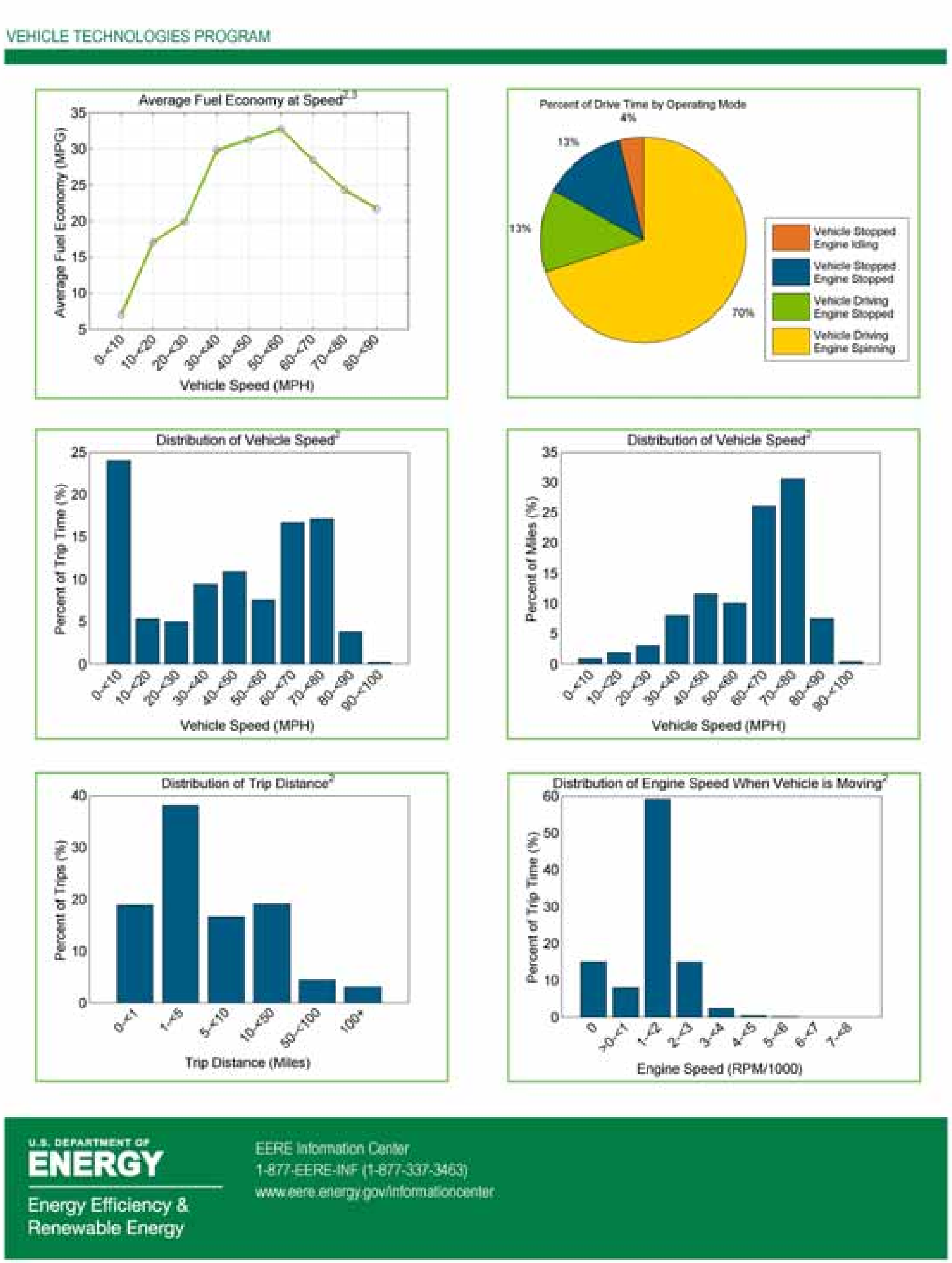
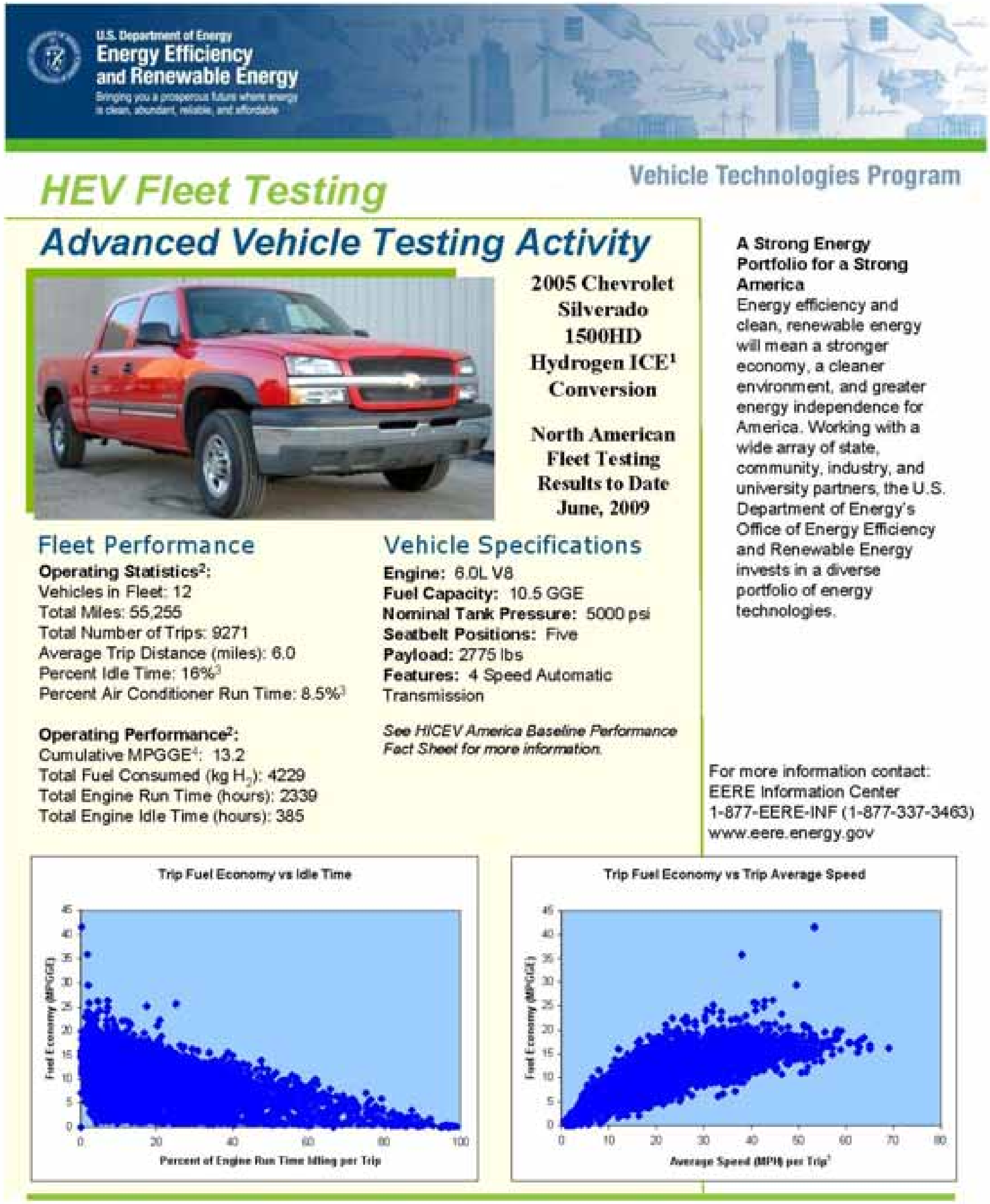
2-Page HEV Fleet Testing Fact Sheets

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





U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Vehicle Technologies Program

HEV Fleet Testing

Advanced Vehicle Testing Activity

2005 Chevrolet Silverado 1500HD Hydrogen ICE[1] Conversion

North American Fleet Testing Results to Date June, 2009

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.

Fleet Performance

Operating Statistics[2]:
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 Performance[2]:
Cumulative MPGGE[4]: 13.2
Total Fuel Consumed (kg H_2): 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

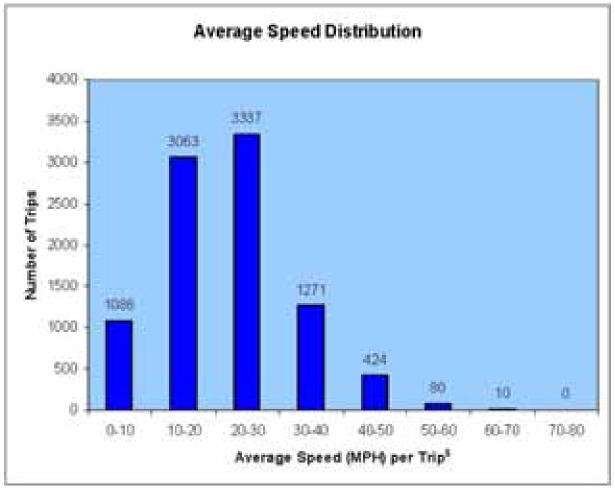
See HICEV America Baseline Performance Fact Sheet for more information.

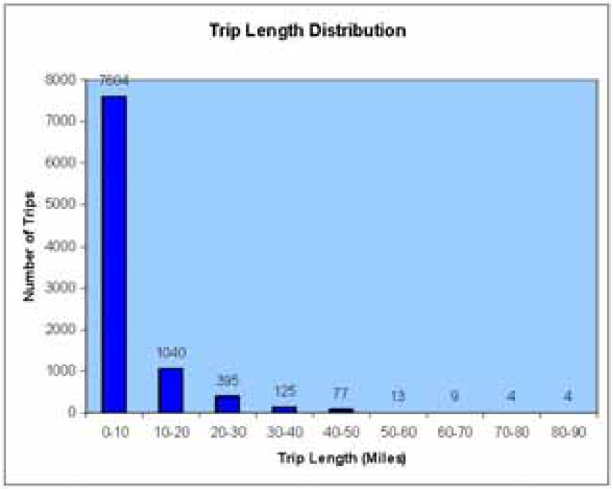
For more information contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

Hydrogen ICE Fact Sheet

- **Twelve 2005 Chevrolet Silverado 1500HD pickups**
- **Operating in Canada and the U.S.**
- **Onboard data logger generated results**
- **10.5 GGE ~100% H_2 onboard storage**
- **Low cost data monitoring activity**

Hydrogen ICE Fact Sheet – cont'd

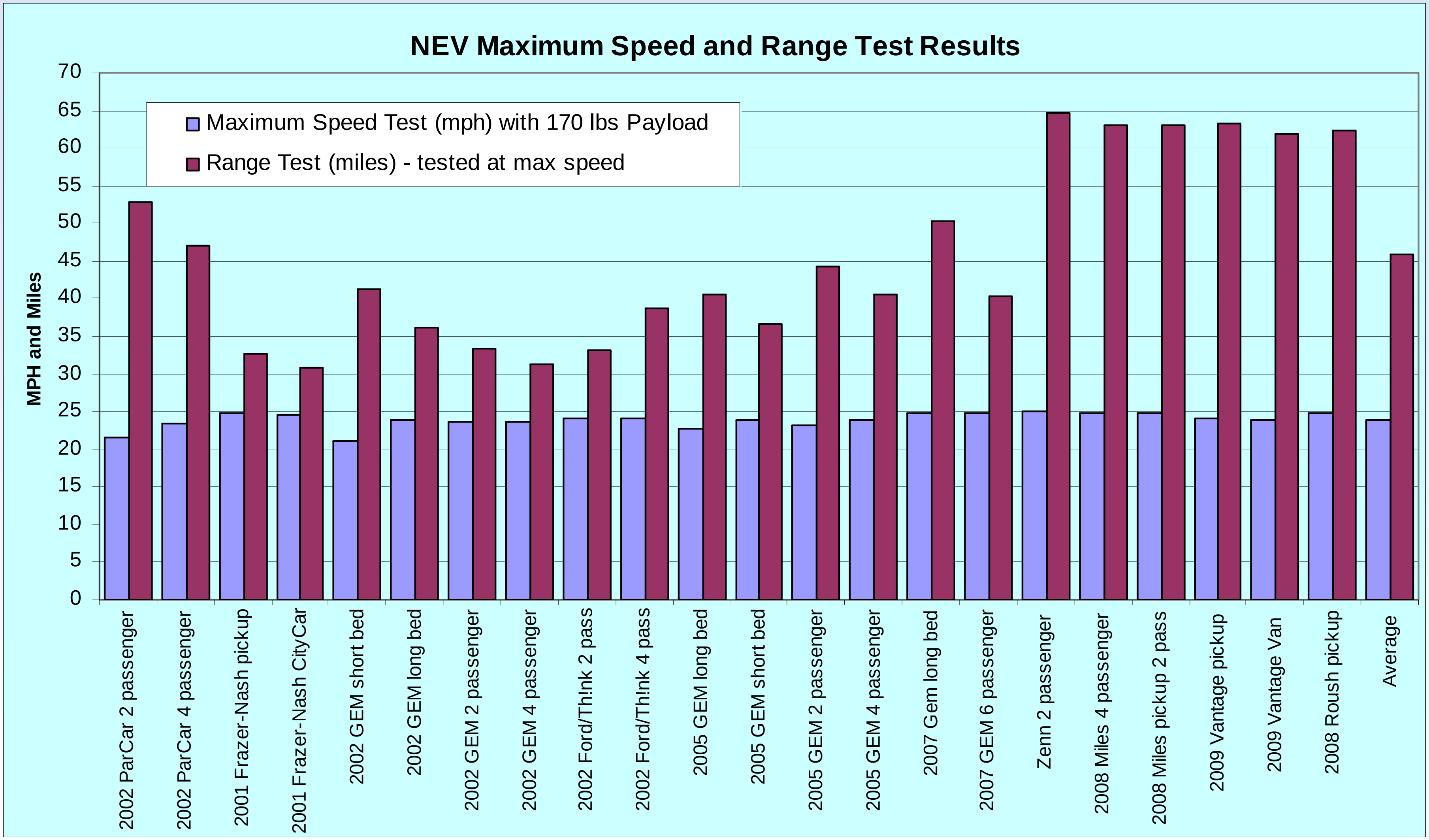




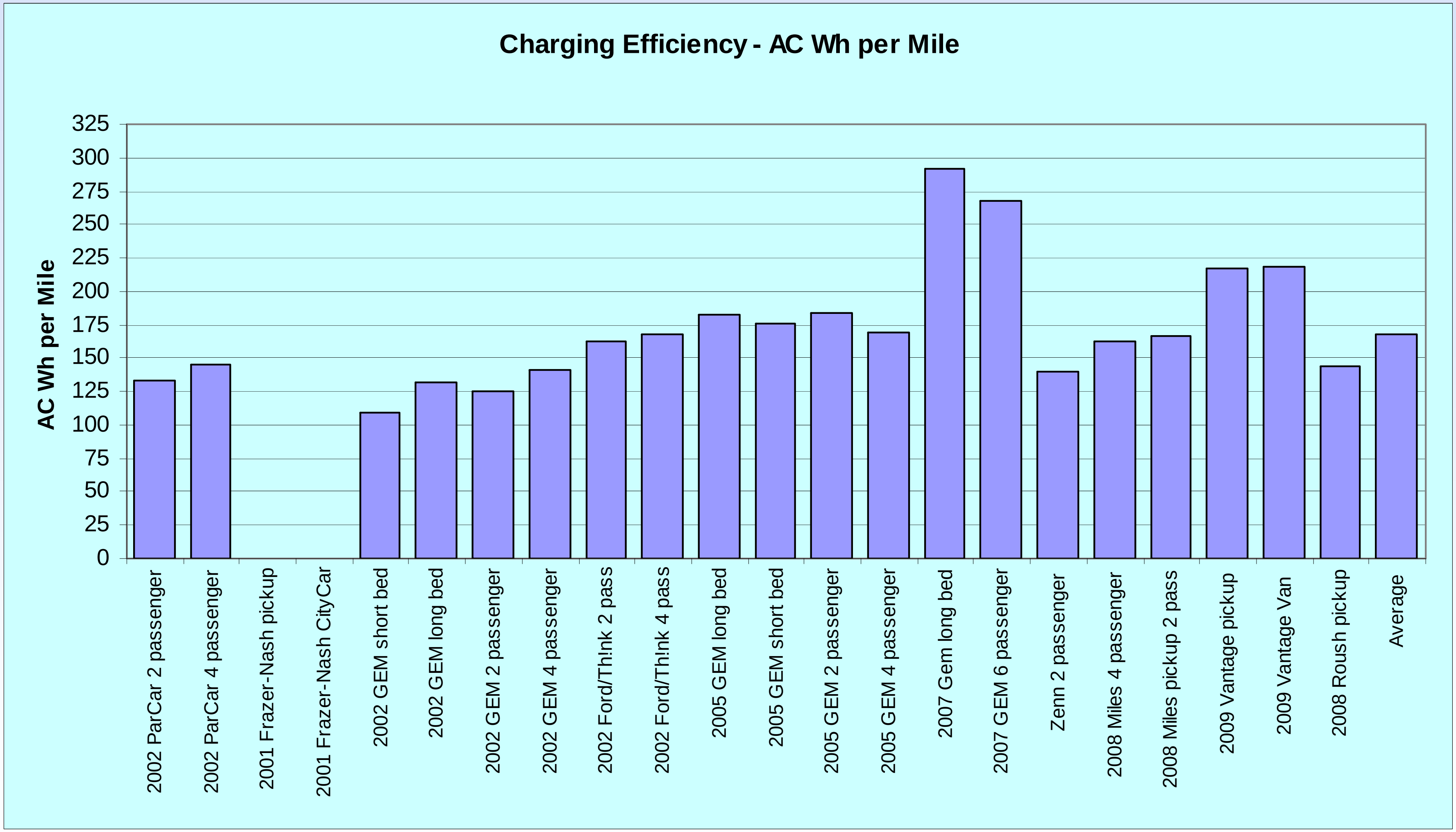
Notes:

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 H_2)
5. Average speed of vehicle when moving, idle time not included in calculation

AVTA NEV Testing



AVTA NEV Testing – cont'd



AVTA BEV Testing

- **FY10 tested first BEV from OEM in 10+ years**
- **Additional FY10 BEVs: Tesla and THINK**
- **FY11 will include: Leaf, iMiEV, Transit, Focus, THINK, BMW, BYD E6**
- **FY11 will also include EREV Volt and PHEV Toyota Prius**

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

BMW MOTORS
2009 MINI E

VEHICLE SPECIFICATIONS

BASE VEHICLE: 2009 BMW MINI E
Seatbelt Positions: Two
Standard Features:
Front Wheel Drive
Front Disc and Rear Disc Brakes
Regenerative Braking With Coast Down
Three-Point Safety Belts
Speedometer
Odometer
State-Of-Charge Meter

BATTERY
Type: Lithium Ion
Number of Modules: 48
Weight of Pack(s): 260 kg
Pack(s) Location: Behind the front seats in the rear cargo area
Nominal System Voltage: 380V

POWER PLANT
Motor Controller: AC Propulsion
Type: AC Induction Motor
Power: 150 kW (200hp)
Torque: 220 Nm (162 ft/lb)

WEIGHTS
Design Curb Weight: 3230 lb
Delivered Curb Weight: 3306 lb
Distribution F/R: 51/49 %
GVWR: 3660 lb
Payload[2]: 354 lb
Performance Goal: 400 lb

DIMENSIONS
Wheelbase: 97.1 inches
Track F/R: 57.4/57.8 inches
Length: 145.6 inches
Width: 66.3 inches
Height: 55.4 inches
Ground Clearance: 6.0 inches
Performance Goal: 5.0 inches

CHARGER
Level 1:
Location: On-board
Type: Conductive
Input Voltages: 120VAC
Level 2:
Location: Off-board
Type: Conductive
Input Voltages: 240 VAC

PERFORMANCE STATISTICS

Acceleration (0-50mph) @ 332 lbs Payload
At 100% SOC: 8.3 seconds
Max Power: 150.2 kW
At 50% SOC: 8.5 seconds
Max Power: 109.7 kW
Performance Goal (0-50mph): 13.5 sec

Maximum Speed @ 332 lbs Payload
At 100% SOC: 81.1 mph
At 50% SOC: 80.7 mph
Performance Goal: 70 mph

Constant Speed Range @55mph[1]
Range: 129.5 miles
Energy Used: 30.273 kWh
Efficiency: 233.8 Wh-DC/mile
Specific Energy: 116.4 Wh/kg
Charging Energy: 36.14 AC kWh
Performance goal: 50 miles

Constant Speed Range @65mph[1]
Range: 104.15 miles
Energy Used: 29.344 kWh
Efficiency: 281.7 Wh-DC/mile
Specific Energy: 112.9 Wh/kg
Charging Energy: 35.40 AC kWh

Driving Cycle Range (UDDS)
Range per SAE J1634: 142.45 miles
Energy Used: 29.656 kWh
Efficiency: 208.2 Wh/mile
Specific Energy: 114.1 Wh/kg
Charging Energy: 36.86 AC kWh
Performance Goal: 60 miles

Driving Cycle Range (HWY)
Range per SAE J1634: 137.34 miles
Energy Used: 30.677 kWh
Efficiency: 223.4 Wh/mile
Specific Energy: 118.0 Wh/kg
Charging Energy: 36.86 AC kWh

Gradeability:
Maximum Speed @ 3%: 80.4 mph
Maximum Speed @ 6%: 80.3 mph
Maximum Grade: 33%

Charging Efficiency:
Efficiency: 258.7 Wh-AC/mi
Energy Cost: @ $0.10/kWh: $0.025/mi

Level 1 Charger (@110V/12A)
Time to Recharge to Complete: 26.5 hrs

Level 2 Charger (@240V/32A)
Time to Recharge to Complete:4.5 hrs

Level 2 Charger (@240V/48A)
Time to Recharge to Complete: 3 hrs

TEST NOTES:
1. Vehicle was operated at the specified test speed until the vehicle could no longer maintain the desired speed.
2. As delivered payload was 354 Lbs.
3. Hours were calculated at time the 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.

eTec/Nissan/INL EV Infrastructure Project

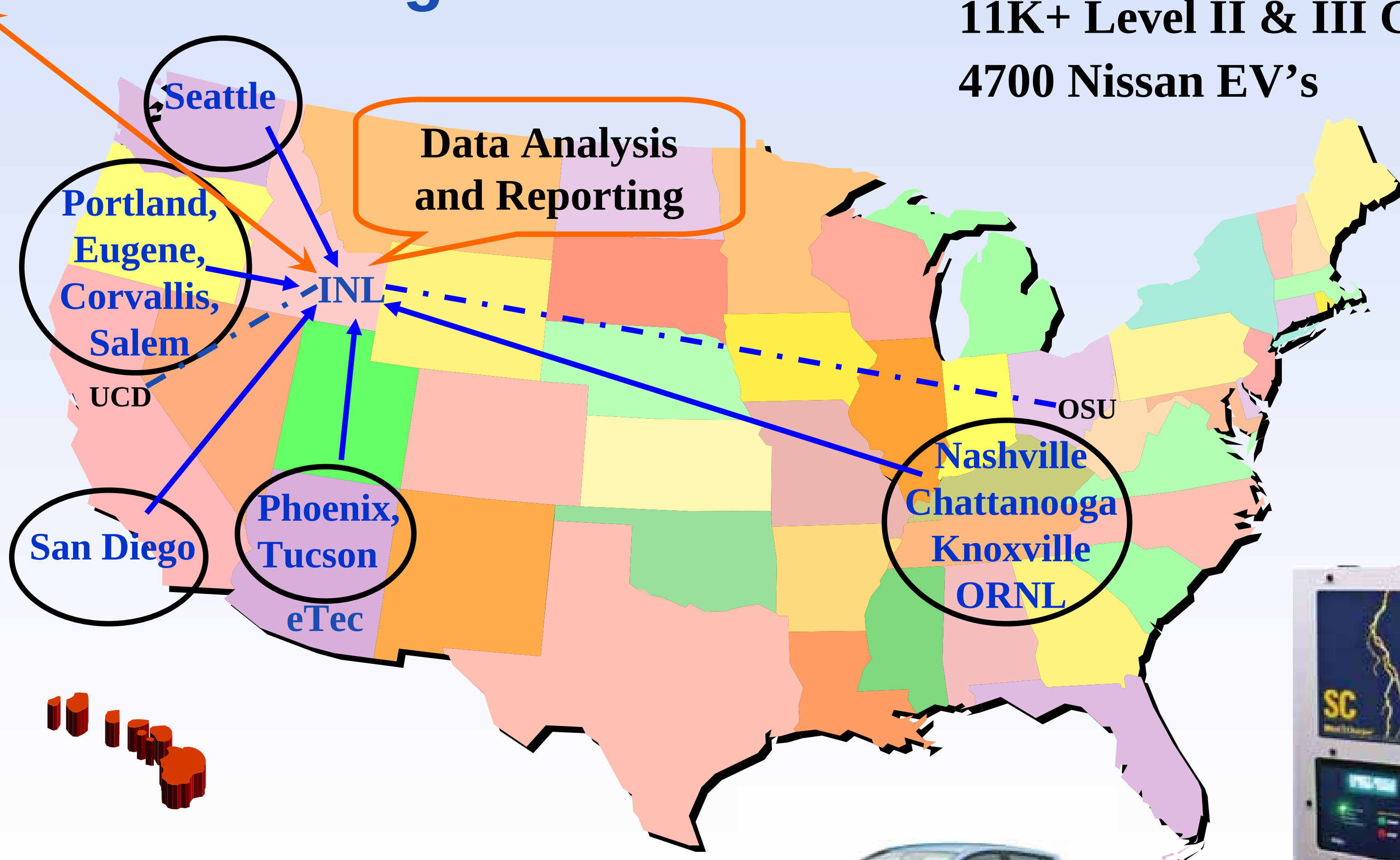
- INL is a principle participant with eTec in the deployment of 4,700 battery electric Nissan Leaf vehicles in 5 states:
  - Oregon, Washington, California, Arizona and Tennessee
- Charging and vehicle data will be collected via data streams from eTec charging infrastructure, Nissan, and possibly 3rd party infrastructure providers
- INL will analyze and report on charging infrastructure utilization for ~11,000 Level II EVSE units, ~300 Level III chargers, and 4,700 Leafs
- INL will report on driver/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
- Probable fast charge / grid energy storage test component

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

Announced BEV Introductions*

- 2009 Subaru 4 seat Stella or R1e (2 in New York now)
- 2009 Chrysler EVs (showing concepts)
- 2009 Smart for Two EV
- 2009 ZENN city BEV
- 2009 Chery (China, Berkshire Hathaway) BYD EV in China
- 2009 Tesla / Daimler Smart Car BEV
- 2010 BMW electric Mini (actually 2009 prototype)
- 2010 Chrysler EV
- 2010 Miles EV
- 2010 Mitsubishi \ Peugeot iMiEV BEV
- (* Presenter makes no accuracy claim for the above dates and products. Some info based on media reports)

Primary source: EDTA http://www.electricdrive.org/index.php?ht=d/sp/i/11551/pid/11551

Announced BEV Introductions* – cont'd

- 2010 Nissan BEV
- 2010 Ford Battery Electric Van
- 2011 Tesla Model S sedan
- 2011 BYD e6 Electric Vehicle
- 2011 Ford Battery Electric Sedan
- 2011 Opel Ampera Extended Range BEV (Europe)
- 2012 Toyota EV sedan
- ? Volkswagen and Toshibia EV develop letter of intent
- (* Presenter makes no accuracy claim for the above dates and products. Some info based on media reports)

Primary source: EDTA http://www.electricdrive.org/index.php?ht=d/sp/i/11551/pid/11551

Announced PHEV Introductions*

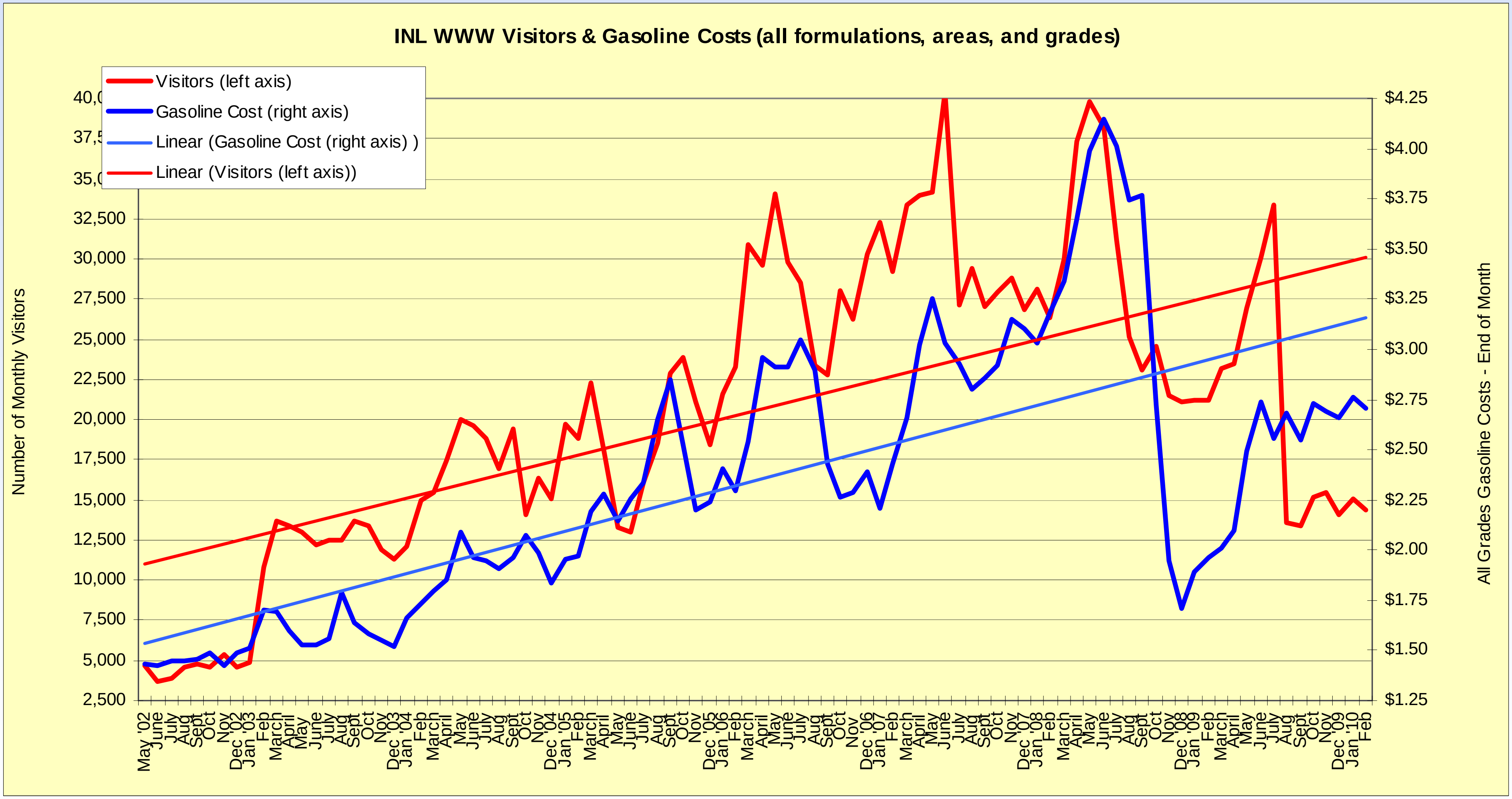
- 2009 Fisker Karma S Plug-in Hybrid (maybe 2010)
- 2010 Saturn VUE Plug-in Hybrid
- 2010 Toyota Plug-in Hybrid (?)
- 2010 Chevrolet Volt Extended Range (actually EVRE)
- 2010 Kia LPG and Electric “hybrid”
- 2009 Chery (China, Berkshire Hathaway) BYD PHEV in Europe
- 2011 BYD F3DM Plug-in Hybrid
- 2012 Ford Escape Plug-in Hybrid
- 2012 Hyundia PHEV
- ? AFS Trinity SUV
- (* Presenter makes no accuracy claim for the above dates and products. Some info based on media reports)

Primary source: EDTA http://www.electricdrive.org/index.php?ht=d/sp/i/11551/pid/11551

Vehicles Selection Considerations

- **Is it an OEM Vehicle or a conversion? If a conversion ask:**
  - **Has the vehicle emissions been certified by CARB or the EPA, or received an exemption?**
  - **Has the vehicle been crashed tested and FMVSS certified per NHTSA reporting requirements?**
  - **Has the converter made the vehicle available to DOE's AVTA or another group for independent testing?**
  - **Conversions need crash testing – Don't believe "its (battery) just another piece of luggage in the trunk"**
- **Always match the vehicle capabilities to missions**
  - **Consider range requirements and operating environment, including ambient temperature, terrain, payload, passenger numbers**
  - **Consider recharging / fueling requirements**
  - **Install the fueling infrastructure(s) before vehicle delivery**

AVTA Webpage Use and Gasoline Costs



Acknowledgement

This work is supported by DOE's Vehicle Technologies Program

Additional Information

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

INL/MIS-10-18073