



U.S. DOE Advanced Vehicle Testing Activity

PHEV Testing Results and Fleet Demonstrations

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AVTA Background

- The Advanced Vehicle Testing Activity (AVTA) is part of DOE's Vehicle Technologies Program
- The Idaho National Laboratory (INL) and Electric Transportation Engineering Corporation (ETEC) conduct the AVTA light-duty vehicle testing; Argonne National Laboratory provides dynamometer testing support

AVTA Goals

- Provide benchmark data to technology modelers, research and development programs, and target and goal setters
- Assist fleet managers in making informed vehicle purchase, deployment and operating decisions



AVTA Test History

- Hybrid electric vehicles
 - 14 models, 42 vehicles, 3.7 million test miles
- Hydrogen ICE (internal combustion engine) vehicles
 - 6 models, 400,000 test miles
- Full-size electric vehicles
 - 40 EV models, 5+ million test miles
- Neighborhood electric vehicles
 - 16 models, 200,000 test miles
- Urban electric vehicles
 - 3 models, 1 million test miles





PHEV Testing Objectives

- Perform independent testing of PHEVs, using:
 - Baseline performance – closed test tracks and dynamometers
 - Accelerated testing – dedicated drivers operating on defined onroad loops
 - Fleet testing
- Document battery life, charging patterns and demand profiles
- Document vehicle operations, and fuel use (both gasoline and electricity) as well as infrastructure requirements
- Document PHEV life-cycle costs



PHEV Baseline Performance Testing

- ETEC conducts initial track testing near Phoenix, AZ
 - Testing includes coastdown (determination of dynamometer coefficients), acceleration, top speed, braking, charging, and durability
- Argonne 5-day dynamometer testing regime includes:
 - Charge depleting and charge sustaining test cycles
 - At least 26 UDDS (Urban Dynamometer Driving Schedule) and HWFEDS (Highway Fuel Economy Driving Schedule) dynamometer test cycles
 - Includes hot and cold test starts



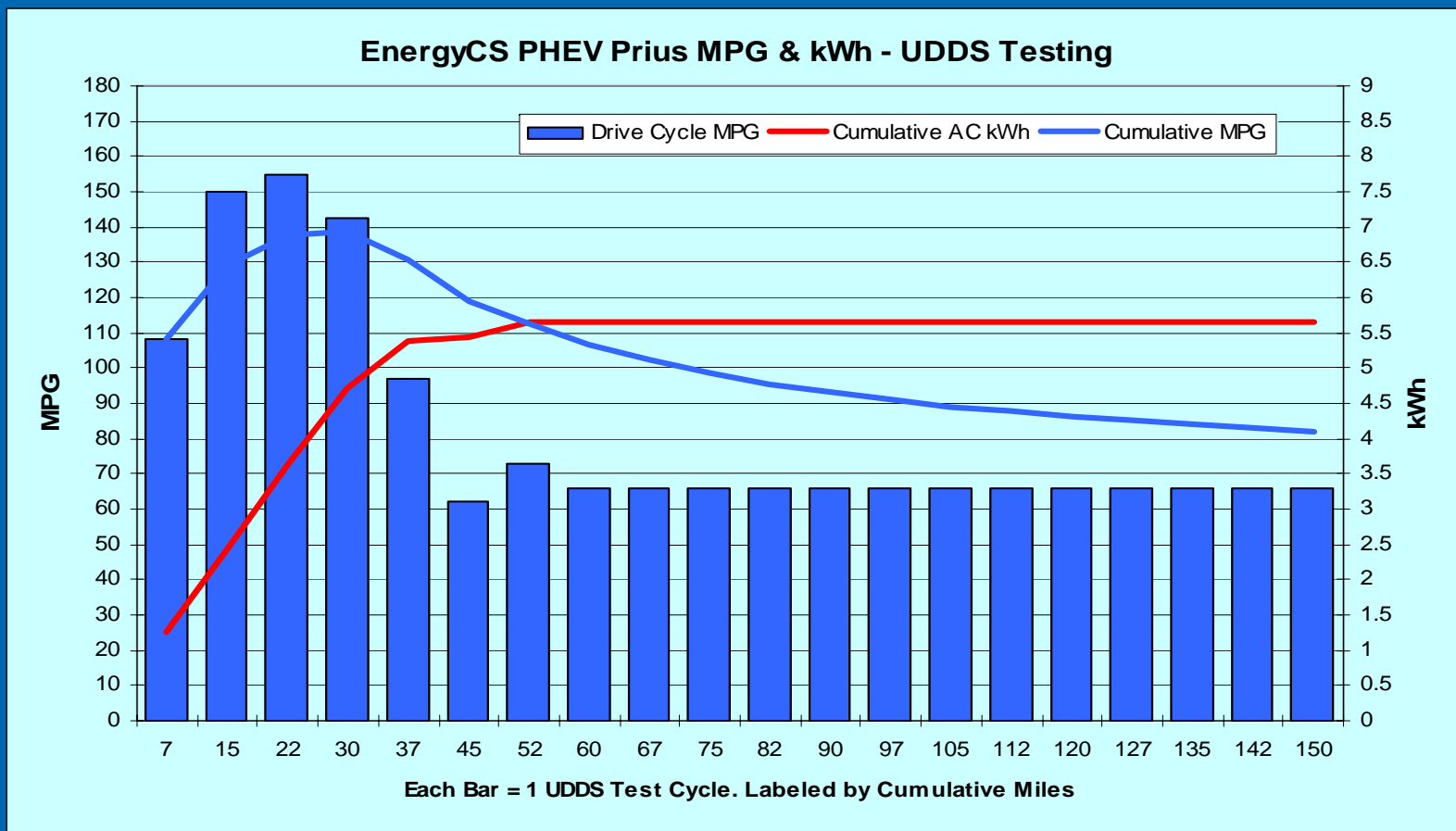
Baseline Performance Testing Results





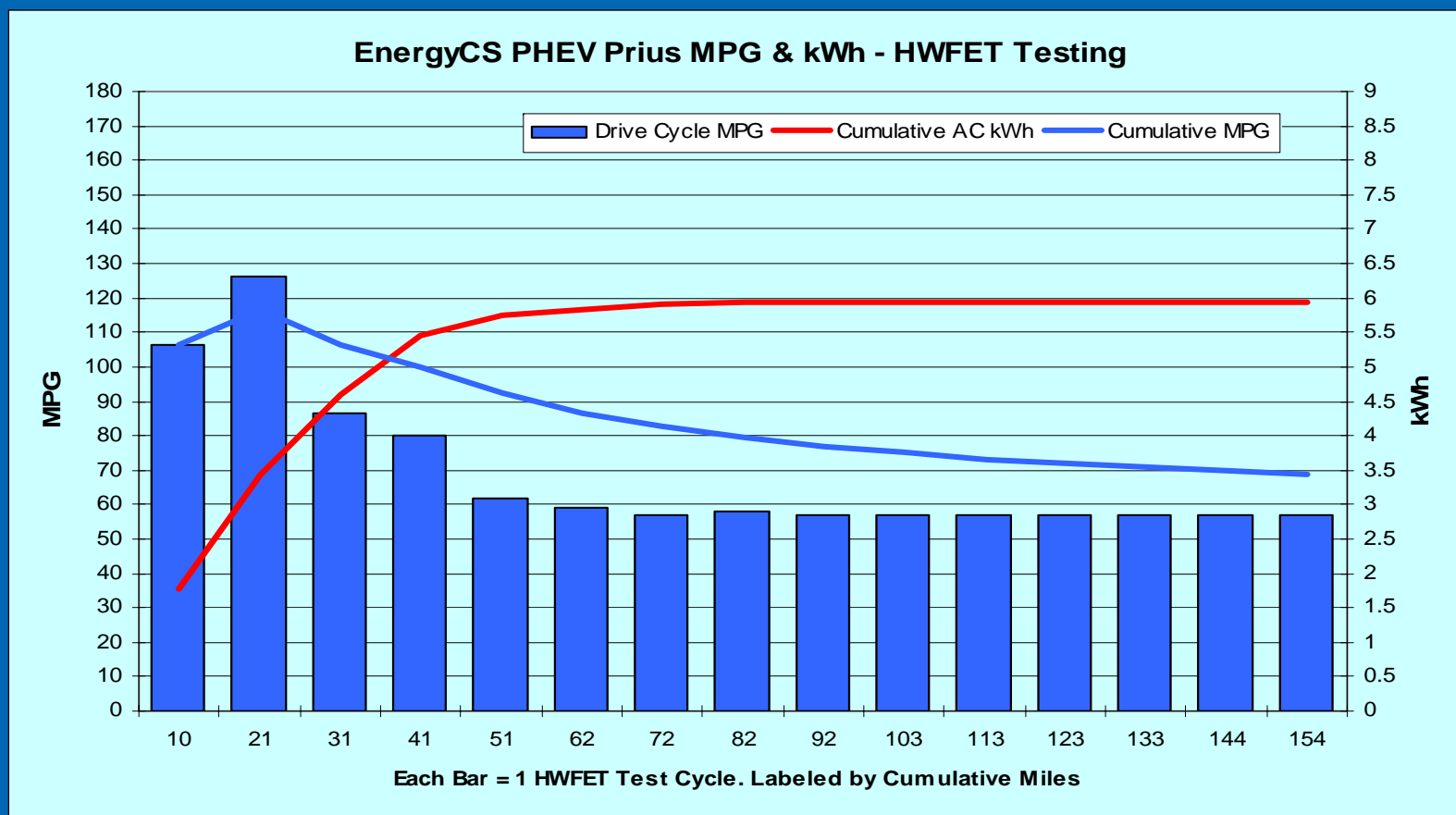
EnergyCS Prius – UDDS Fuel Use

- 9 kWh Valence (Li) pack only (AC kWh)



EnergyCS Prius – HWFETS Fuel Use

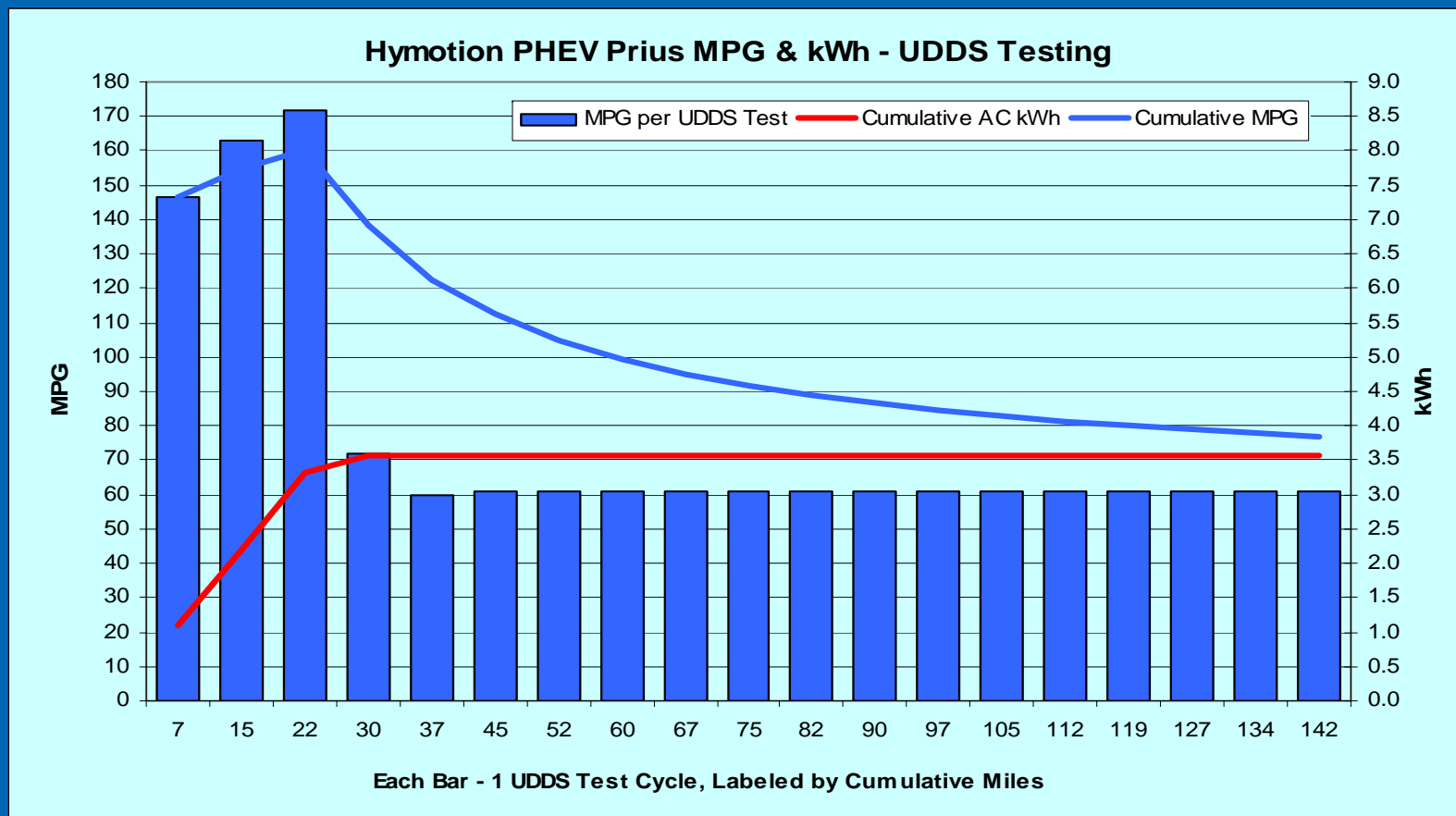
- 9 kWh Valence (Li) pack only (AC kWh)





Hymotion Prius – UDDS Fuel Use

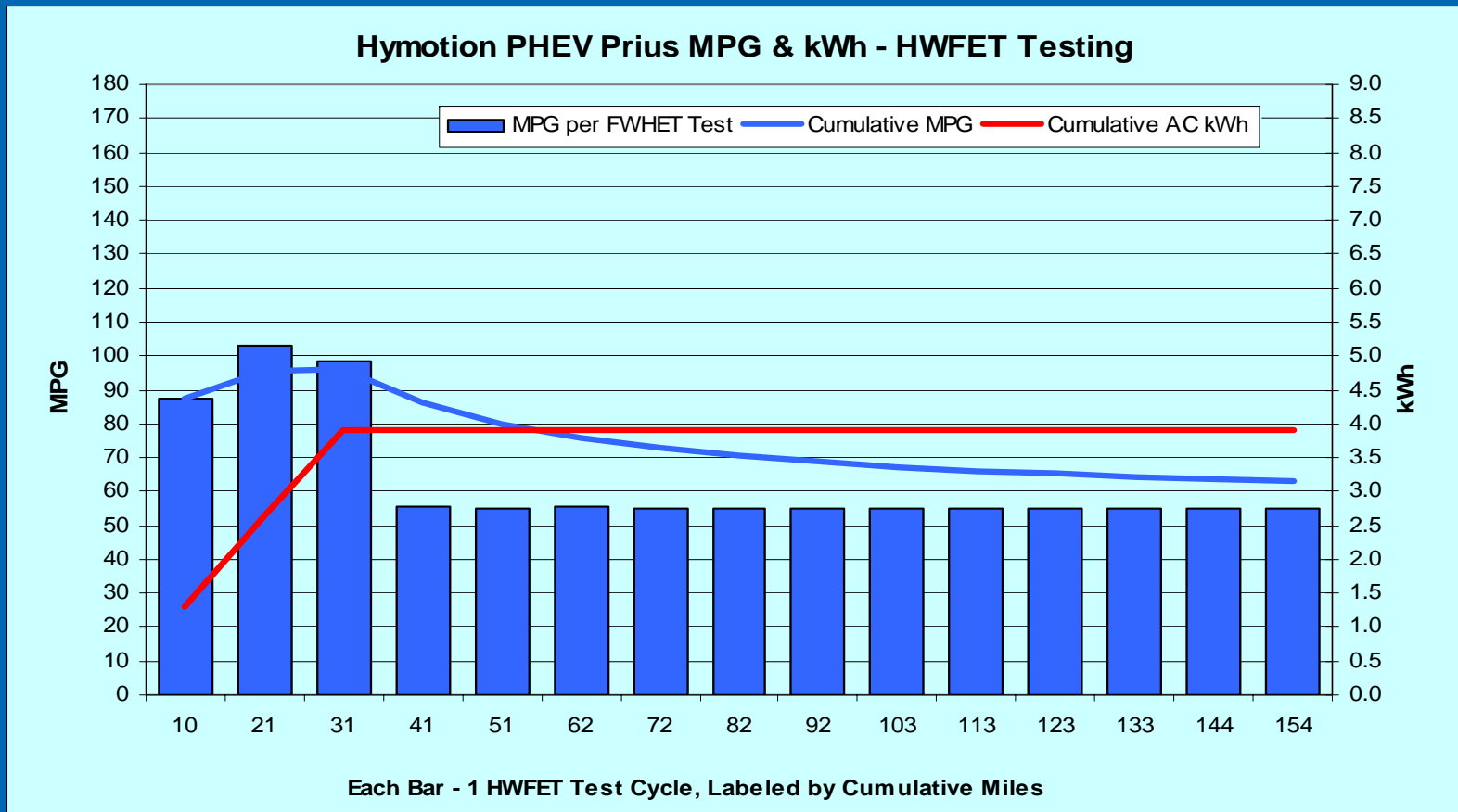
- 5 kWh A123Systems (Li) V1 and Prius packs (AC kWh)





Hymotion Prius – HWFETS Fuel Use

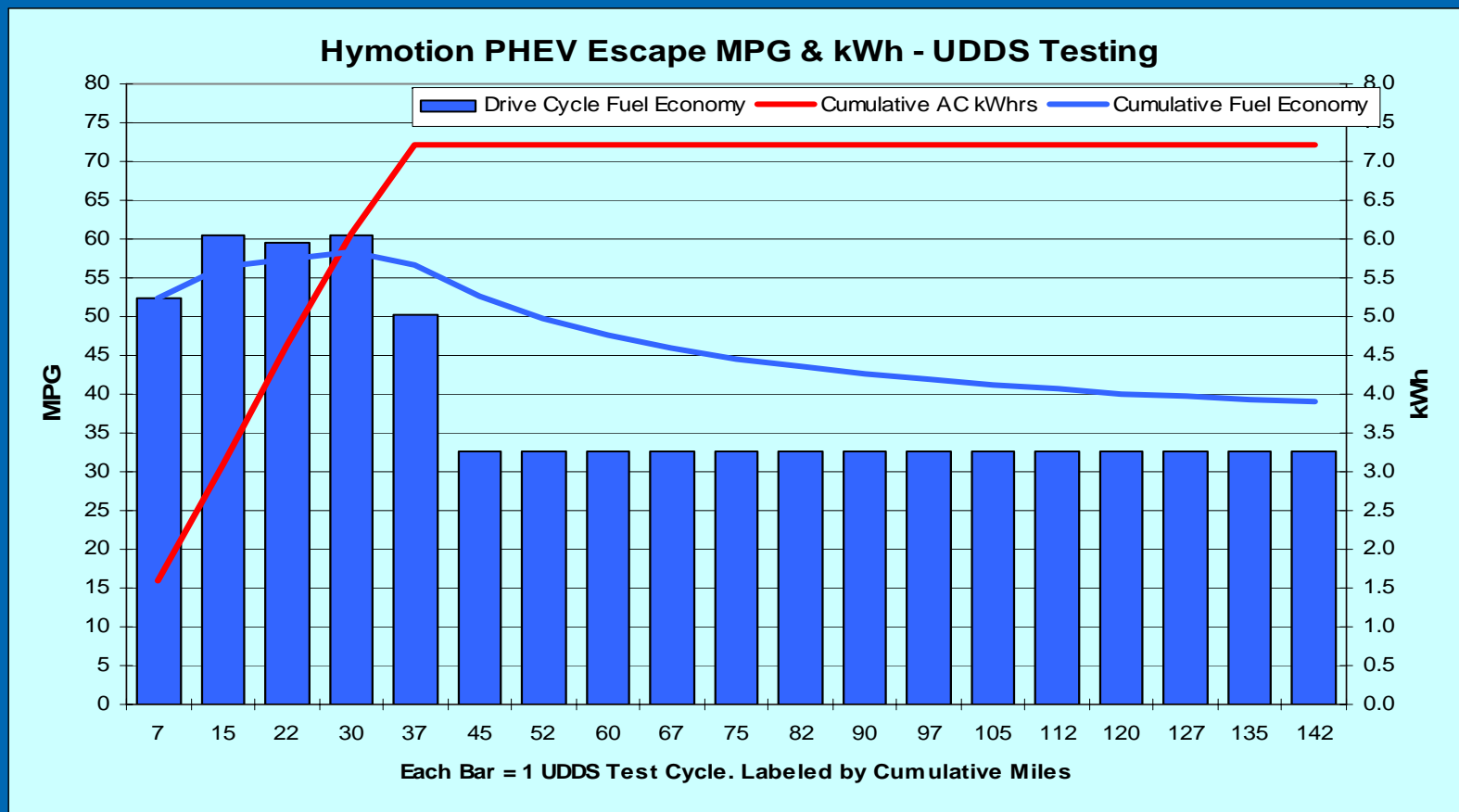
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Hymotion Escape – UDDS Fuel Use

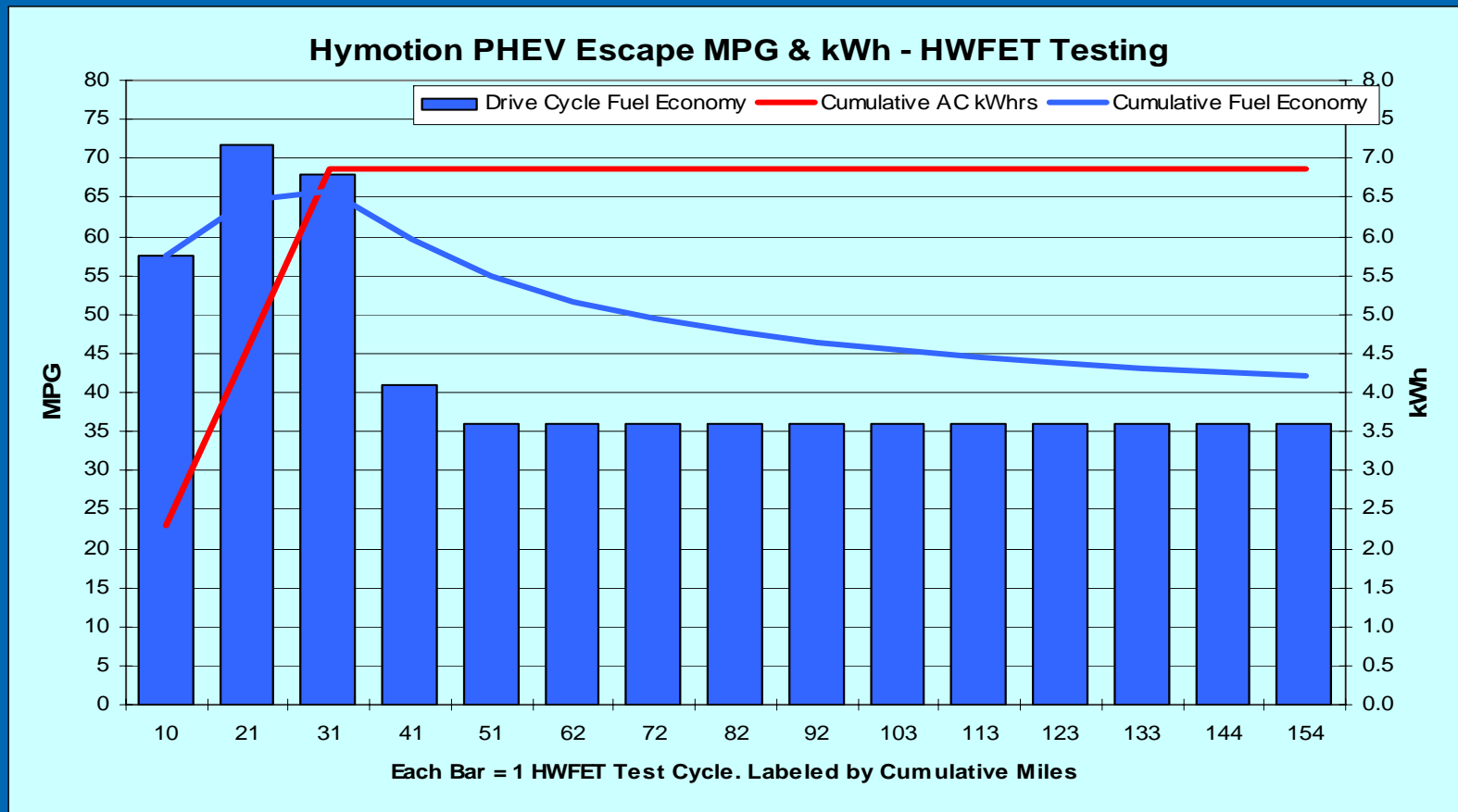
- 8.5 kWh A123Systems (Li) and Escape packs (AC kWh)





Hymotion Escape – HWFETS Fuel Use

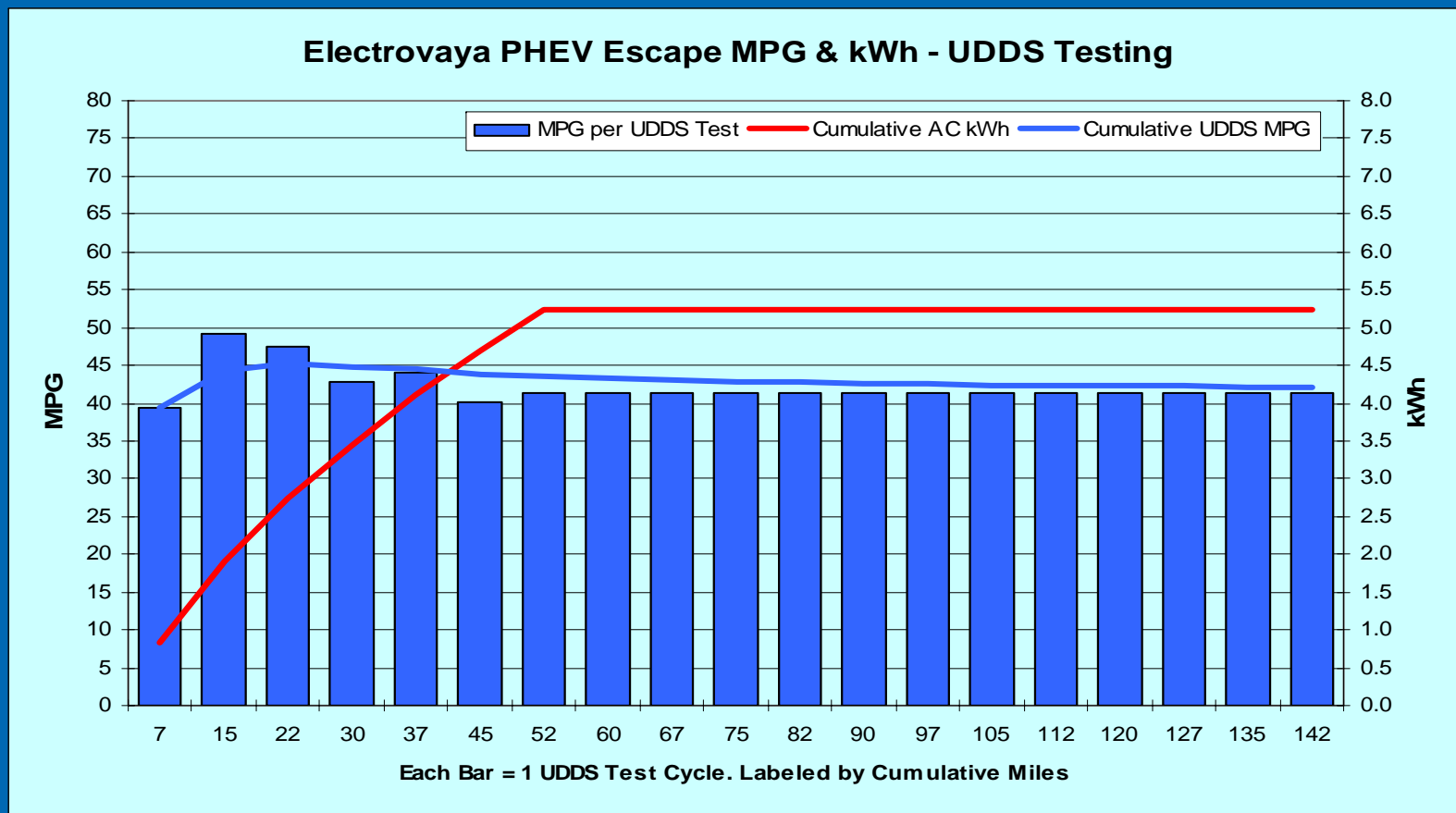
- 8.5 kWh A123Systems (Li) and Escape packs (AC kWh)





Electrovaya Escape – UDDS Fuel Use

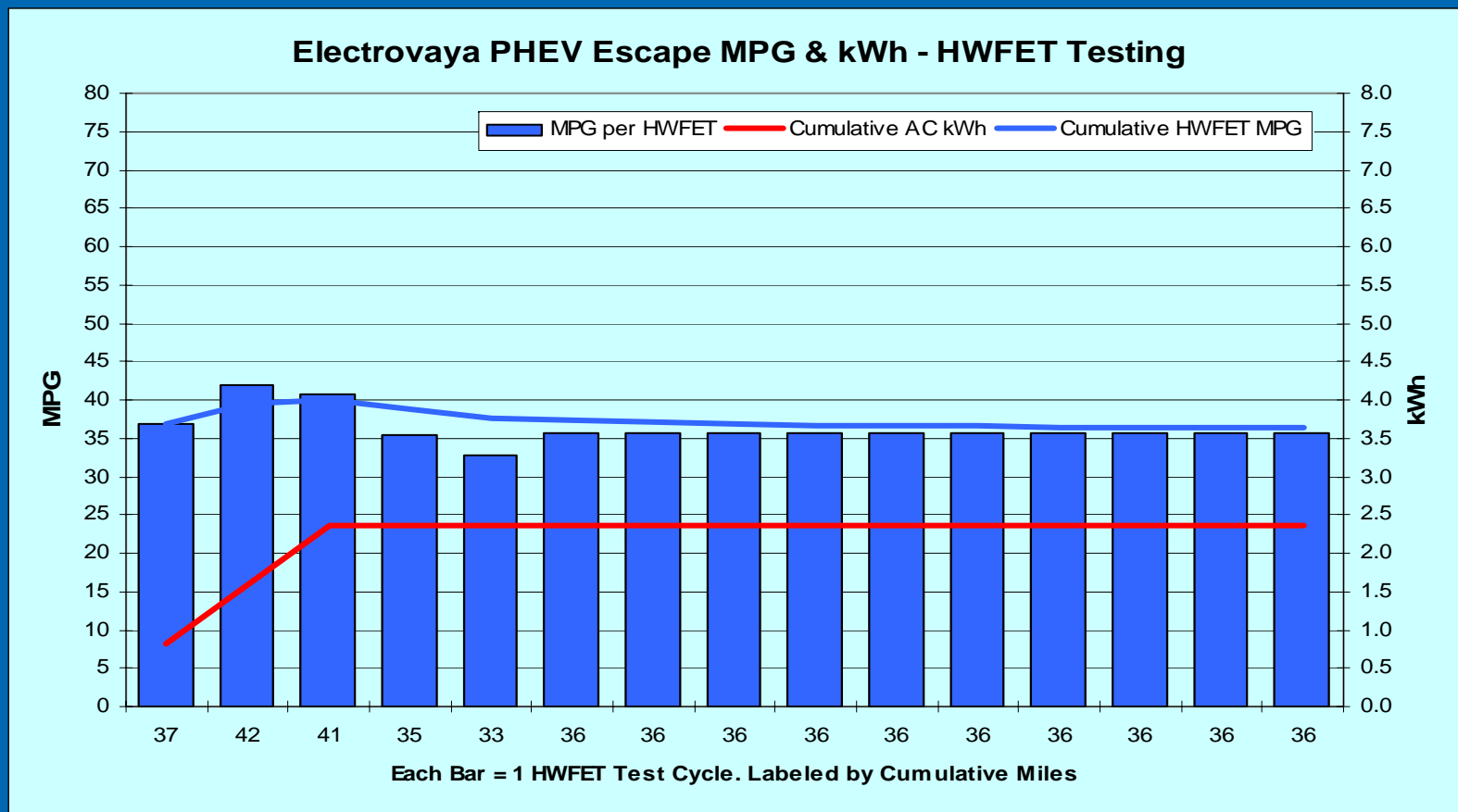
- 12 kWh Electrovaya (Li) and Prius packs (AC kWh)





Electrovaya Escape – HWFETS Fuel Use

- 12 kWh Electrovaya (Li) and Prius packs – (AC kWh)



Kangoo Test Results

- Renault Kangoo – Series PHEV with 9.6 kWh (usable) Saft NiCad pack and 650cc gasoline engine

Test Cycle	AC kWh per Mile	Miles per Gallon
Battery Only - UDDS	0.268	
Battery Only - HWFETS	0.155	
Battery Only @ Constant 45 mpg	0.271	
Battery and Gas Cold UDDS	0.144	42.3
Battery and Gas Hot UDDS	0.110	39.4
Battery and Gas Hot HWFETS	0.042	40.9



PHEV Accelerated Testing

- Dedicated drivers (Phoenix, AZ) provide broad view of fuel use over 5,440 miles of charging and operations

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	128.1
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	4	0	12	15	600**	26.48	11.31	54.1
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	2340	2500	9.84	147	4840	Weighted Average		84.5

*Rerun to 600 miles

**Software updated and cells replaced. May be rerun. Each total distance slightly greater than 600 miles. HEV version = 44 mpg



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	136.33	4.81	127.2
20	1	1	8	30	600	122.02	5.37	115.9
40	4	0	12	15	600	84.10	6.05	101.1
40	2	2	12	15	600	87.22	5.78	106.9
40	0	4	12	15	600	79.82	8.54	73.1
60	2	4	12	10	600	55.33	8.98	68.9
80	2	6	12	8	640	43.99	11.36	58.3
100	2	8	12	6	600	35.98	8.43	73.2
200	2	18	12	3	600	15.0	11.02	54.8
Total	2540	3100	1404	167	5,440	Weighted Average		79.5

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



Renault Kangoo – Accelerated Testing

Cycle	Urban	Highway	Charge	Reps	Total	Electricity		Gasoline	
(mi)	(10 mi)	(10 mi)	(hr)	(N)	(mi)	kWh	Mi/kWh	Gals	MPG
10	1	0	4	60	600	359.60	1.7	0	
20	1	1	8	30	600	131.96	4.6	0	
40	4	0	12	5	200	35.18	5.6	0	
40	2	2	12	5	200	33.22	6.0	0	
40	0	4	12	5	200	28.60	7.0	0	
60	2	4	12	10	600	57.96	10.4	13.3	45.1
80	2	6	12	8	640	44.62	14.4	16.6	38.6
100	2	8	12	6	600	Deleted*			
200	2	18	12	3	600	Deleted*			
Total	1560	1480	876	123	3,040				

* Testing ended when gasoline engine and inverter failed.
 Each total distance slightly greater than 600 miles.



Hymotion Escape – 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			
40	4	0	12	15	600			
40	2	2	12	15	600	76.29	15.99	38.7
40	0	4	12	15	600	114.14	11.92	51.5
60	2	4	12	10	600	97.18	13.70	45.3
80	2	6	12	8	640	77.69	16.05	41.3
100	2	8	12	6	600	58.64	15.69	39.8
200	2	18	12	3	600			
Total	2340	3100	1344	162	5440	Weighted Average		

Each total distance slightly greater than 600 miles. HEV version = 27 mpg



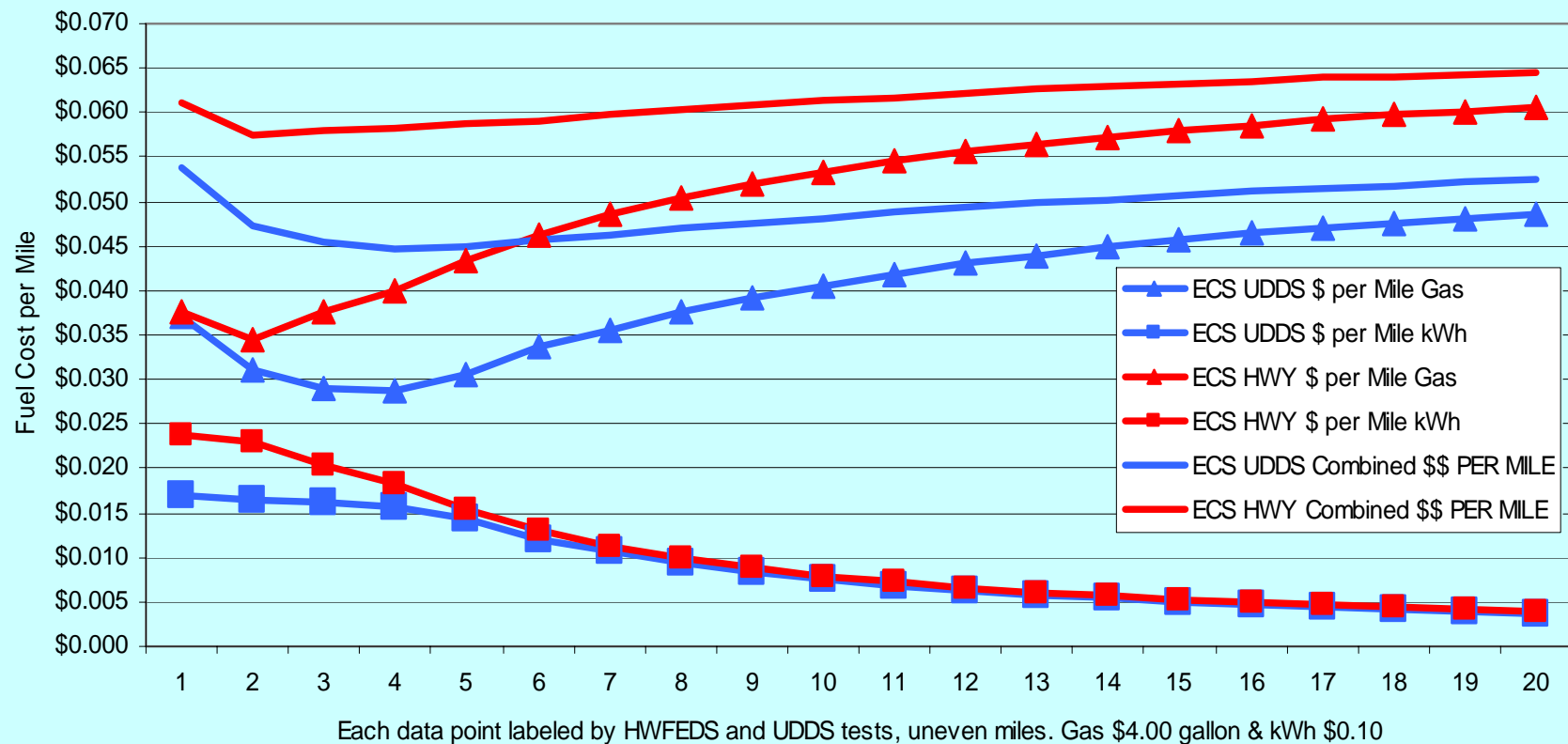
Electrovaya Escape – Accelerated Testing

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			
40	4	0	12	15	600	71.3	16.42	37.3
40	2	2	12	15	600	69.8	14.34	43.1
40	0	4	12	15	600			
60	2	4	12	10	600			
80	2	6	12	8	640			
100	2	8	12	6	600			
200	2	18	12	3	600			
Total	2340	3100	1344	162	5440	Weighted Average		

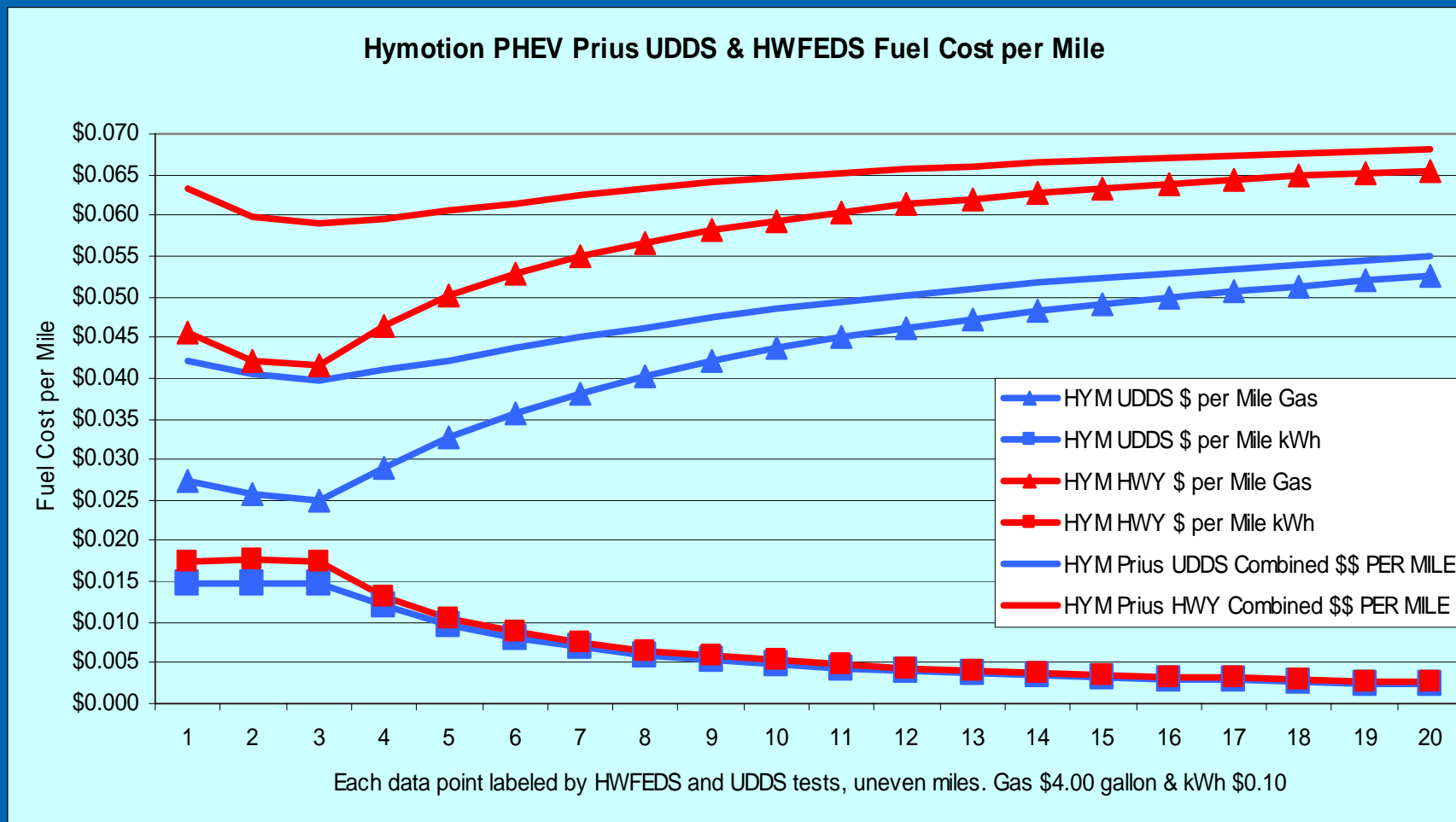
Each total distance slightly greater than 600 miles. HEV version = 27 mpg

EnergyCS Prius – Fuel Costs

EnergyCS PHEV Prius UDDS & HWFEDS Fuel Cost per Mile



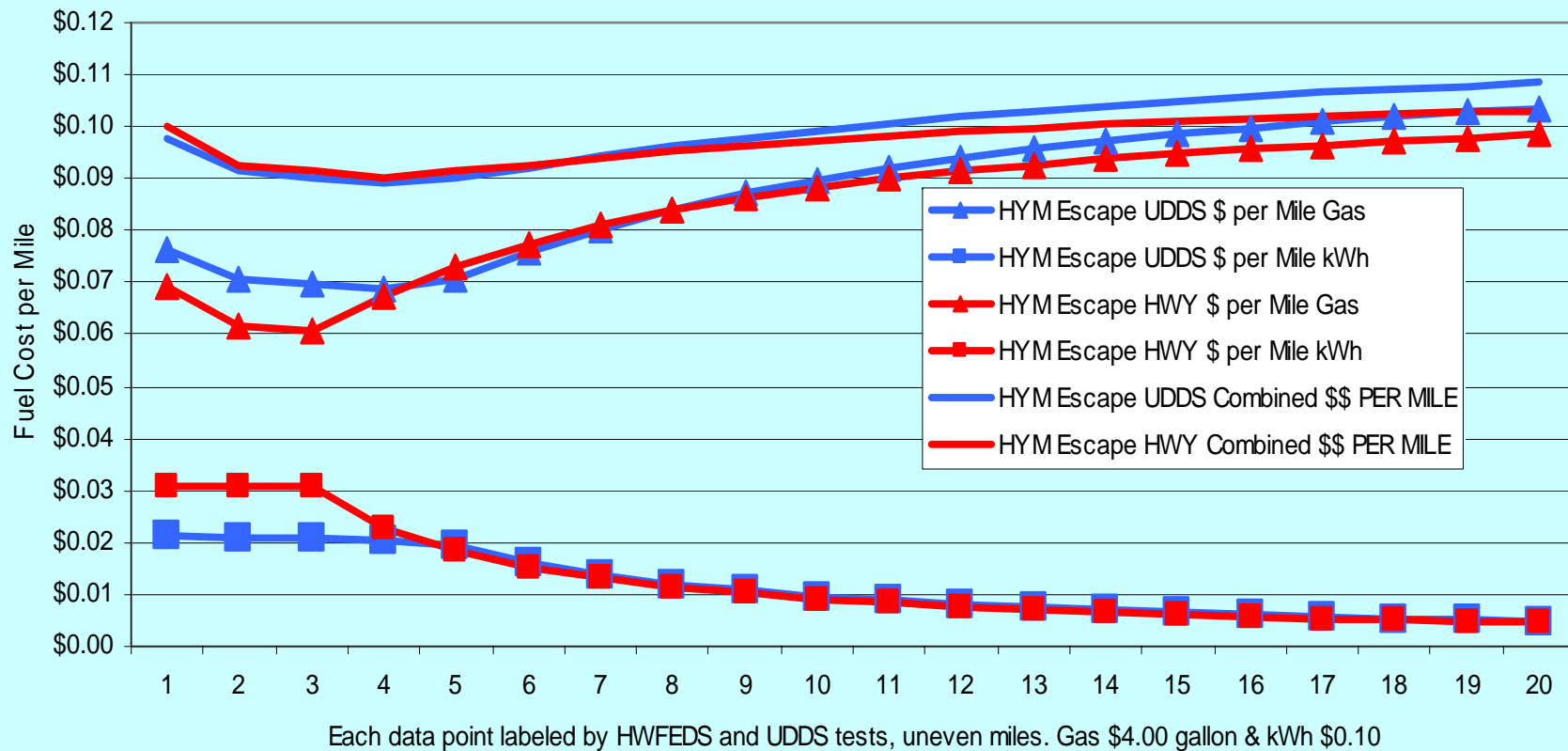
Hymotion Prius – Fuel Costs





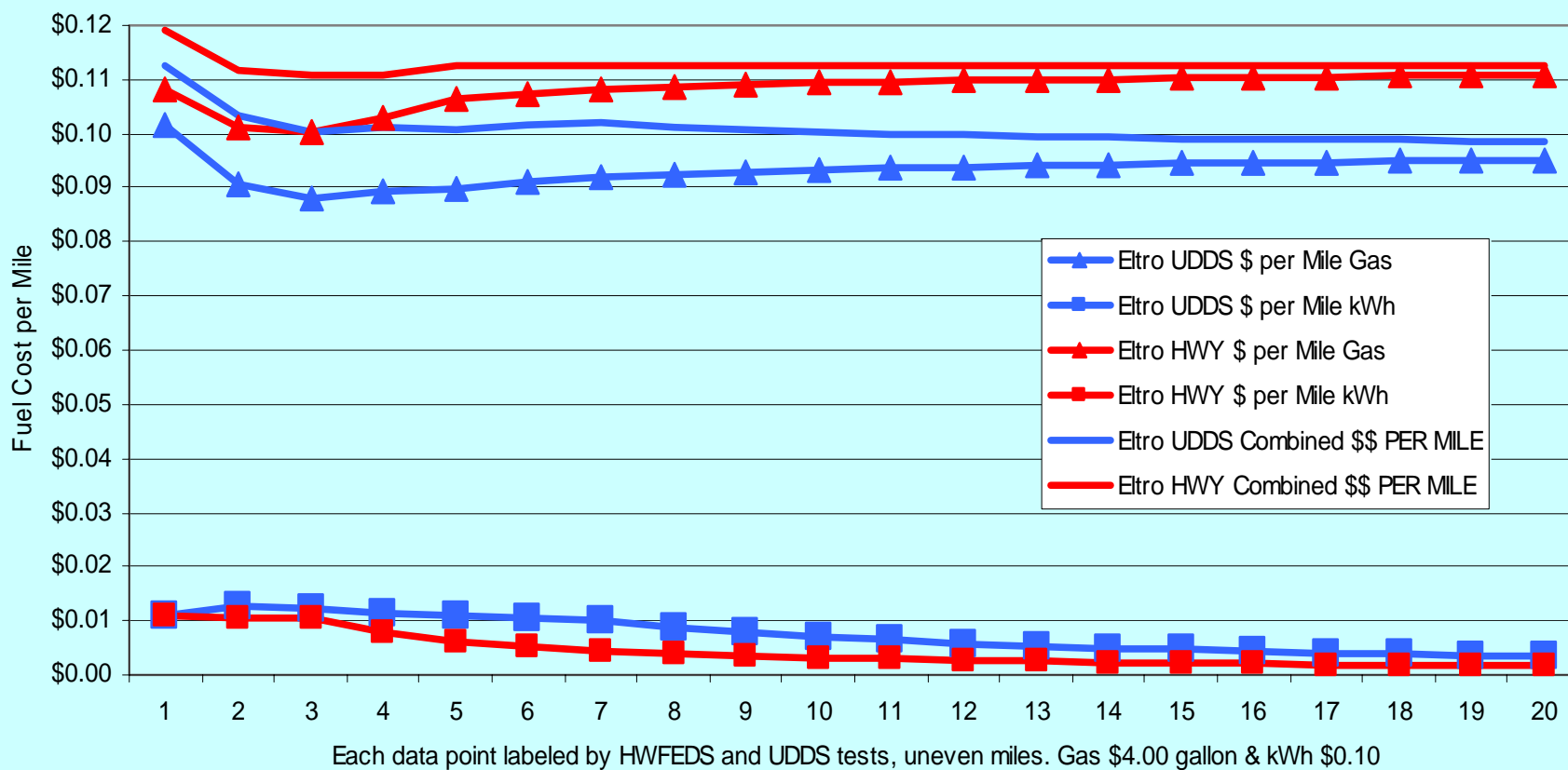
Hymotion Escape – Fuel Costs

Hymotion PHEV Escape UDDS & HWFEDS Fuel Cost per Mile



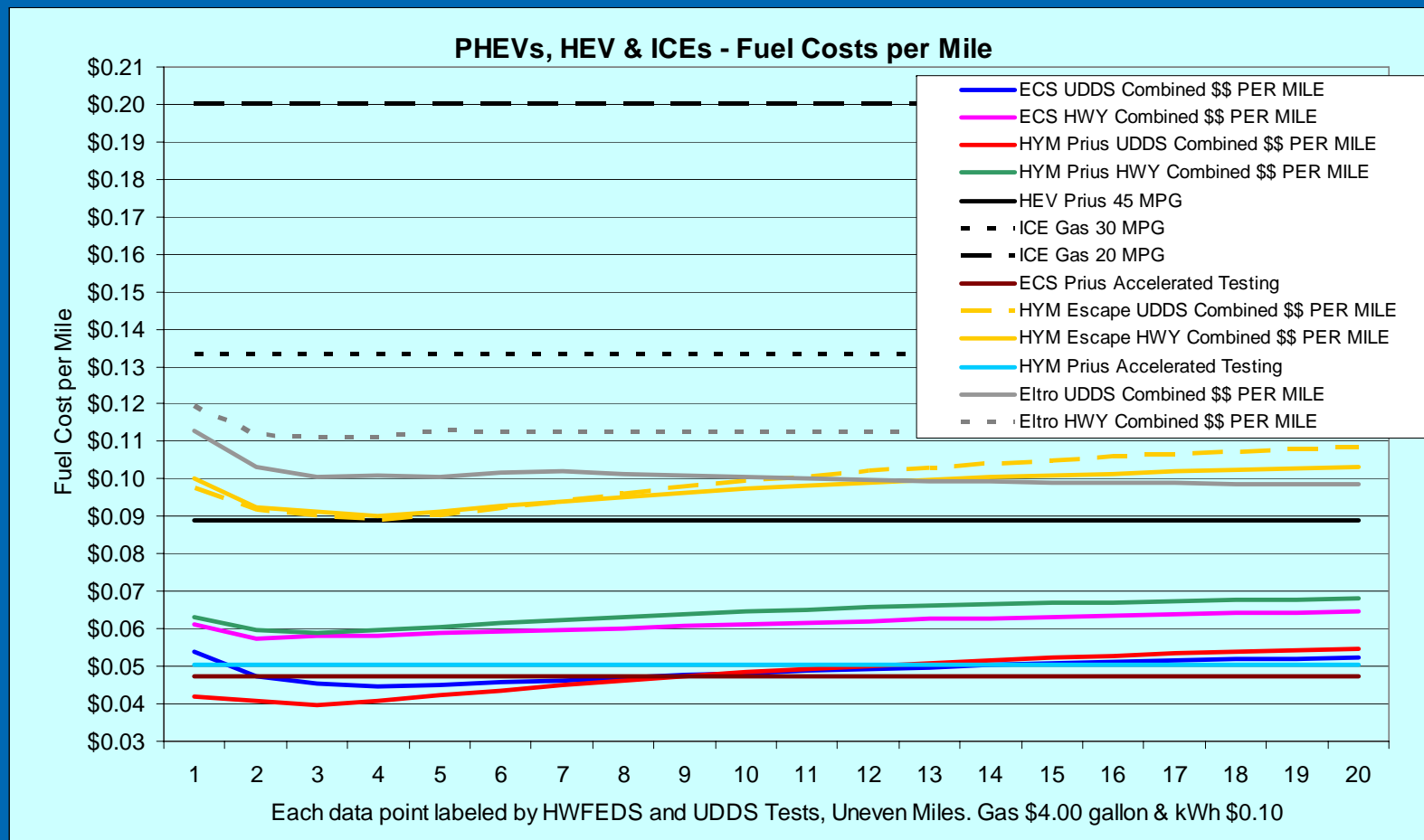
Electrovaya Escape – Fuel Costs

Electrovaya PHEV Escape UDDS & HWFEDS Fuel Cost per Mile





PHEV Vs. HEV and ICE Fuel Costs per Mile





Onroad Demonstration Partners and Fleet Data Collection Activities





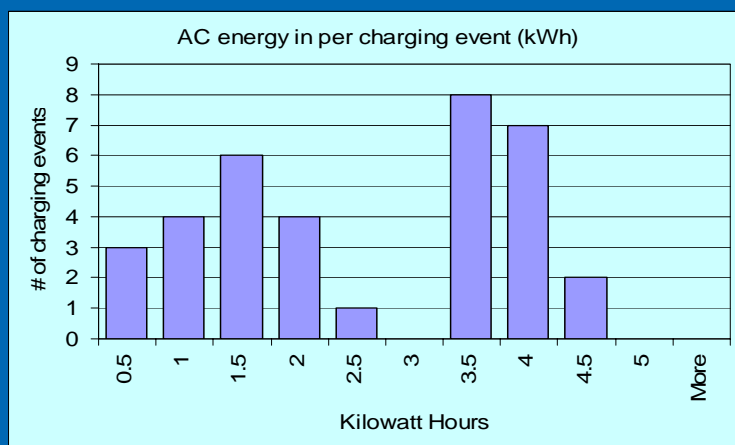
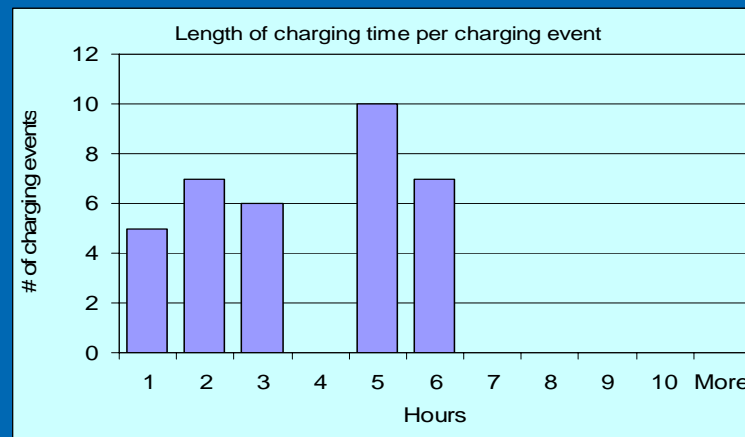
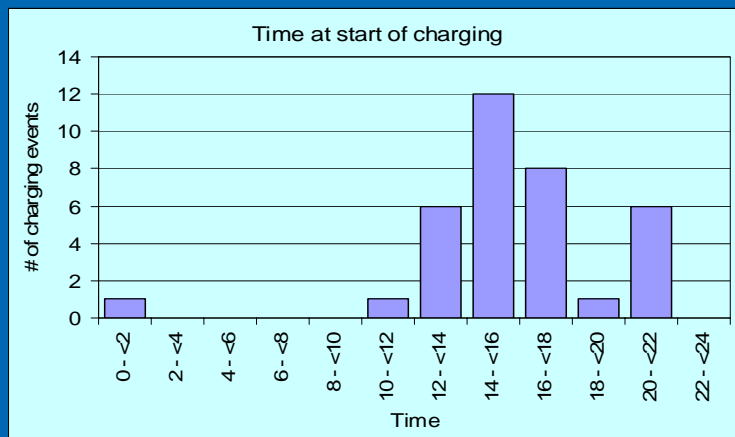
Hymotion Joint Data Collection

- Kvaser data loggers installed 50 PHEVs North America
- Onboard data includes vehicle performance, fuel use, and charging and driving profiles
- Participants include electric utilities, water agencies, universities, county and provincial governments:
 - Northeast: Vermont, New Hampshire, New York
 - East / South East: Toronto, Virginia, South Carolina, North Carolina, Kentucky, Florida
 - North / Central: Wisconsin, North Dakota, Indiana, Manitoba
 - Southwest: Arizona, Texas
 - West Coast: California, Oregon
- Started 2007



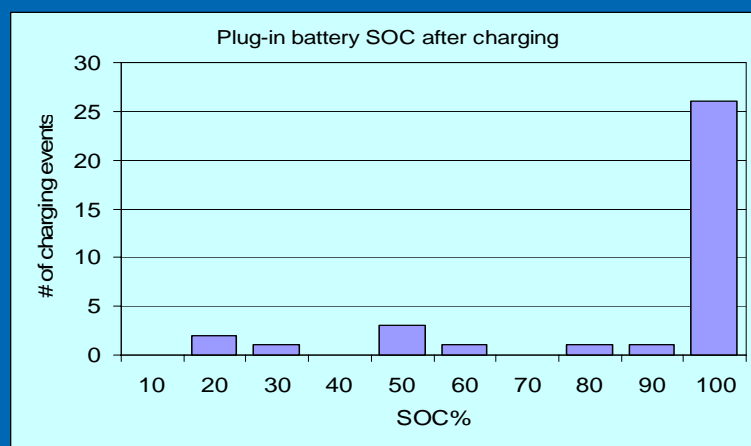
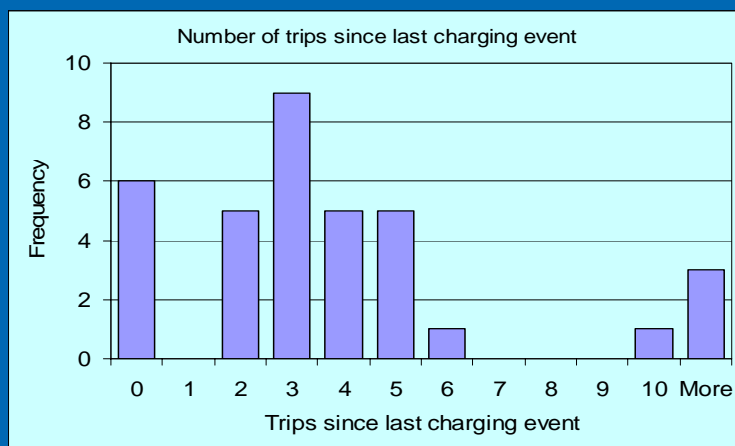
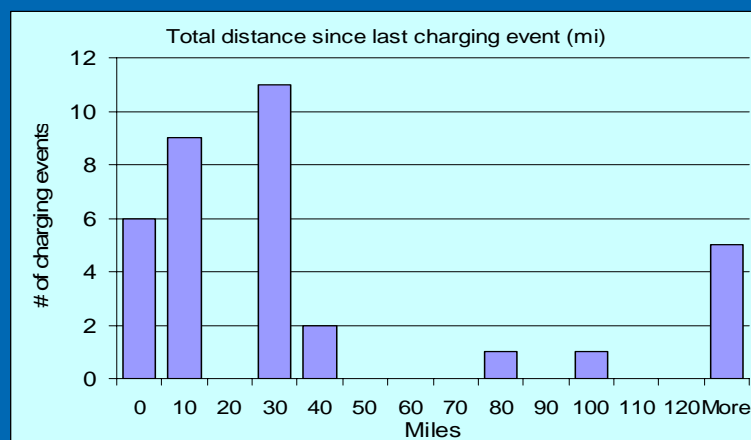
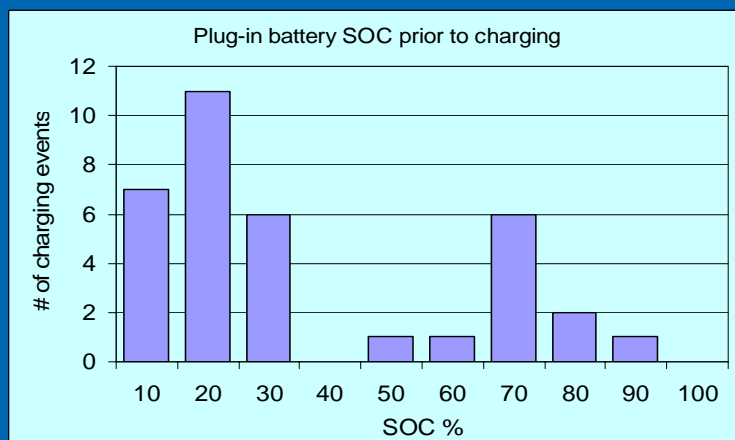
Single Hymotion Prius Charging Profiles

- 3 months, 2212 miles, 35 charges



Single Hymotion Prius Charging Profiles

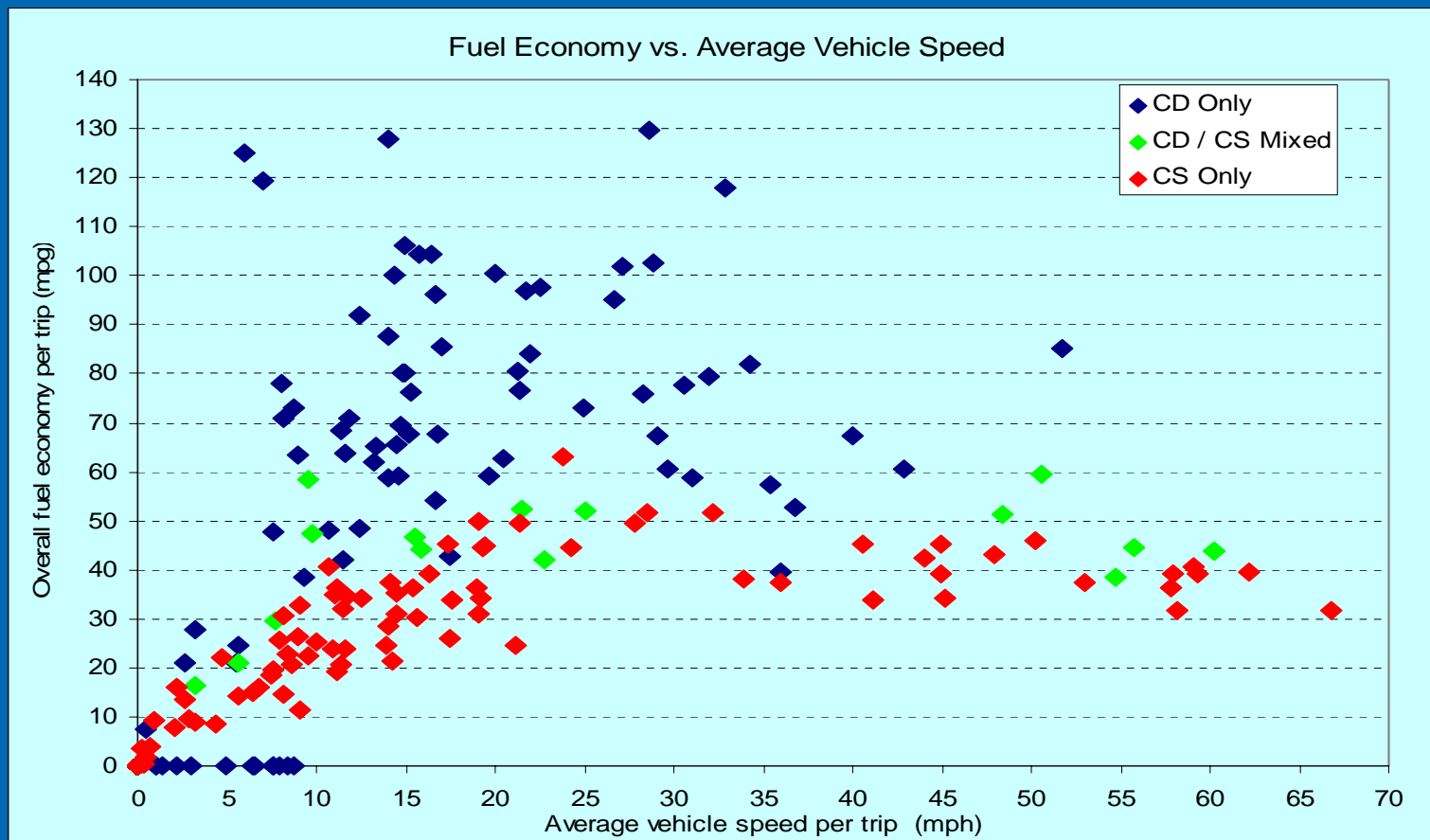
- 3 months, 2212 miles, 35 charges





Single Hymotion Prius MPG Vs. Speed

- 3 months, 2212 miles

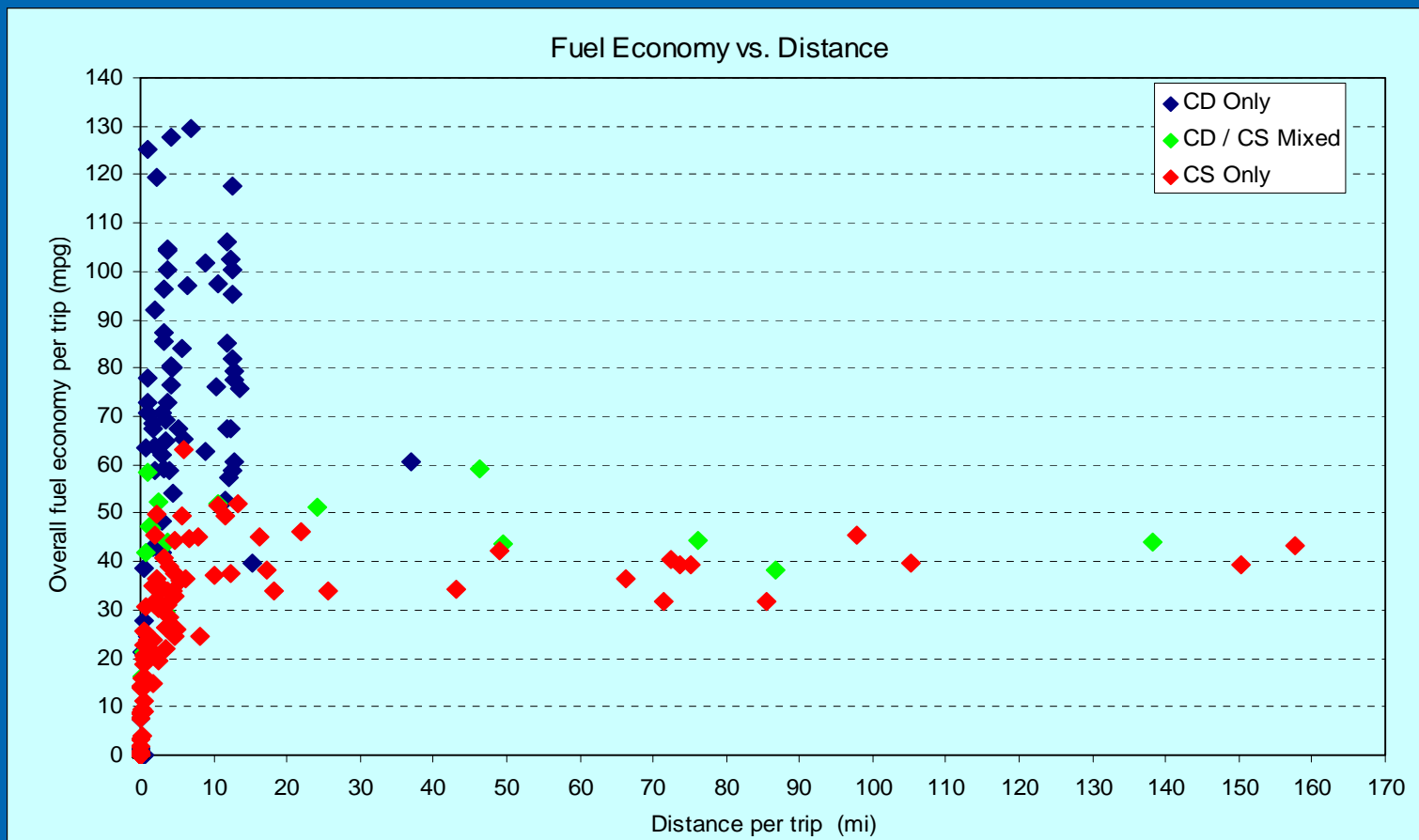


CD – charge depleting, S - sustaining



Single Hymotion Prius MPG Vs. Trip Distance

- 3 months, 2212 miles



CD – charge depleting, S - sustaining



26 Hymotion Prius - January thru May 2008

- Below averages do NOT tell the whole PHEV energy-use potential – see following May only slides

Charge / Operating Mode	Number of Trips	Distance Traveled (Miles)	Miles per Gallon)
Charge Depleting (CD)	3,073	14,820	59
Mixed CD / CS	404	11,121	49
Charge Sustaining (CS)	1,358	16,059	40
All trips combined	4,835	42,000	48





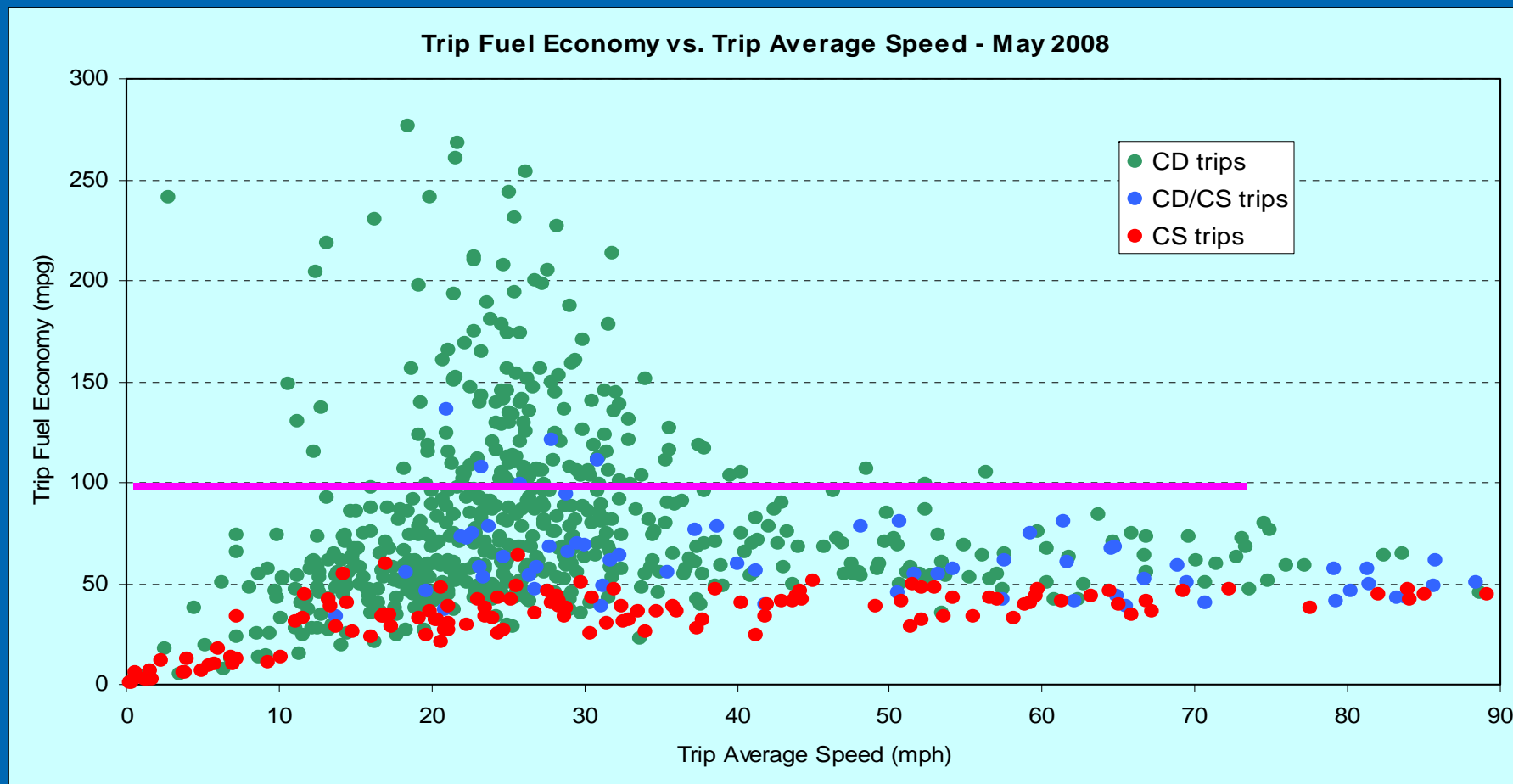
13 Hymotion Prius in May 2008 - MPG

- Below averages do NOT tell the whole PHEV energy use potential – see next 3 slides

Charge / Operating Mode	Number of Trips	Total Distance (Miles)	Average Trip Distance (miles)	MPG	DC kWh per Mile
Charge Depleting (CD)	575	3,040	5.3	72.0	0.138
Mixed CD / CS	67	1,840	27.5	52.1	0.050
Charge Sustaining (CS)	133	1,411	10.6	40.2	
Electric vehicle only (EV)	137	127	0.9		0.236
Total	912	6,417	7.0		
CD, CS, CD/CS results (excludes EV results)	775	6,291	8.1	55.9	

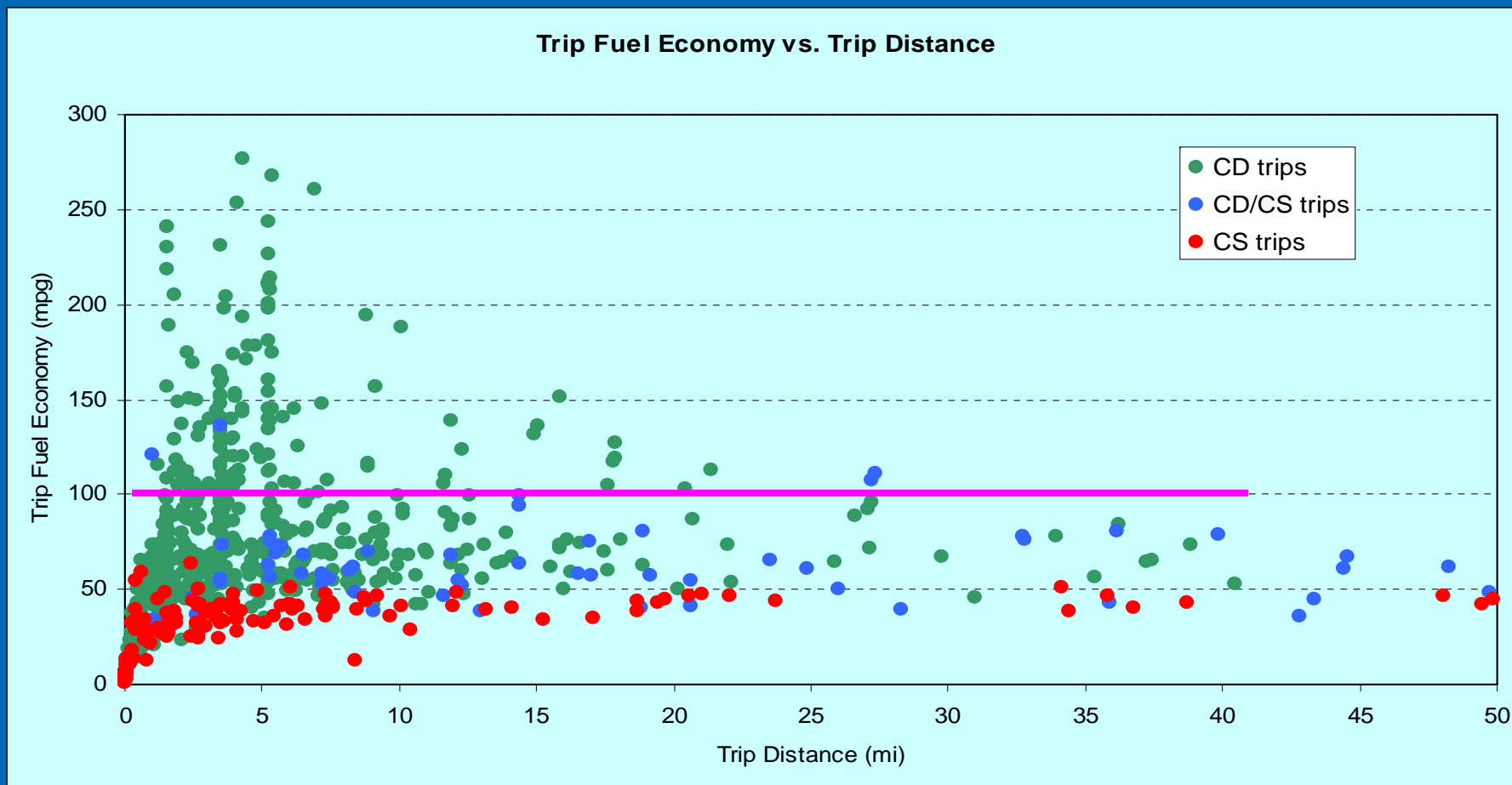


13 Hymotion Prius MPG Vs. Speed





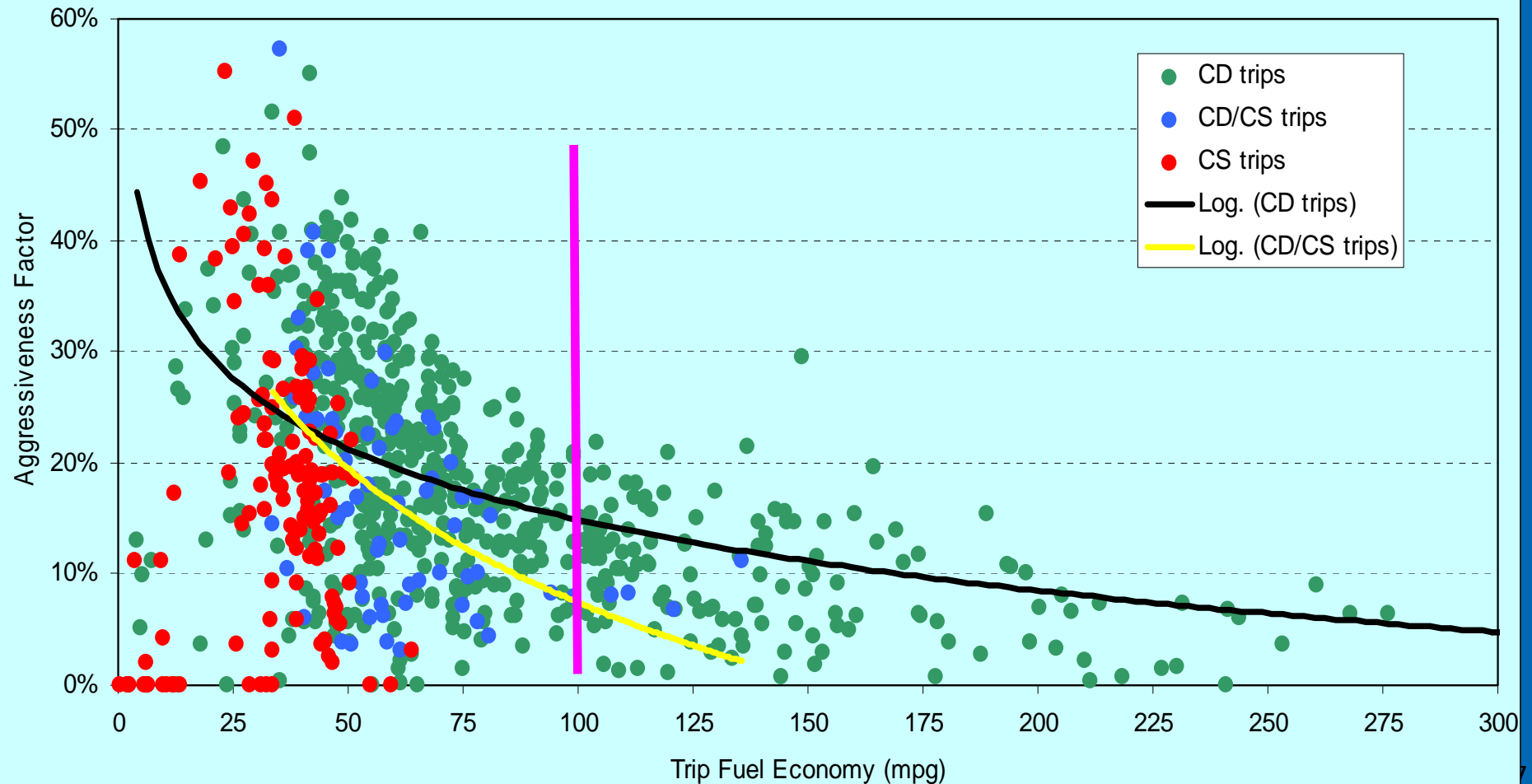
13 Hymotion Prius MPG Vs. Distance





13 Hymotion Prius and Aggressive Driving

MPG vs. Trip Aggressiveness (Percent of time above the 40% accelerator pedal position)



NYSERDA

- AVTA is testing New York State Energy Research and Development Agency's PHEV conversions, stated 2007

Model	Baseline Testing	Accelerated Testing
EnergyCS Prius	Completed	Near completion, restarted
Hymotion Prius	Completed	Completed
Hymotion Escape	Completed	Ongoing
Electrovaya Escape	Completed (problems)	Restarted
HybridsPlus Escape	Not started	Suspended

- Fleet testing of ~20 PHEVs later CY08





Fleet Demonstration Partners

- **Seattle-area, using 13 Hymotion Prius with:**
 - City of Seattle (4)
 - King County (4)
 - Port of Seattle (2)
 - Puget Sound Clean Air Agency (3)
 - Started 4/2008, 4 converted to date
- **Tacoma Power**
 - 2 current Green Car Company lead acid Prius
 - 2 Hymotion Prius adding
- **Going forward, these and all other demonstration PHEVs are using V2Green onboard data loggers with cellular data transfer and GPS**





Fleet Demonstration Partners – cont'd

- Washington State-wide, Port of Chelan lead, with 14 Hymotion Prius with:
 - Benton County PUD, Chelan County Public Works, City of Wenatchee, Douglas County PUD, Energy Northwest, Green IT Alliance, McKinstry, Port of Chelan, University of Washington, Walla Walla Community College and Wenatchee Valley College
 - Started 4/2008, 1 converted to date
- University of California Davis, with 13 Hymotion Prius
 - Up to 70 AAA of California public drivers will each operate a vehicle for ~2 months
 - First study of public use of PHEVs, charging practices and locations, started April 2008, 7 vehicles converted



Fleet Demonstration Partners – cont'd

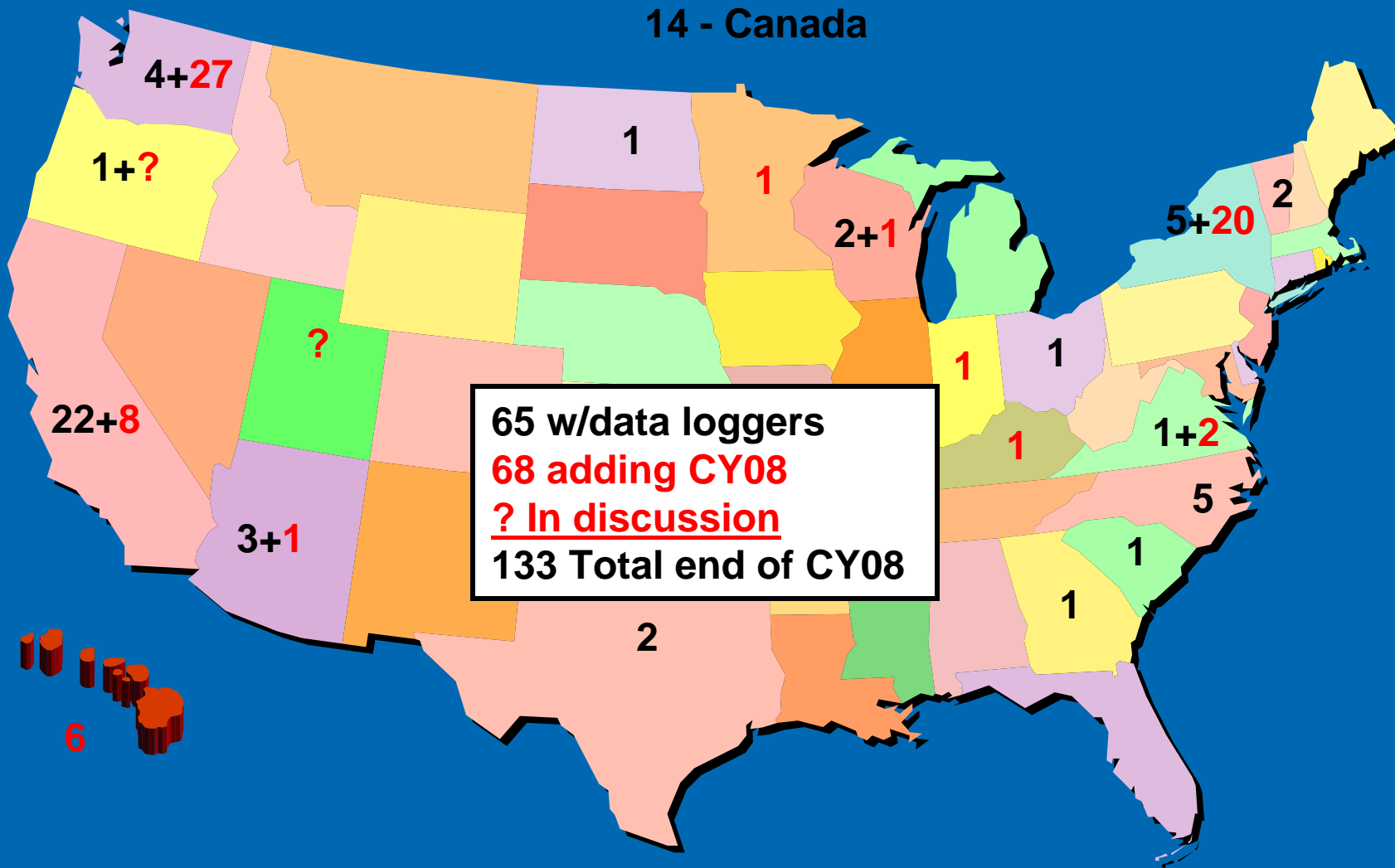
- **National Rural Electric Cooperative Association**
 - Total of ten Prius and Escape PHEVs from Hymotion, EnergyCS, and Hybrids Plus operated by rural electric coop utilities, 6 converted to date, started 2007
 - Includes: Jackson Electric Membership Coop (GA), Salem Electric (OR), Four County Electric Membership Corp. (NC), Central Electric Power Coop (SC), Great River Electric (MN), and Buckeye Rural Electric Coop (OH)
- **Hawaii demonstration with 6 Hymotion Prius on Maui and Oahu**
 - State of Hawaii, University of Hawaii, Hawaiian Electric Company, Maui Electric Company, Maui County, U.S. Air Force. Planned start 11/2008





Total PHEV Demonstrations

14 - Canada





Charging Infrastructure

- National Electric Code requires
 - Dedicated branch circuit
 - GFCI (ground fault circuit interrupt)
 - “EV” extension cord
 - Unique connector “plug”





Other PHEV Testing

- Ford E85 Escape PHEV demonstration, started 6/2008
- Hymotion Prius with A123Systems V2 battery – conduct vehicle/battery testing, summer 2008
- PHEV charging at commercial facility studies - collecting data on PHEVs and commercial facilities to document energy profiles of recharging PHEVs as portion of facility profiles. Started 5/2008
- Defining time-of-day demand charging demonstration and battery analysis impacts on 13 PHEVs in Seattle





Other PHEV Testing – cont'd

- Defining bidirectional vehicle-to-grid (V2G) charging study with electric utilities participating
 - 6 kW and 20 kW levels, using two lithium battery PHEVs, cellular charging control, documenting infrastructure requirements and costs
- Daimler PHEV Sprinter – conduct vehicle/battery testing, start Fall 2008
- Conduct vehicle/battery testing on PHEVs when received via DOE's original equipment manufacture's PHEV solicitation
- Consider other PHEV conversions for vehicle/battery testing



Acknowledgement

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Energy's Vehicle Technologies Program**

Tien Duong, Lee Slezak and Ro Sullivan

Additional Information

<http://avt.inl.gov>

or

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

INL/CON-08-14506