



Idaho National Laboratory

U.S. DOE Advanced Vehicle Testing Activity

National PHEV Fleet Testing and Demonstration Activities

Jim Francfort
Beyond Oil: Transforming Transportation
Redmond, Washington
September 2008

AVTA Background and Goal

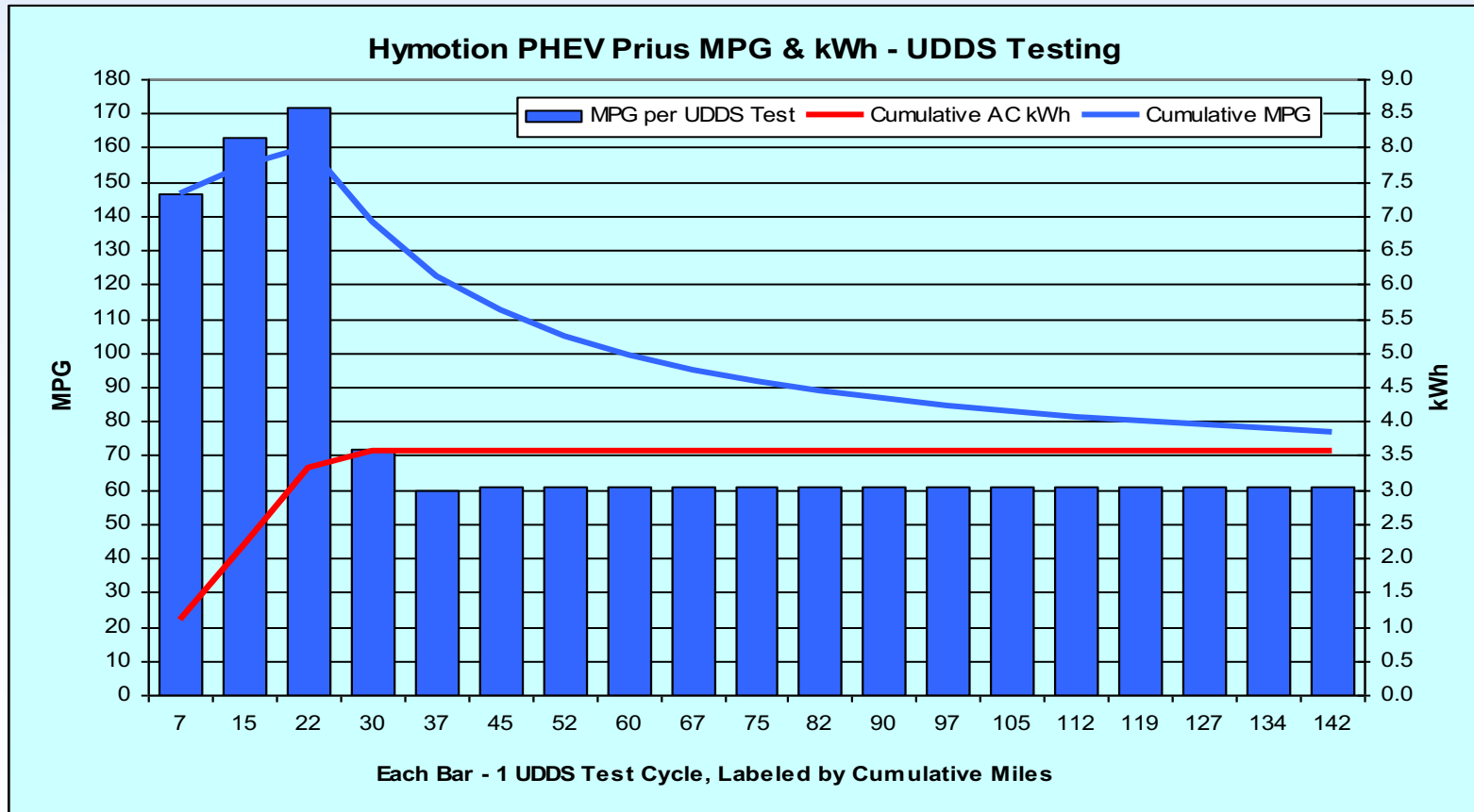
- **The Advanced Vehicle Testing Activity (AVTA) is part of DOE's Vehicle Technologies Program**
- **The AVTA is primarily conducted by the Idaho National Laboratory (INL) and Electric Transportation Engineering Corporation (ETEC - Phoenix, AZ), and Argonne National Laboratory performs dynamometer testing**
- **AVTA Goal / Data Audience**
 - **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**

PHEV Questions

- Are PHEVs technically and economically feasible as a transportation option?
- What are the petroleum savings and electricity demands?
- Will fleets and the public adapt to plugging in (charging) PHEVs to maximize mpg?
- Is a two-fuel scenario a difficult transition?
- What are the charging infrastructure needs, including 110V versus 220V? Fast charging?
- V2Grid – economic benefit or liability to the vehicle operator?
- Are there societal and economic issues and benefits?
- To answer these questions, the AVTA is testing and field demonstrating nine different PHEV models and charging infrastructure

Hymotion Prius – UDDS Fuel Use

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



Hymotion Prius – Accelerated Testing

| Cycle | Urban | Highway | Charge | Reps | Total | Electricity | Gasoline | |
|--------------|-------------|-------------|-------------|------------|--------------|-------------------------|----------|-------------|
| (mi) | (10 mi) | (10 mi) | (hr) | (N) | (mi) | AC 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

EnergyCS Prius – Accelerated Testing

| Cycle | Urban | Highway | Charge | Reps | Total | Electricity | Gasoline | |
|--------------|-------------|-------------|-------------|------------|-------------|-------------------------|----------|-------------|
| (mi) | (10 mi) | (10 mi) | (hr) | (N) | (mi) | AC 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 rerun. Each total distance slightly greater than 600 miles. HEV version = 44 mpg

Hymotion Escape – Accelerated Testing

| Cycle | Urban | Highway | Charge | Reps | Total | Electricity | Gasoline | |
|--------------|-------------|-------------|-------------|------------|-------------|-------------------------|----------|------|
| (mi) | (10 mi) | (10 mi) | (hr) | (N) | (mi) | AC kWh | Gals | MPG |
| 10 | 1 | 0 | 4 | 60 | 600 | | | |
| 20 | 1 | 1 | 8 | 30 | 600 | In | testing | |
| 40 | 4 | 0 | 12 | 15 | 600 | 57.51 | 14.91 | 41.1 |
| 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 | 26.09 | 17.72 | 33.5 |
| 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 (mi) | Urban (10 mi) | Highway (10 mi) | Charge (hr) | Reps (N) | Total (mi) | Electricity AC kWh | Gasoline | |
|---------------|------------------|--------------------|----------------|-------------|---------------|-------------------------|----------|------|
| | | | | | | | 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 | In | testing | |
| 60 | 2 | 4 | 12 | 10 | 600 | 44.79 | 16.64 | 37.3 |
| 80 | 2 | 6 | 12 | 8 | 640 | 42.72 | 16.30 | 40.8 |
| 100 | 2 | 8 | 12 | 6 | 600 | 20.85 | 21.17 | 29.2 |
| 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

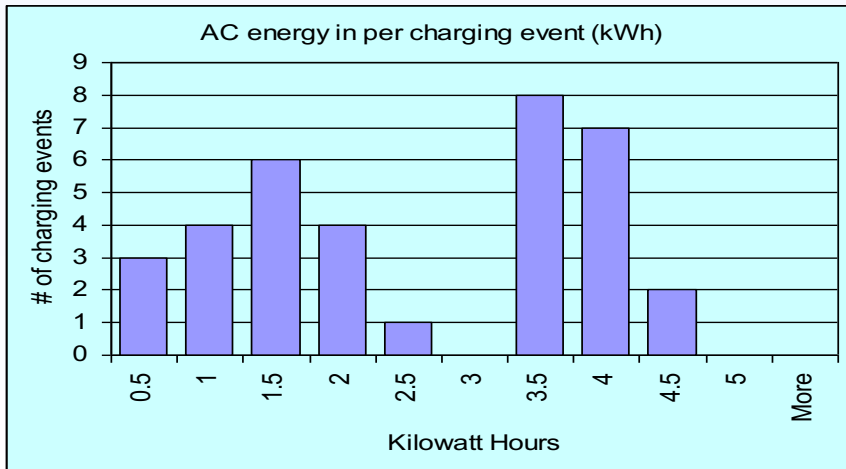
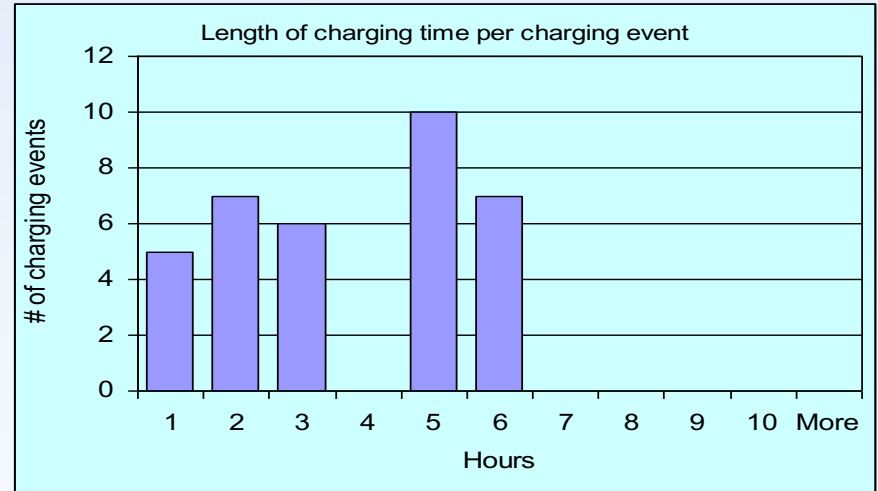
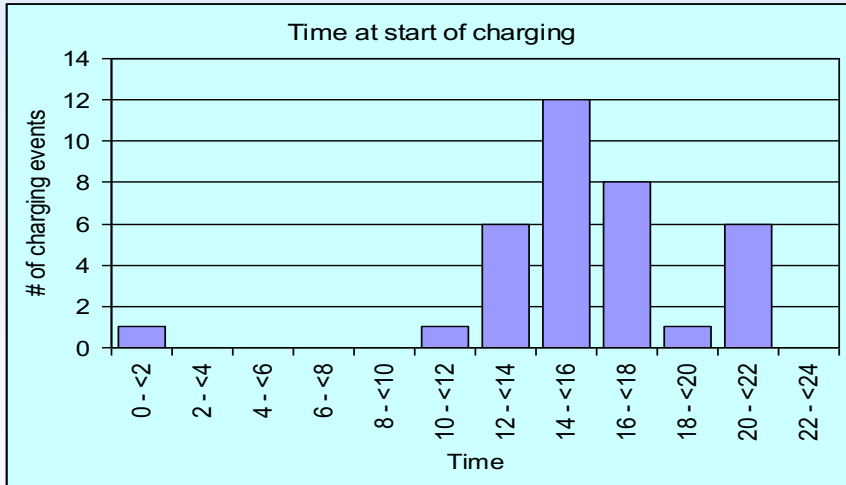
Hymotion/A123Systems Joint Data Collection

- Kvaser data loggers installed on 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



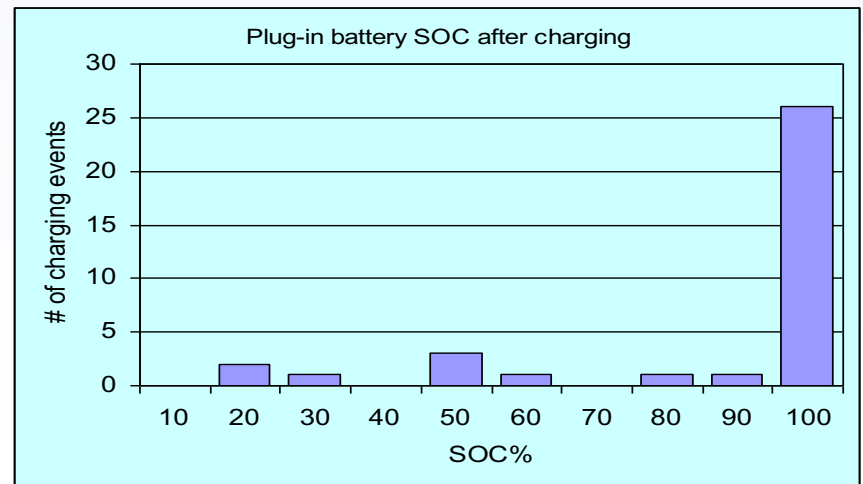
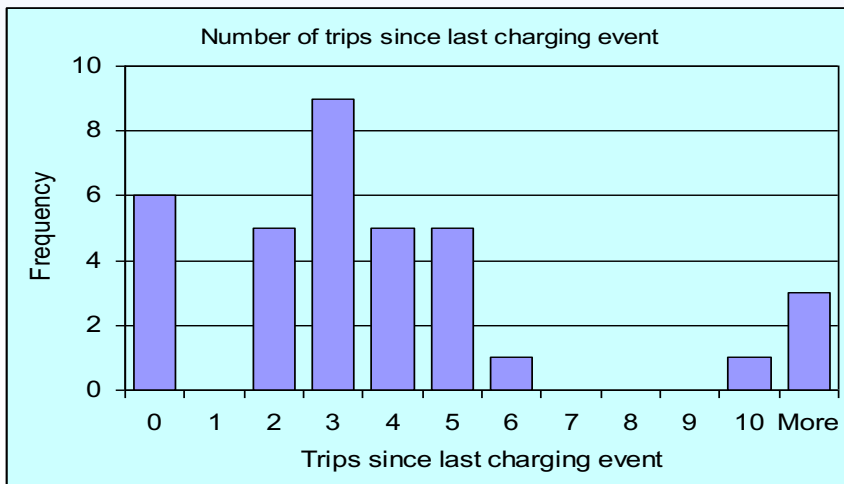
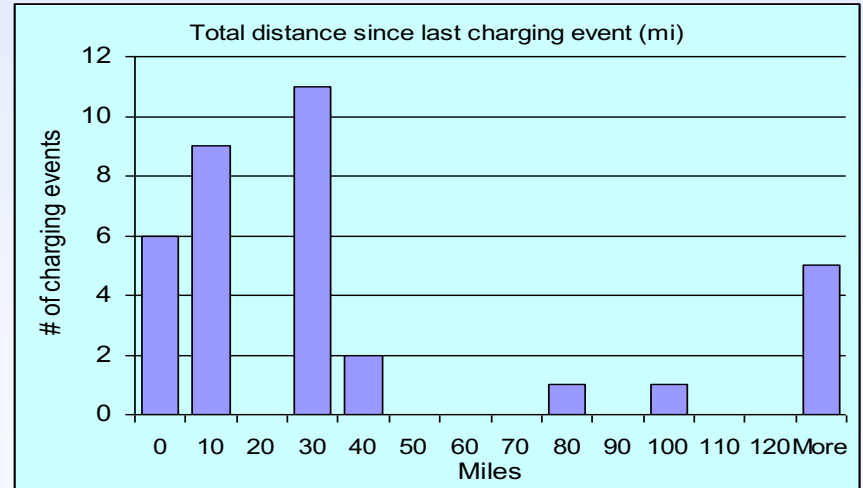
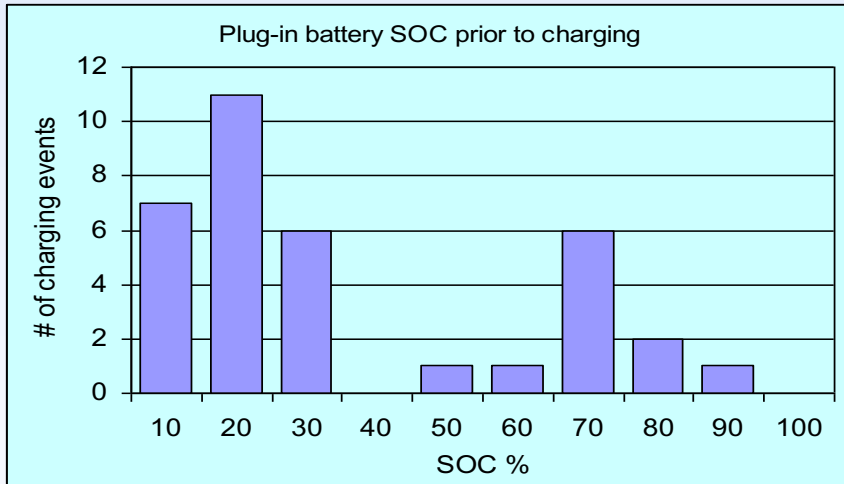
Single Hymotion Prius Charging Profiles

- 3 months, 2212 miles, 35 charges



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- 3 months, 2212 miles, 35 charges



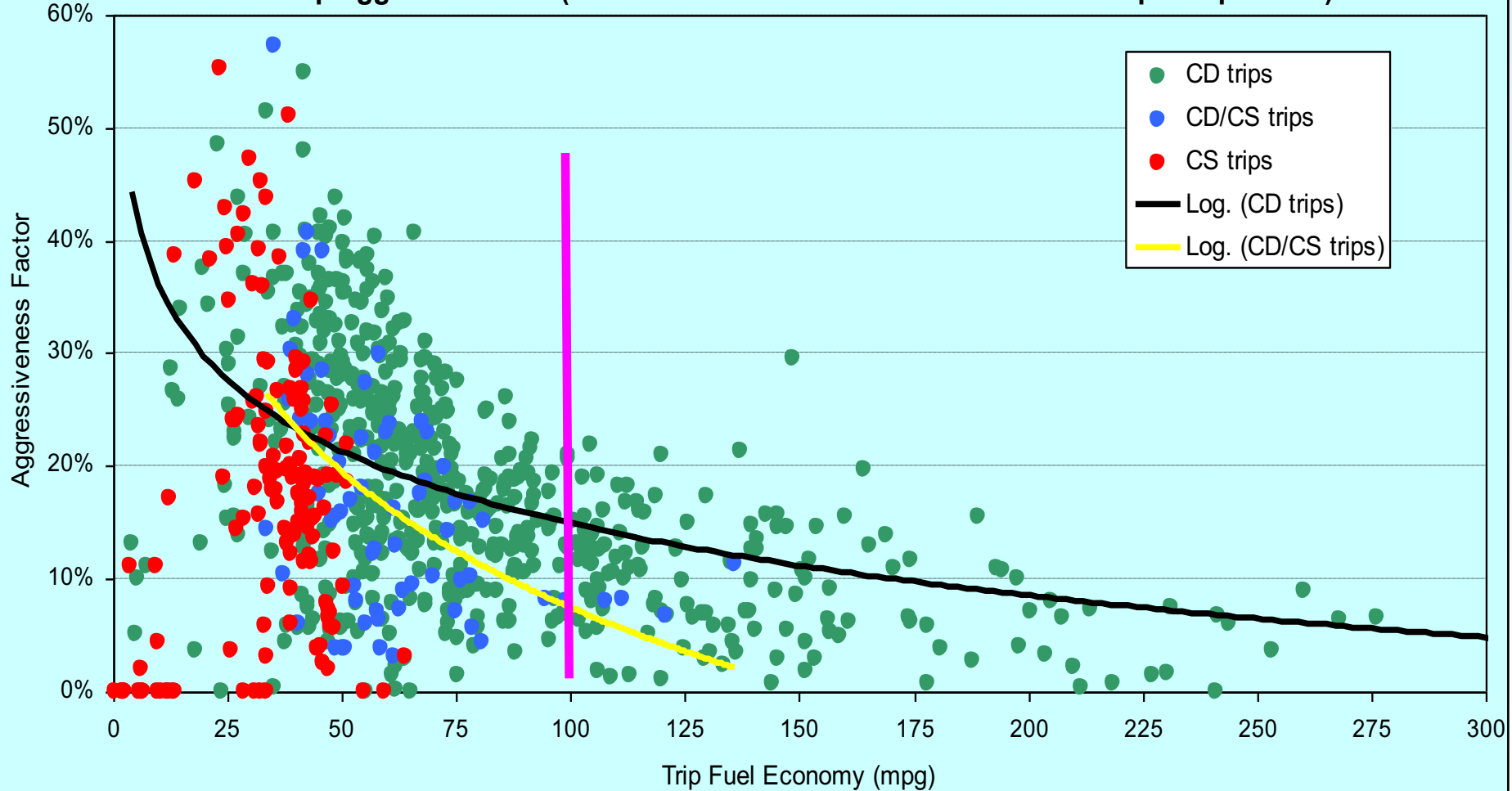
13 Hymotion Prius in May 2008 - MPG

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

| 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 and Aggressive Driving

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



NYSERDA Testing Partnership

- AVTA is testing New York State Energy Research and Development Agency's PHEV conversions, stated 2007
- Fleet testing of ~20 PHEVs later CY08

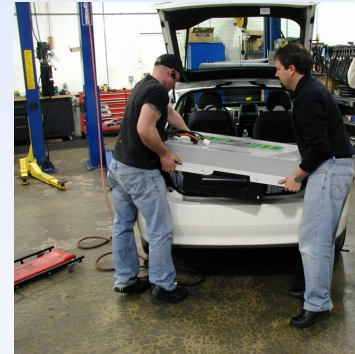
| Model | Baseline Testing | Accelerated Testing |
|--------------------|----------------------|----------------------------|
| EnergyCS Prius | Completed | Near completion, restarted |
| Hymotion Prius | Completed | Completed |
| Hymotion Escape | Completed | Ongoing |
| Electovaya Escape | Completed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



Seattle Area Demonstration

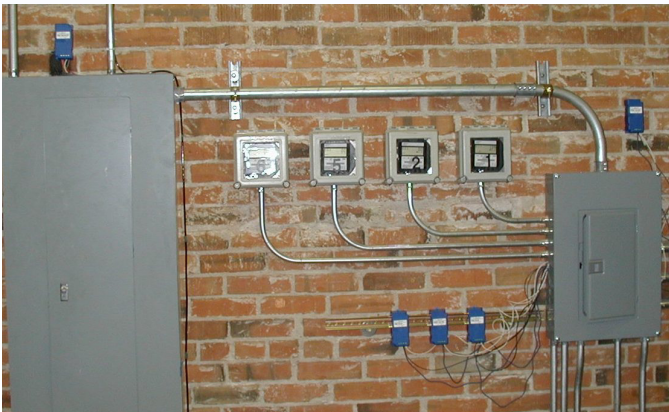


- **13 Hymotion Prius operations in partnership with:**
 - **City of Seattle (4)**
 - **King County (4)**
 - **Port of Seattle (2)**
 - **Puget Sound Clean Air Agency (3)**
 - **Started 4/2008, five vehicles converted to date**
- **City of Seattle lead time-of-day charging demonstration on above 13 Seattle area PHEVs. Includes INL battery impact analysis. Uses V2Green wireless charging control**
- **These and all future demonstration PHEVs are using V2Green onboard data loggers with cellular data transfer and GPS**



Tacoma Power Demonstration

- **Vehicle demonstration with data loggers using:**
 - **2 Manzanita lead acid Prius, 1st quarter 2008**
 - **2 Hymotion Prius adding late 2008**
- **Charging infrastructure study**
 - **After 4 PHEVs in operation, collect data on one section of administration building (800 amp, 480 volt, 3 phase load) and PHEV charging infrastructure**
 - **Document demand and energy profiles of PHEV charging as portion of facility profiles**
 - **WiFi local energy meter (LEM) data collection system**



Fleet Demonstration Partners – cont'd

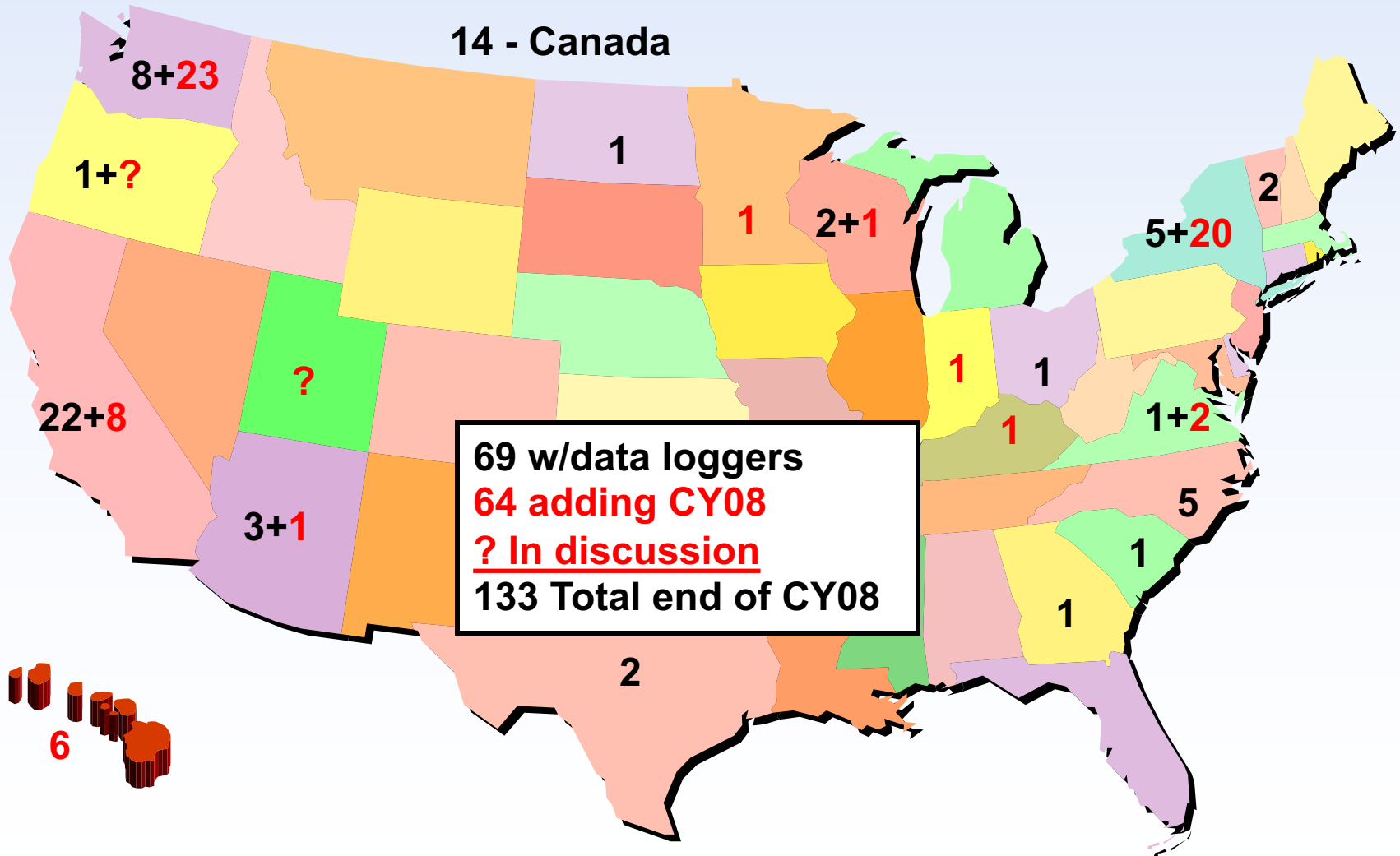
- **Washington State-wide, Port of Chelan leading, with 14 Hymotion Prius with:**
 - **Benton County PUD, Chelan County Public Works, City of Wenatchee, Douglas County PUD, Energy Northwest, Green IT Alliance, McKinstry, Port of Chelan, University of Washington, Walla Walla Community College and Wenatchee Valley College**
 - **Started 4/2008, 1 converted to date, more Sept. 2008**
- **University of California Davis, with 12 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 to date**

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, 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

PHEV Demonstrations: 20 States/Provinces



Other PHEV Testing

- **Hymotion/A123Systems V2 Prius battery hot weather vehicle/battery testing, summer 2008**
- **PHEV charging studies at three commercial facilities with PHEV charging (Tacoma Power is one). Started 5/2008**
- **Bidirectional vehicle-to-grid (V2G) charging study with electric utilities participating. Fall 2008**
 - **6 kW and 20 kW levels, using two lithium battery PHEVs, V2Green cellular charging control, documenting infrastructure requirements and costs**
- **Ford E85 Escape PHEV demonstration, started 6/2008**
- **Daimler PHEV Sprinter testing. Start spring 2009**
- **Conduct vehicle/battery testing on PHEVs when received via DOE's OEM PHEV solicitation**
- **Will consider other suitable PHEV conversions for vehicle/battery testing**

Acknowledgement

This work is supported by the U.S. Department of Energy's Vehicle Technologies Program:
Pat Davis, Tien Duong, Lee Slezak and Ro Sullivan

Additional Information

<http://avt.inl.gov>

or

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

INL/CON-08-14724