

Idaho National Laboratory

U.S. Department of Energy - Vehicle Technologies Program

Advanced Vehicle Testing Activity - PHEV Testing Results and Fleet Demonstrations

Jim Francfort

**PHEV Workshop
Alternative Fuels & Vehicles
Las Vegas, Nevada – May 2008**

This presentation does not contain any proprietary or sensitive information

Presentation Outline

- **Background - Idaho National Laboratory and DOE's Advanced Vehicle Testing Activity**
- **Testing history and objectives**
- **Baseline performance and accelerated onroad testing**
 - **Testing methods**
 - **Testing results**
- **Fleet demonstrations**
 - **Partners**
 - **Testing results**
- **Charging infrastructure examples**
- **Other PHEV testing activities**

Idaho National Laboratory

- Eastern Idaho based U.S. Department of Energy (DOE) multi-program laboratory
- 890 square mile site with 3,600 staff
- Support DOE's strategic goal:
 - Increase U.S. energy security and reduce the nation's dependence on foreign oil

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 Applications (ETA - Phoenix, AZ), with Argonne National Laboratory performing dynamometer testing
- AVTA Goal
 - 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 Testing History

- Hybrid electric vehicles
 - 14 models, 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 in track, laboratory and onroad environments
- Document battery life, charging patterns and demand profiles, vehicle operations, and fuel use (both gasoline and electricity)
- Document PHEV infrastructure requirements and costs in real-world environments
- Document life-cycle costs

PHEV Baseline Performance Testing

- Initial track testing conducted by ETA near Phoenix
 - Testing includes coastdown (determination of dynamometer coefficients), acceleration, top speed, charging, and durability
- Five day dynamometer testing regime performed at Argonne
 - Testing includes at least 26 drive cycle tests
 - Charge depleting and charge sustaining test cycles
 - UDDS (Urban Dynamometer Driving Schedule) and HWFEDS (Highway Fuel Economy Driving Schedule) dynamometer test cycles
 - Includes air conditioning (AC) off and on cycles

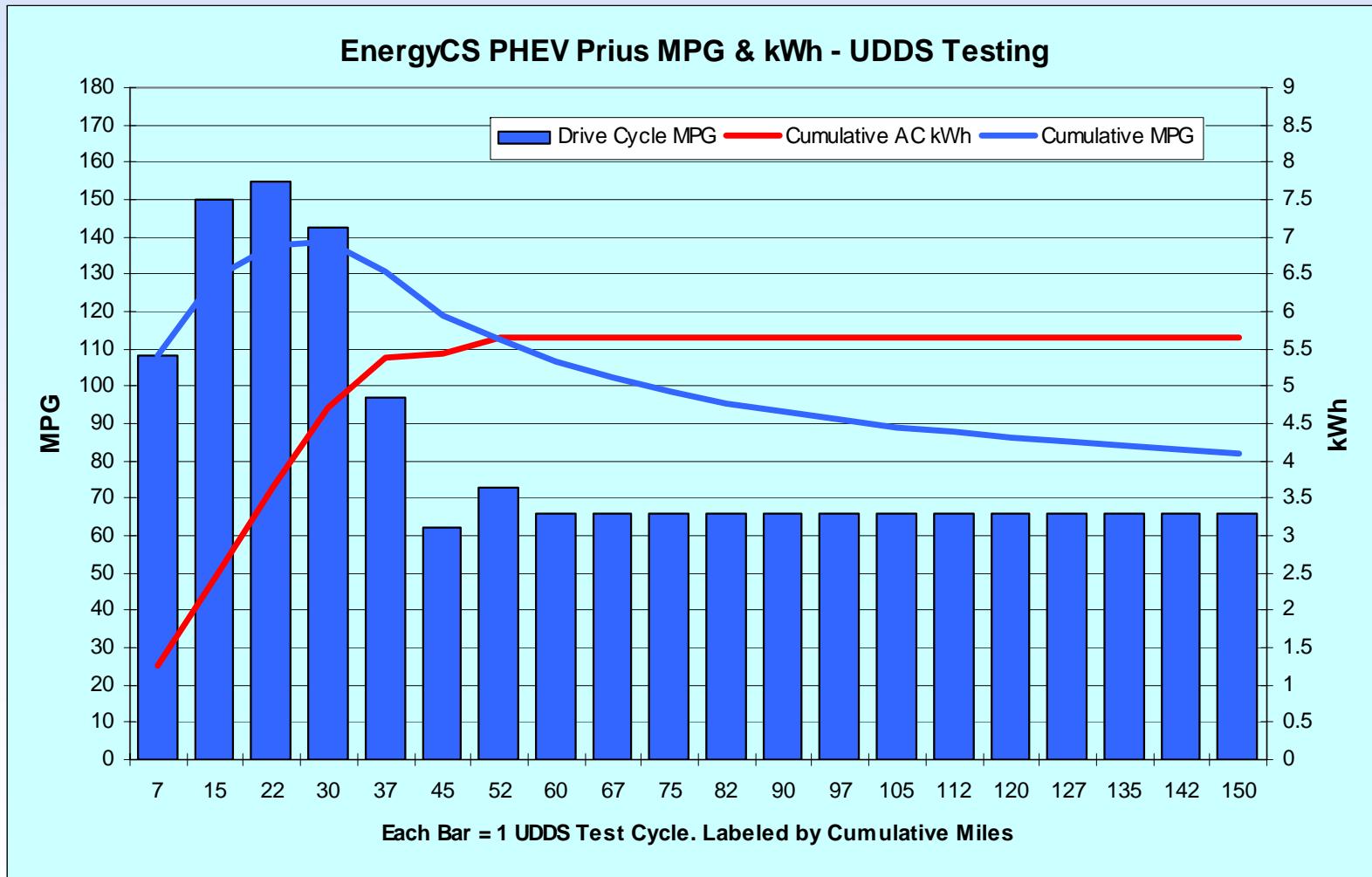
Baseline Performance Testing Results

|  <p>U.S. DEPARTMENT OF ENERGY ADVANCED VEHICLE TESTING ACTIVITY</p> | <h1>PHEVAMERICA</h1> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|---|---|--------------------|---------------------------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|----|------|------|-----|-------|------|-----|------|------|--|--|------------------|--------------------|---------------------------|----|-------|------|----|-------|------|----|------|------|----|------|------|----|------|------|-----|------|------|-----|------|------|
| |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Base Vehicle Description | | Make: Toyota Model: Prius Year: 2006 VIN: 3TOKB2U76508841 Number of Passengers: 5 Hybrid Configuration: Series/Parallel | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Energy CS Plug-In Hybrid | | Vehicle Specifications | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Weights Design Curb Weight: 3160 Vehicle Test Weight: 3400 lbs GWR: 3795 lbs GAWR F/R: 2135/2120 Distribution: 54.2%/45.8% Payload: 635 lbs Performance Goal: 400-Brs | | Electric Drive System Battery Manufacturer: Valence Battery Type: Li-ion Number of Cells: 2376 Nominal Cell Voltage: 3.7V Nominal System Voltage: 230.4V Nominal Pack Capacity: 10 kWh Measured Usable Capacity: 4.08 kWh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Engine Model: 16V-FIRE Output: 76 HP @ 5000 RPM Configuration: 4 Cylinder In-line Displacement: 1.5L Fuel Tank Capacity: 11.9 gal Fuel Types: Unleaded | | Charge System: Input Voltages: 120V Required Breaker Currents: 15-Amp Charger Power Output: 1.2 kW Charger Plug Type: NEMA 5-15 Estimated 100% Charge Time: 6.5 Hrs Estimated 100% Charge Time: 8 Hrs | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UDS Fuel Economy* | | Vehicle Test Results | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 200 | 66.6 | 5.93 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TEST NOTES: <ul style="list-style-type: none"> 1. Fuel economy uses EPA standard urban/ferry cycle. 2. Vehicle tested at ambient temperature while off for a maximum of 15 hours prior to testing. 3. Average non-cold start charge depleting fuel economy. 4. When calculating range, average charge remaining and energy trade with appropriate energy conversion calculation. 5. Actual vehicle range may fall below calculated range. 6. Calculated cumulative fuel economy values, inclusive cold start. 7. A/C energy based on measured charge efficiency. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <small>This vehicle meets all HEV America Minimum Requirements listed on back of this sheet. Values in bold indicate the performance that was not met. All other values are as is unless otherwise specified.</small> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

|  PHEVAMERICA U.S. DEPARTMENT OF ENERGY ADVANCED VEHICLE TESTING ACTIVITY |  | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---------------------------------|-----------------------|---------------------------------|---------------------------------|-----------------------|---------------------------------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|----|-------|------|-----|-------|------|-----|-------|------|-----|-------|------|-----|-------|------|
| Hymotion Plug-in Hybrid | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| VEHICLE SPECIFICATIONS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Weights | Electric Drive System | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Design Curb Weight: 3037 lbs | Battery Manufacturer: A123 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vehicle Test Weight: 3337 lbs | Battery Type: Li-ion | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GWWR: 3795 lbs | Number of Cells: 656 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GAWR: F/R: 2515/2200 | Nominal Cell Voltage: 3.7V | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Distribution: 54.2%/45.8% | Nominal System Voltage: 14.8V | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Forklift: 750 lbs | Nominal Pack Capacity: 4.7 kWh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Performance Goal: 400-800 | Measured Useable Capacity: 2.96 kWh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Engine | Charge System | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Model: INFINI-FRE | Input Voltages: 120V | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Output: 76 HP @ 3000 RPM | Input Currents: 13-Amp | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Configuration: 4-Cylinder In-line | Charger Power Output: 1.3 kW | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Displacement: 1.5L | Charger Plug Type: NEMA 5-15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fuel Tank Capacity: 11.9-gal | Estimated 80% Charge Time: 4.4 hrs | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fuel Type: Unleaded | Estimated 100% Charge Time: 5.5 hrs | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UDDS Fuel Economy* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 80 | 88.88 | 3.58 | 80 | 70.52 | 3.92 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| TEST NOTES: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Calculated fuel economy uses EDR standard urban/dyno cycle. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. Includes 10 min warm-up period at 100% load followed by 12 hours prior to testing. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3. Average use cold start charge depleting fuel economy. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4. Miles measured from average charge depleting fuel economy tests with appropriate energy controls and rebalance. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5. Actual operating fuel economy varies, include cold start. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6. Calculated cumulative fuel economy values, include cold start. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7. A/C energy based on measured charge efficiency. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <small>* The vehicle meets all GM's initial GM-1 requirements (bottom of back of the sheet). GM does not indicate the performance goal was met. All power and energy values are TC unless otherwise specified.</small> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vehicle Test Results | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Base Vehicle Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Make: Toyota Model: Prius Year: 2007 VIN: JTDXKB20577558820 Number of Passengers: 5 Hybrid Configuration: Series/Parallel | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Charge Depleting: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acceleration 0-60 MPH: Time: 11.26 seconds | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acceleration 1/4 Mile: Time: 20.27 seconds | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Speed: 74.34 MPH | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acceleration 1 Mile: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Speed: 103.4 MPH | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Charge Sustaining: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acceleration 0-60 MPH: Time: 13.41 seconds | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acceleration 1/4 Mile: Time: 20.42 seconds | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Speed: 74.02 MPH | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acceleration 1 Mile: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Speed: 104.0 MPH | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brake Test @ 60 MPH: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Distance Required: 153.0 ft | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fuel Economy with A/C Off* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cold Start Charge Depleting: Fuel Economy: 146.72 MPG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A/C kWh Consumed: .297 kWh/mile | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Charge Depleting: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Average Fuel Economy: 167.7 MPG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A/C kWh Consumed: .340 kWh/mile | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Charge Sustaining: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fuel Economy: 160.8 MPG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fuel Economy with A/C On** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cold Start Charge Depleting: Fuel Economy: 128.9 MPG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A/C kWh Consumed: .399 kWh/mile | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Charge Depleting: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Average Fuel Economy: 153.2 MPG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A/C kWh Consumed: .397 kWh/mile | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Charge Sustaining: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fuel Economy: 146.5 MPG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

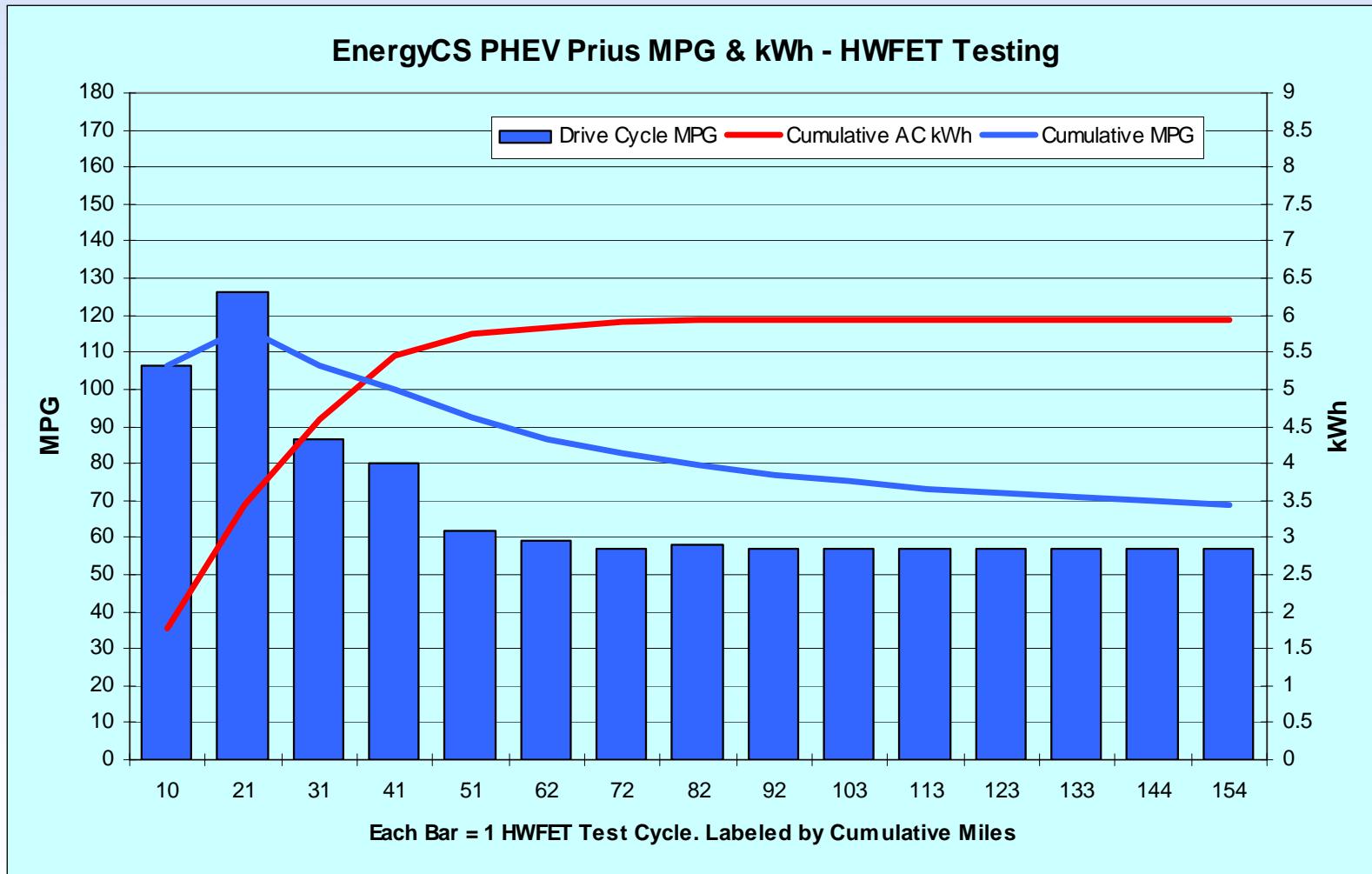
EnergyCS Prius – UDDS Fuel Use

- 9 kWh Valence lithium pack – AC kWh



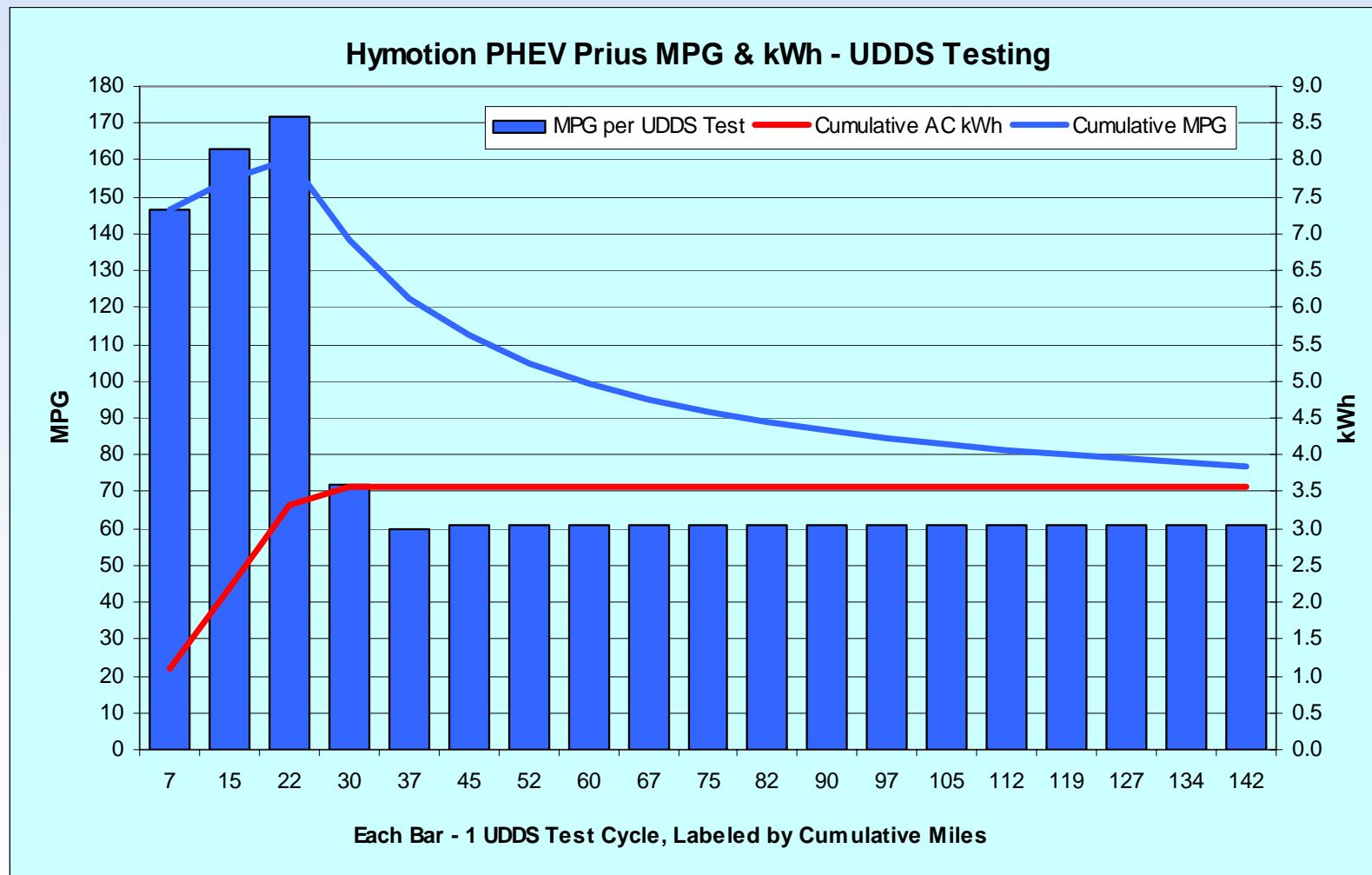
EnergyCS Prius – HWFETS Fuel Use

- 9 kWh Valence lithium pack – AC kWh



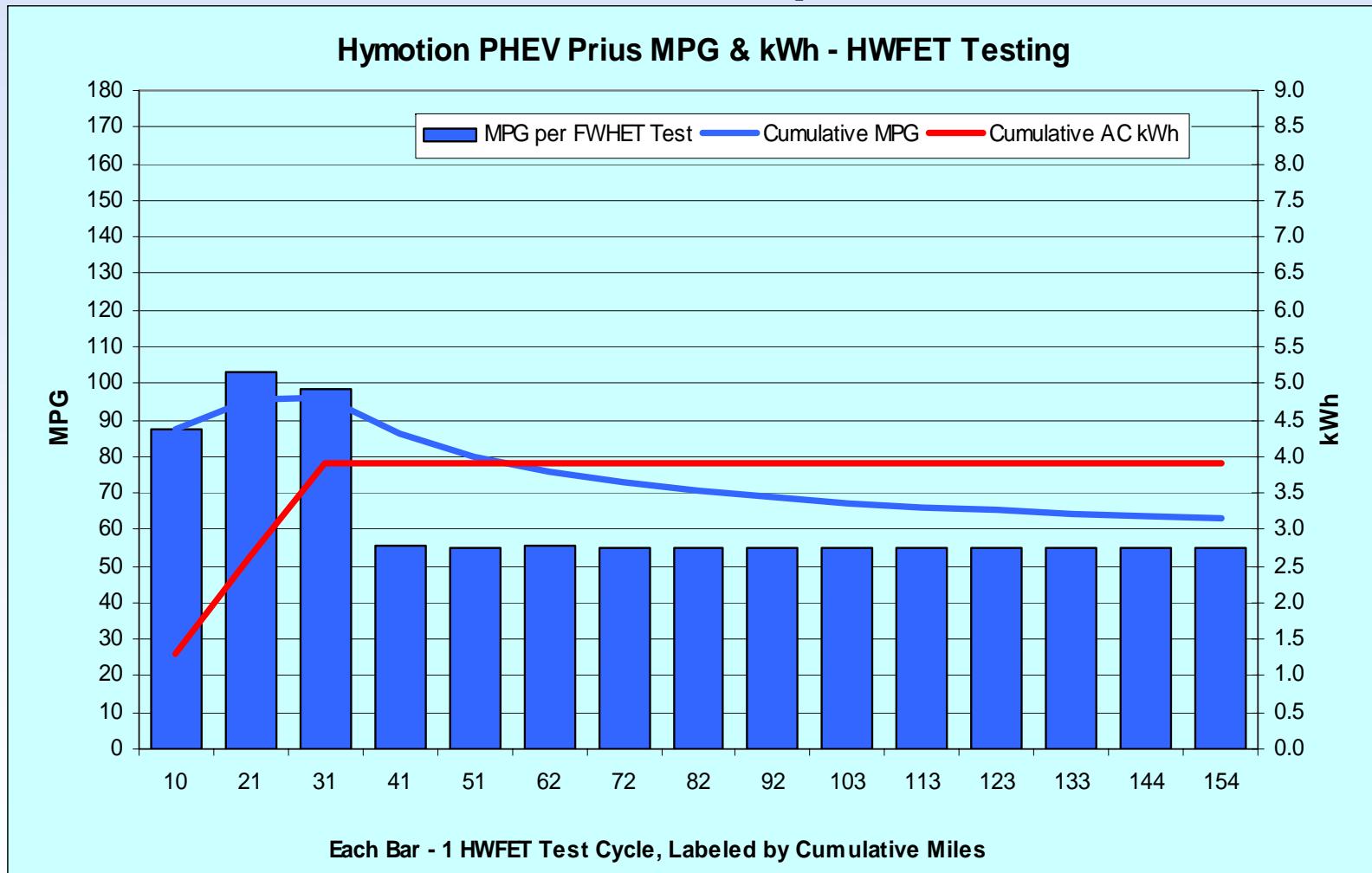
Hymotion Prius – UDDS Fuel Use

- 5 kWh A123 lithium and Prius packs – AC kWh



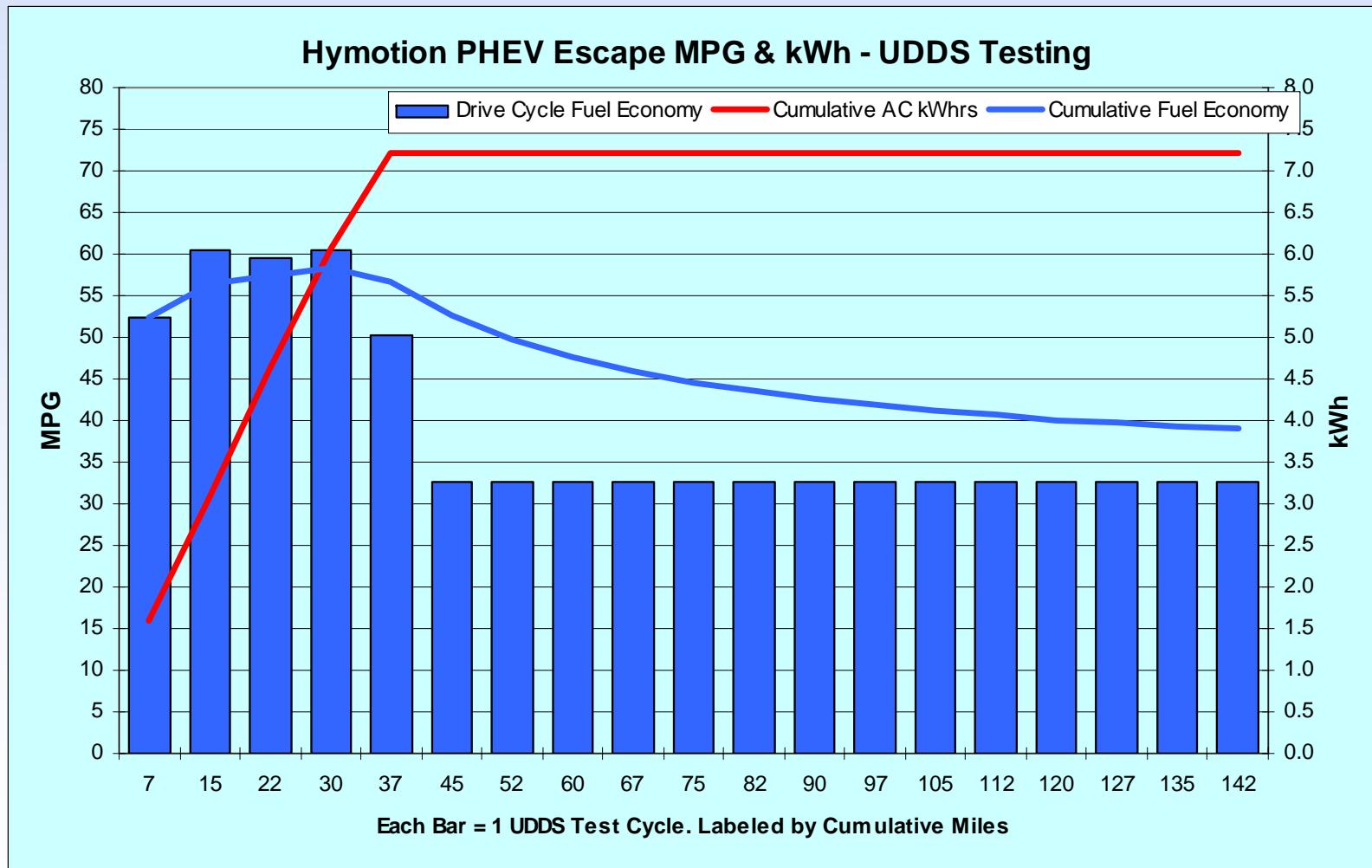
Hymotion Prius – HWFETS Fuel Use

- 5 kWh A123 lithium and Prius packs – AC kWh



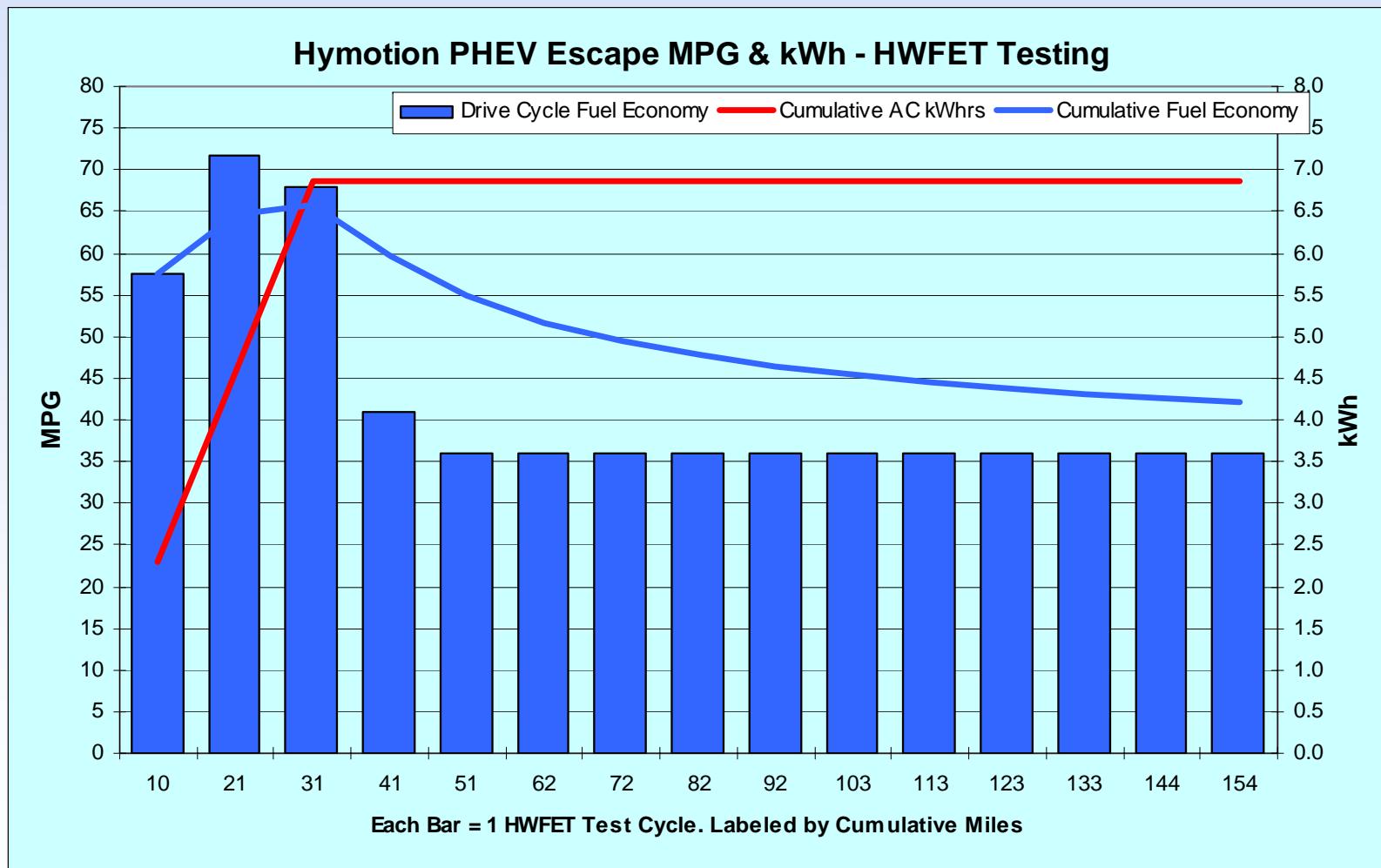
Hymotion Escape – UDDS Fuel Use

- 8.5 kWh A123 lithium and Escape packs – AC kWh



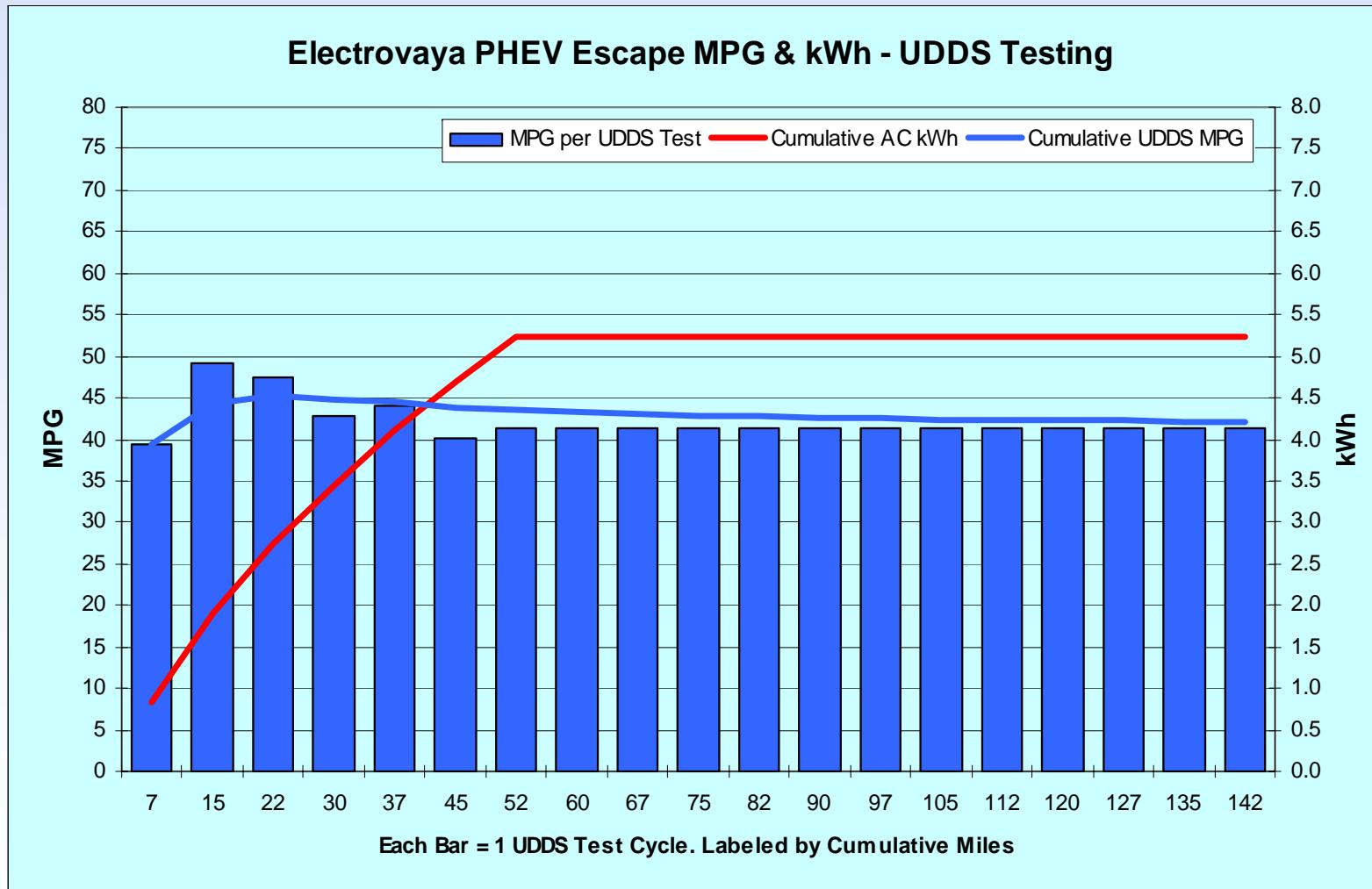
Hymotion Escape – HWFETS Fuel Use

- 8.5 kWh A123 lithium and Escape packs – AC kWh



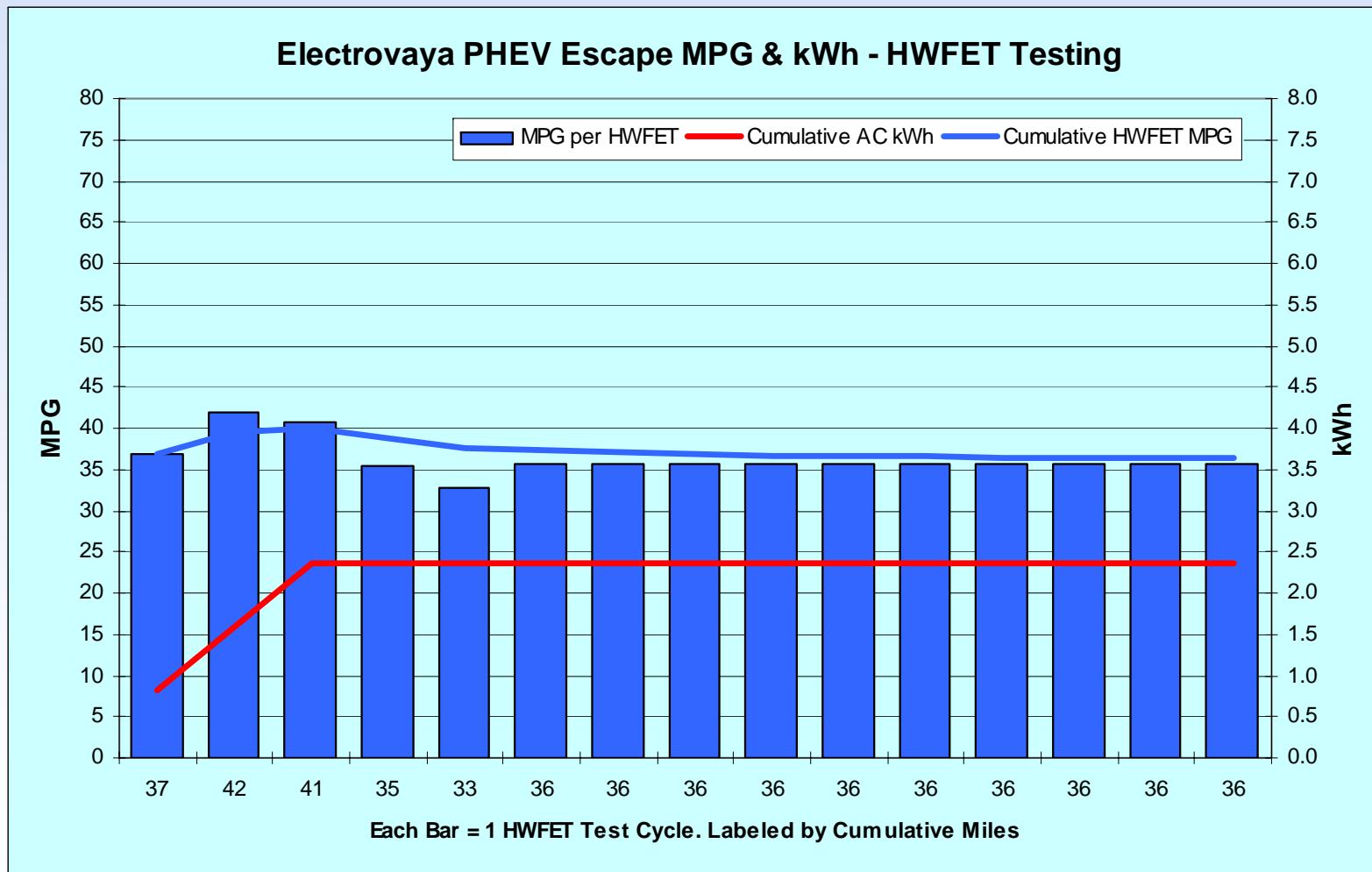
Electrovaya Escape – UDDS Fuel Use

- 12 kWh Electrovaya lithium and Prius packs – A/C kWh

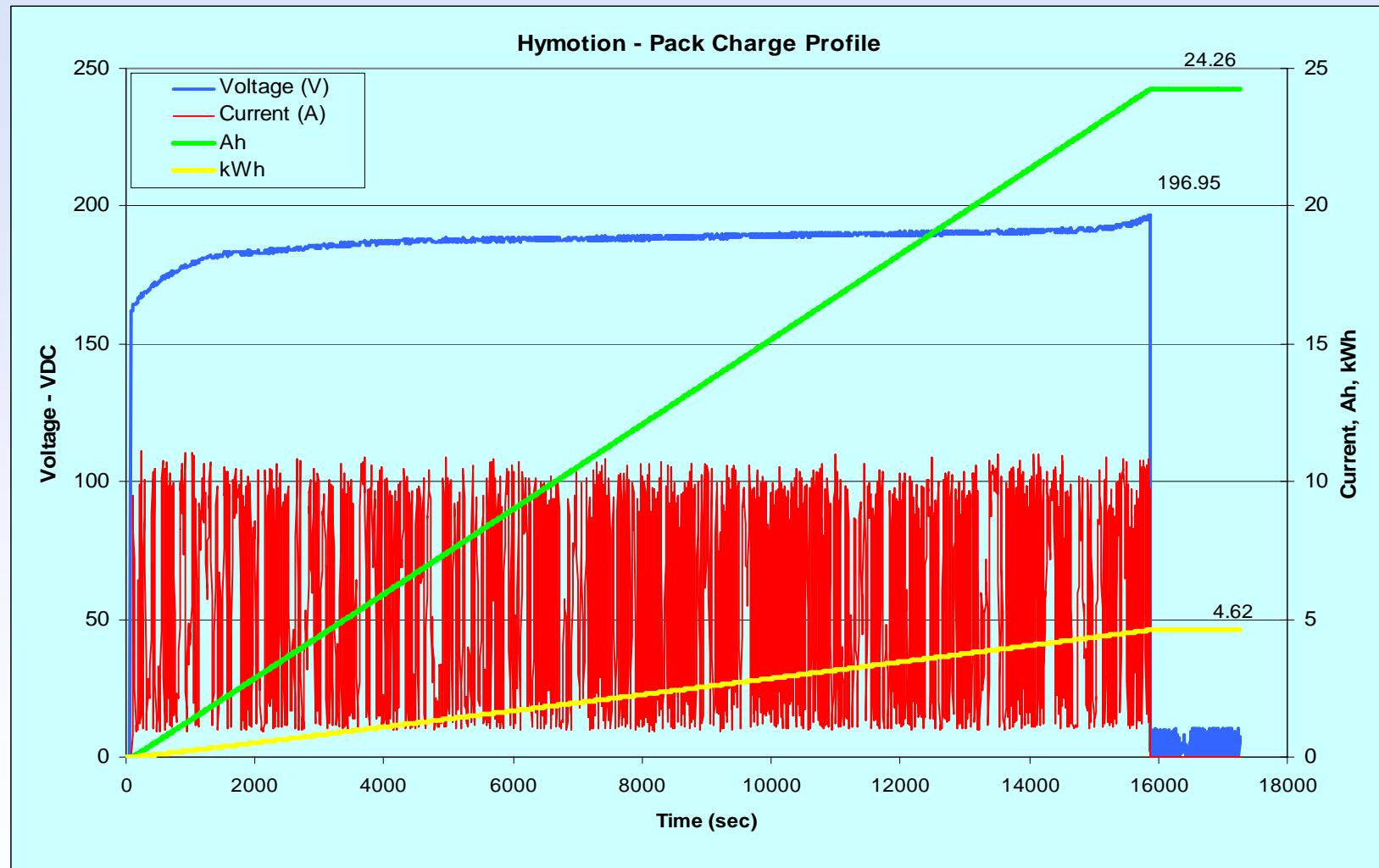


Electrovaya Escape – HWFETS Fuel Use

- 12 kWh Electrovaya lithium and Prius packs – A/C kWh

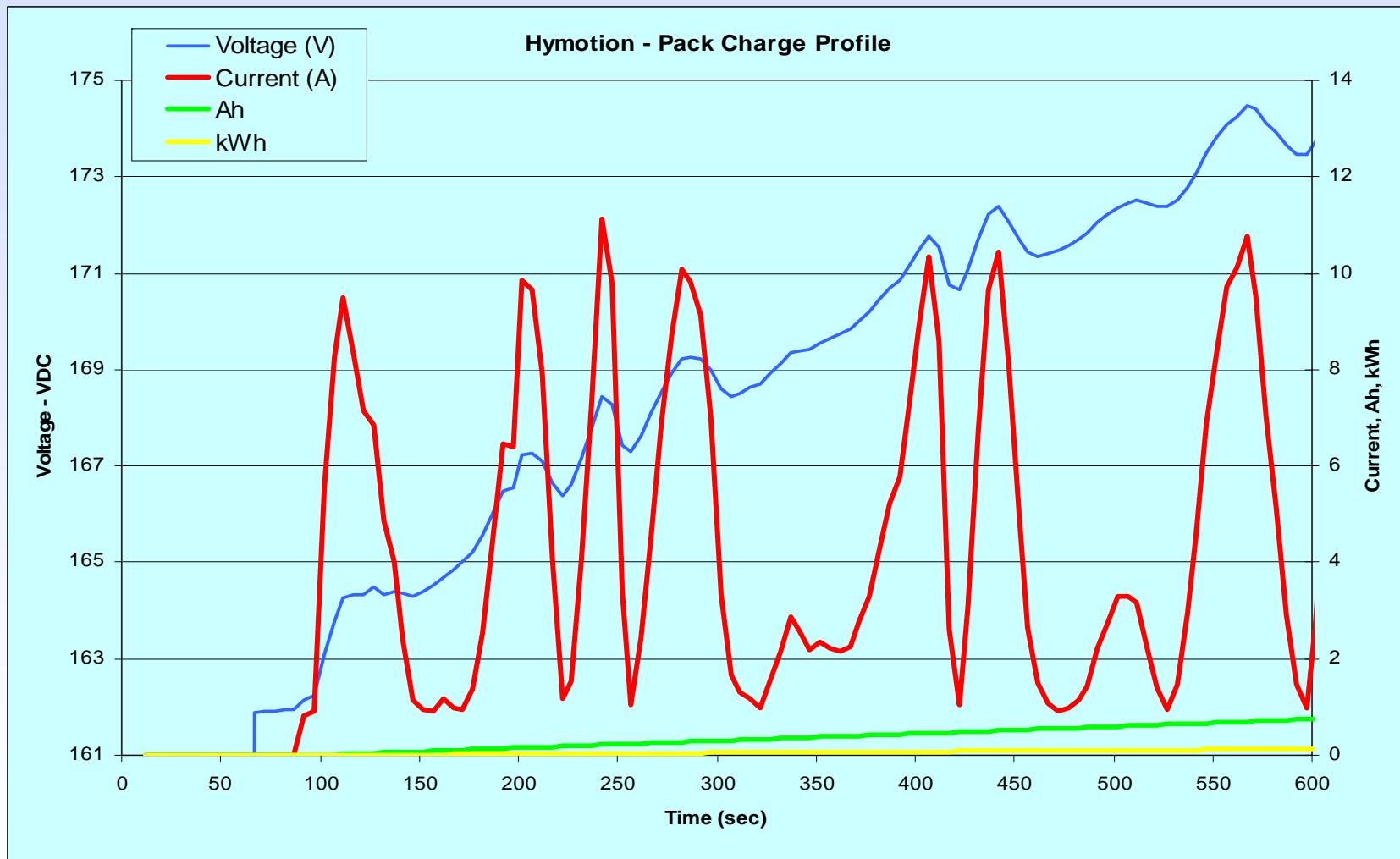


Hymotion Battery Charge Profile



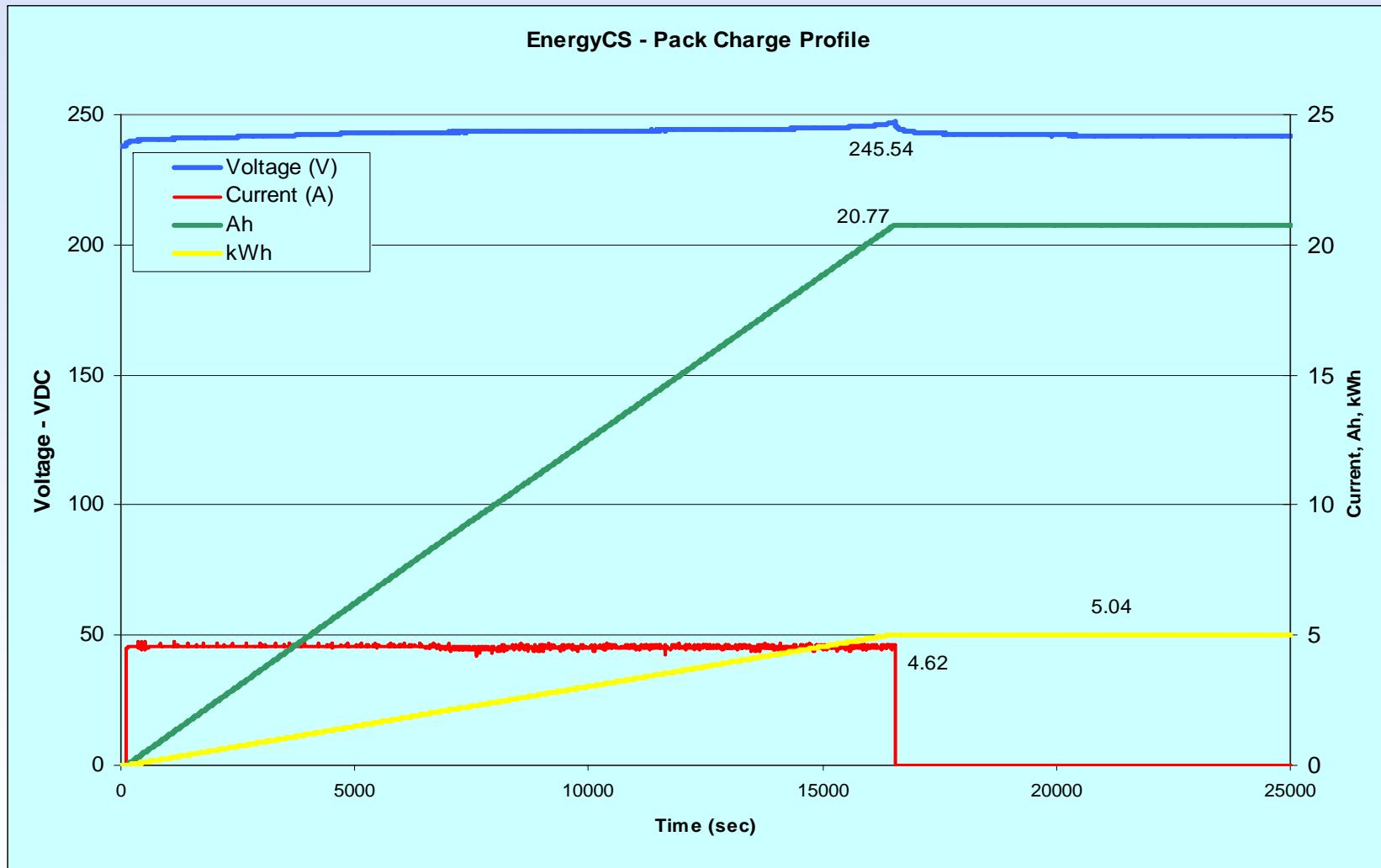
A123 Systems Lithium Ion Battery - DC kWh

Hymotion Cell Charge Profile



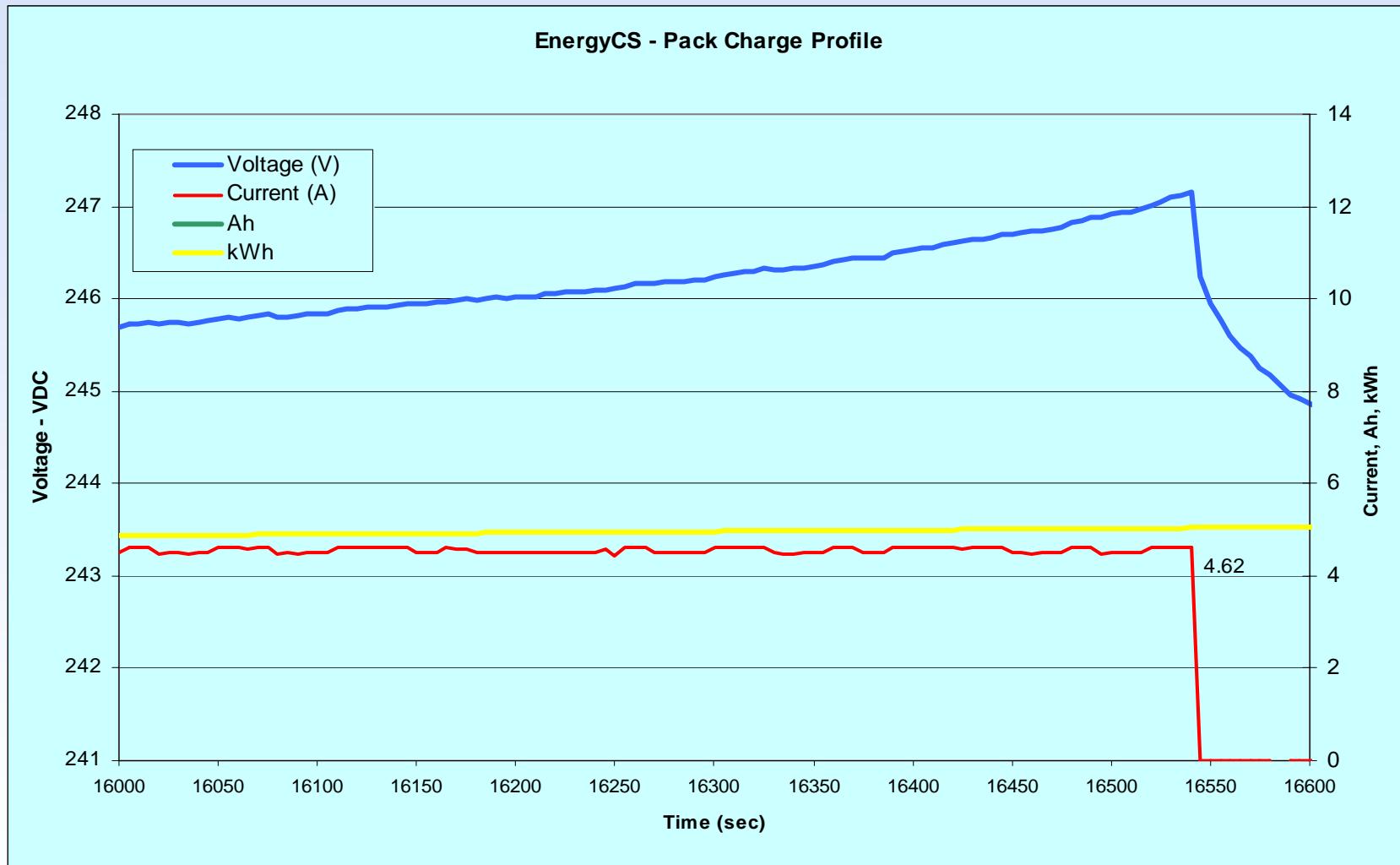
A123 Systems Lithium Ion Battery – DC kWh

EnergyCS Battery Charge Profile



Valence Lithium Ion Battery – DC kWh

EnergyCS Cell Charge Profile



Valence Lithium Ion Battery – DC 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 |



Accelerated Onroad Testing

- Uses dedicated drivers
- Predetermined and repeatable drive cycles
- Combinations of urban and highway loops
- 5,440 total onroad test miles per PHEV model
- 162 drive and charging cycles that include a minimum of 1,344 hours of charging
- Compliments dynamometer testing by allowing a broader view of fuel use over many more miles and charging events in on-road environment
- Test PHEV batteries at completion of accelerated testing and at 25k, 50k and ? miles

PHEV Accelerated Testing

- Accelerated testing in Phoenix over 5,440 miles
- GPS units track distance, average and maximum speeds

| 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 (mi) | Highway (10 mi) | Charge (hr) | Reps (N) | Total (mi) | Electricity kWh | Gasoline Gals | Gasoline 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 | 984 | 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 | 86.4 | |

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 | 1.67 | 0 | - |
| 20 | 1 | 1 | 8 | 30 | 600 | 131.96 | 4.55 | 0 | - |
| 40 | 4 | 0 | 12 | 5 | 200 | 35.18 | 5.59 | 0 | - |
| 40 | 2 | 2 | 12 | 5 | 200 | 33.22 | 6.02 | 0 | - |
| 40 | 0 | 4 | 12 | 5 | 200 | 28.60 | 6.99 | 0 | - |
| 60 | 2 | 4 | 12 | 10 | 600 | 57.96 | 10.35 | 13.3 | 45.1 |
| 80 | 2 | 6 | 12 | 8 | 640 | 44.62 | 14.34 | 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 | Weighted Average | | 101.7 | |

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

Hymotion Escape – Accelerated Testing

| Cycle | Urban (mi) | Highway (mi) | Charge (hr) | Reps (N) | Total (mi) | Electricity kWh | Gasoline Gals | Gasoline 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 | | | |
| 40 | 0 | 4 | 12 | 15 | 600 | | | |
| 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 | | | |
| 200 | 2 | 18 | 12 | 3 | 600 | | | |
| Total | 2340 | 3100 | 1344 | 162 | 5440 | Weighted Average | | |

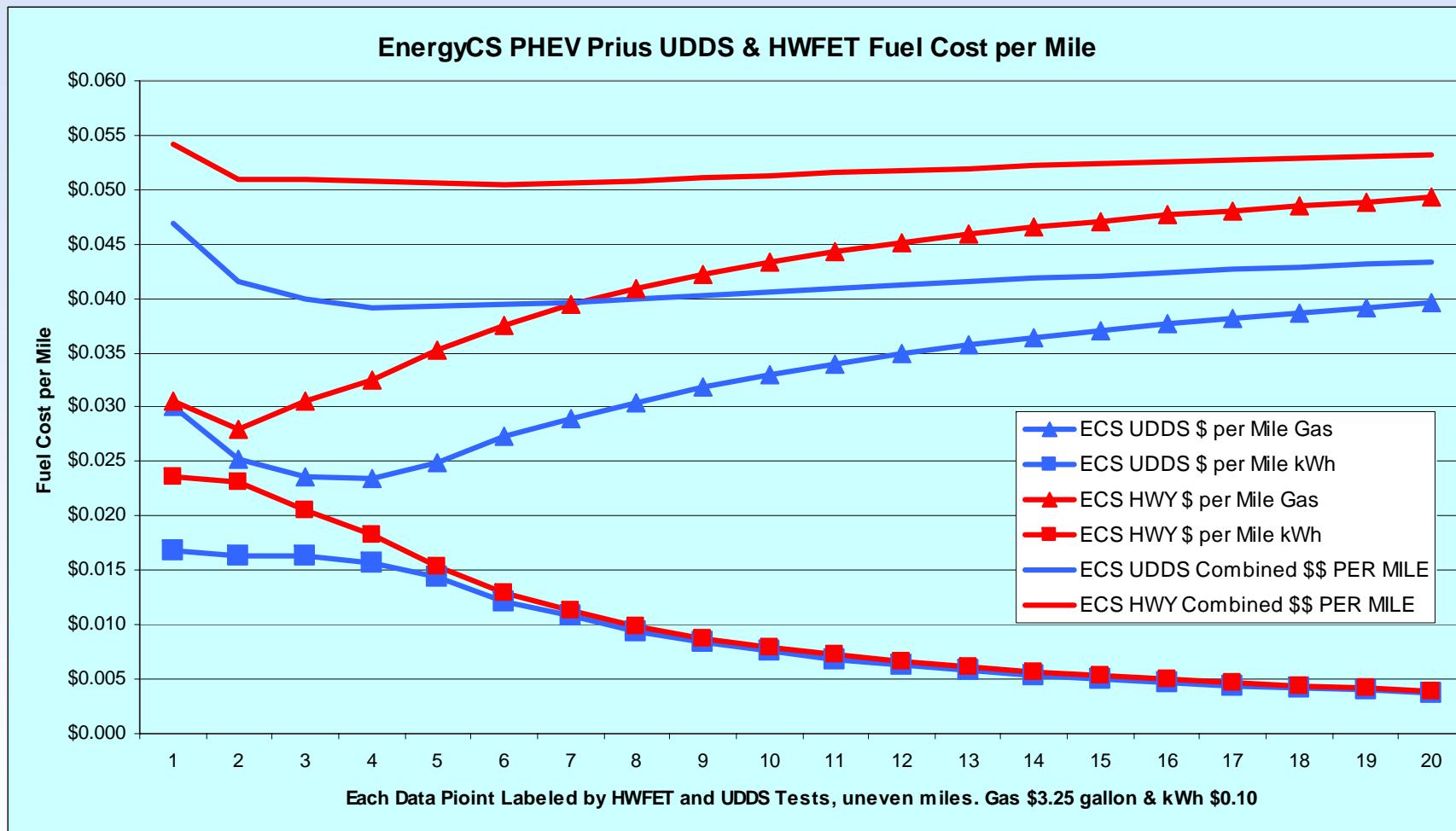
Each total distance slightly greater than 600 miles. HEV version = 27 mpg

HybridsPlus Escape – Accelerated Testing

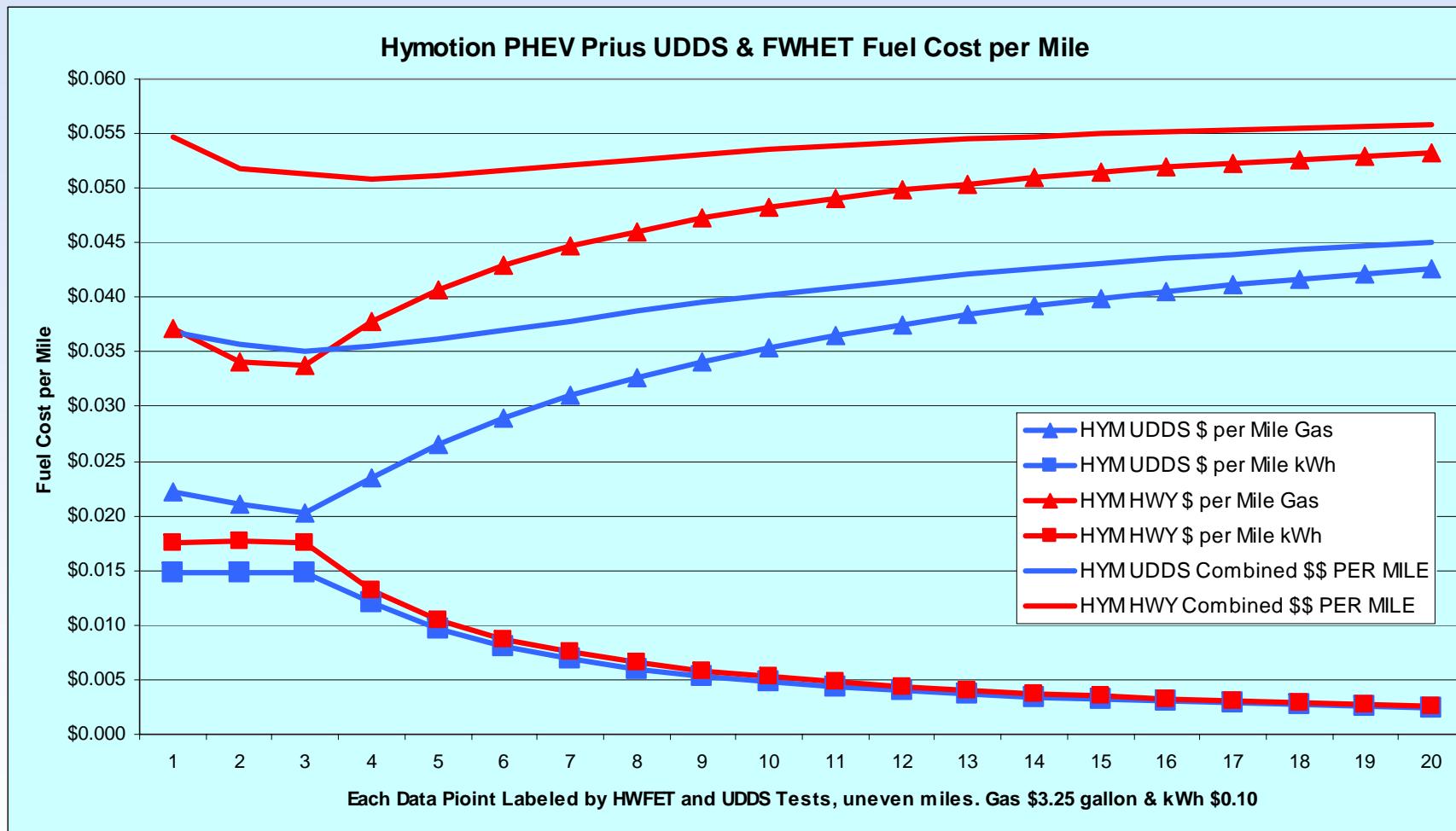
| Cycle | Urban | Highway | Charge | Reps | Total | Electricity | Gasoline | |
|--------------|-------------|-------------|-------------|------------|-------------|-------------------------|-------------|-----|
| (mi) | (10 mi) | (10 mi) | (hr) | (N) | (mi) | kWh | Gals | MPG |
| 10 | 1 | 0 | 4 | 60 | 600 | | In progress | |
| 20 | 1 | 1 | 8 | 30 | 600 | | | |
| 40 | 4 | 0 | 12 | 15 | 600 | | | |
| 40 | 2 | 2 | 12 | 15 | 600 | | | |
| 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

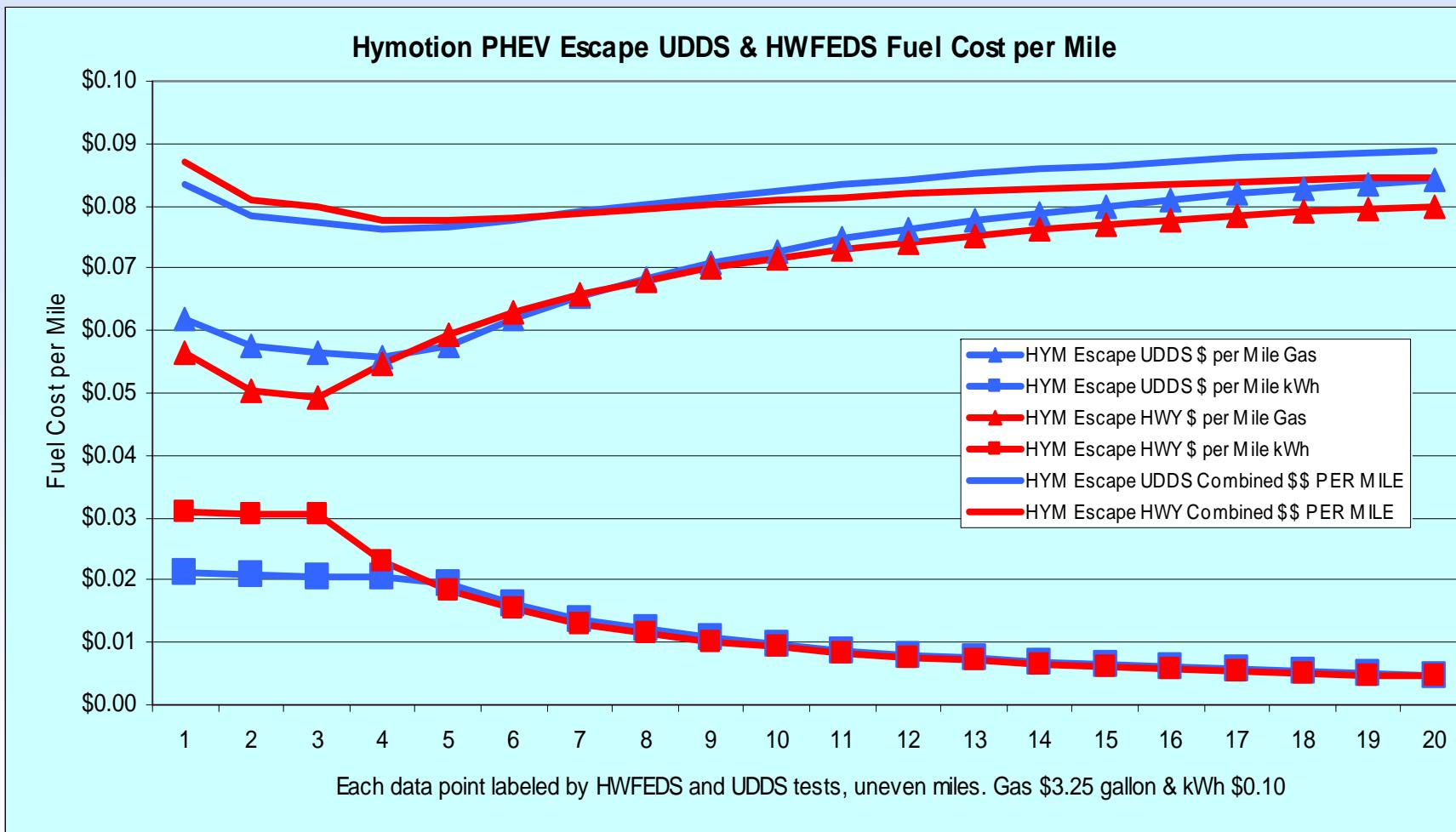
EnergyCS Prius – Fuel Costs



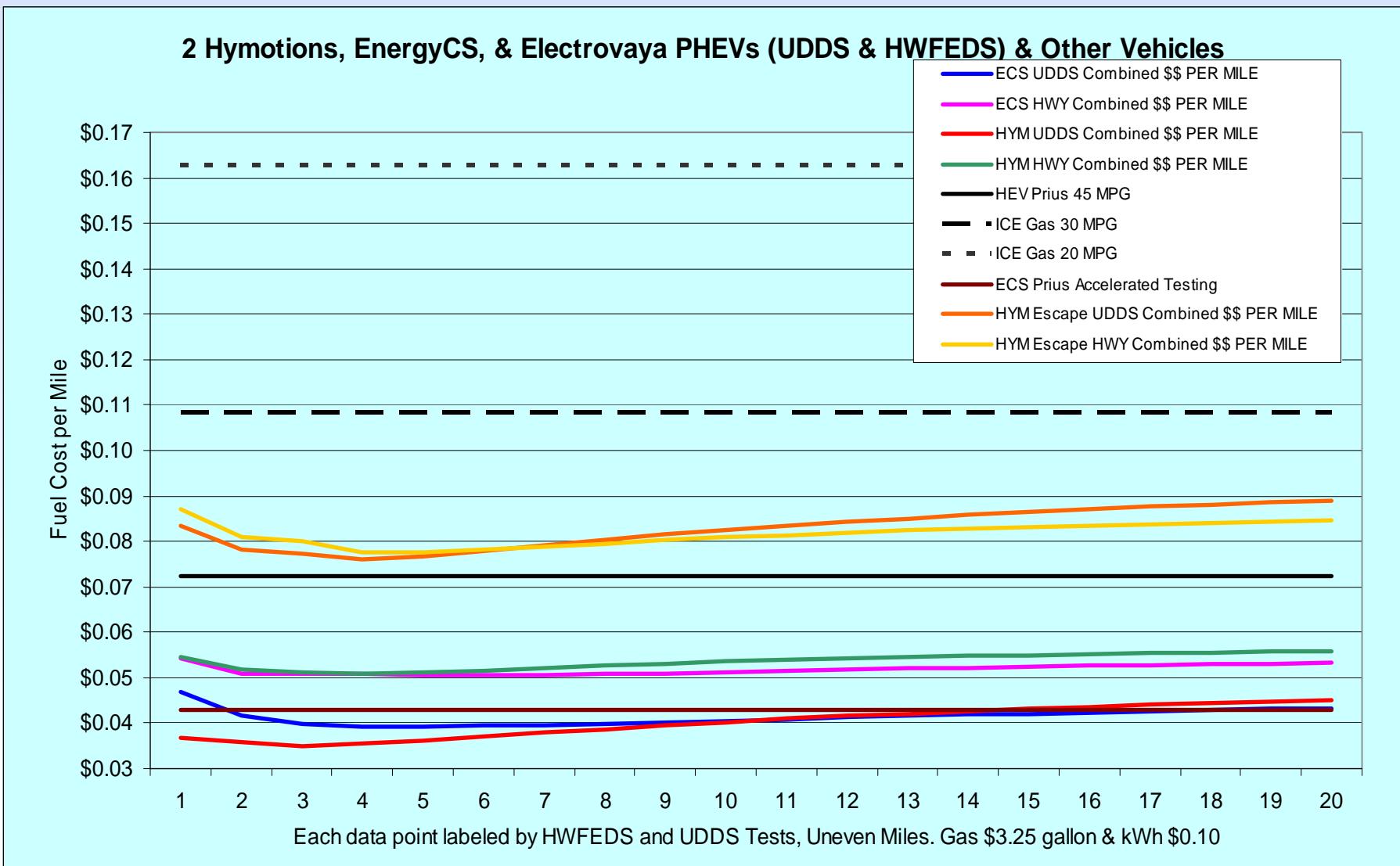
Hymotion Prius – Fuel Costs



Hymotion Escape – Fuel Costs



PHEV Fuel Costs per Mile



Onroad Demonstration Partners and Fleet Data Collection Activities

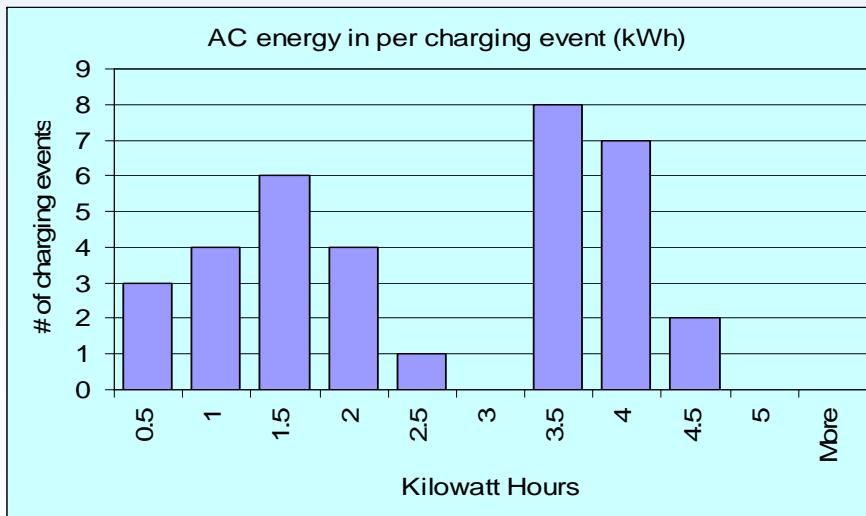
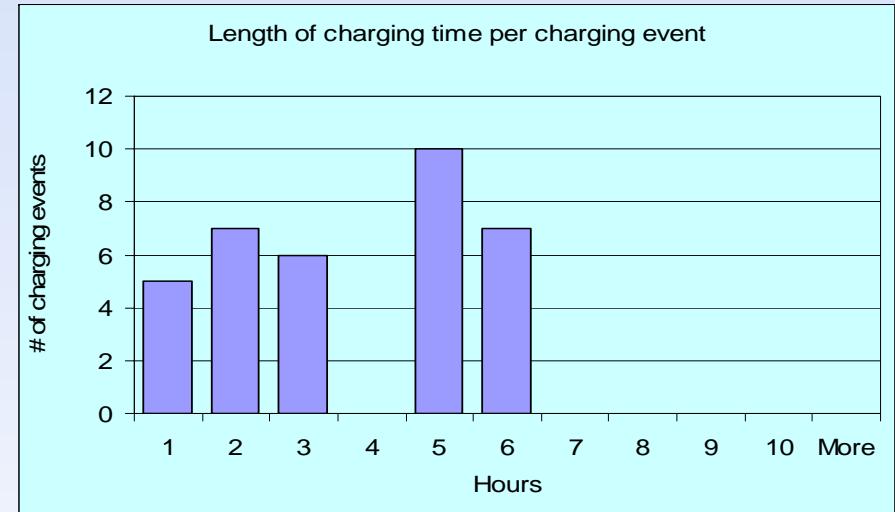
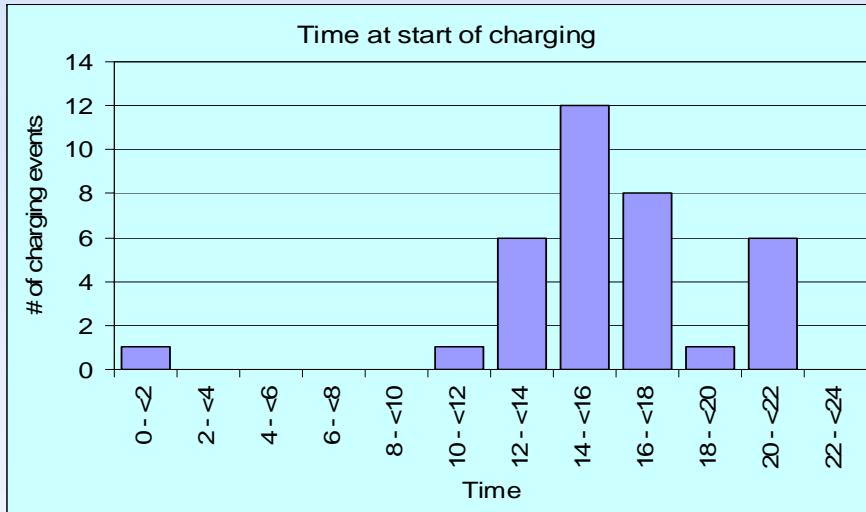
Hymotion Joint Data Collection

- Kvaser data loggers installed 50 PHEVs North American
- Onboard data includes vehicle performance, fuel use, and charging and driving profiles
- Offboard data - fuel use and maintenance data
- 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



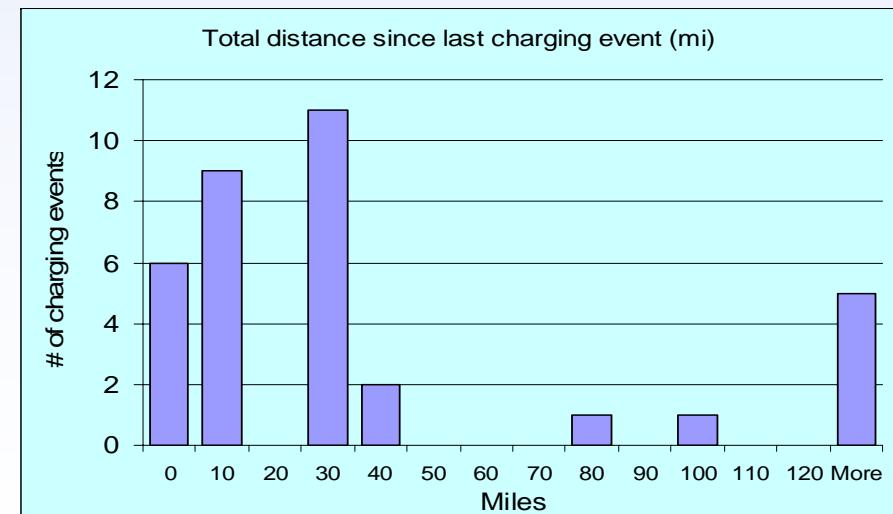
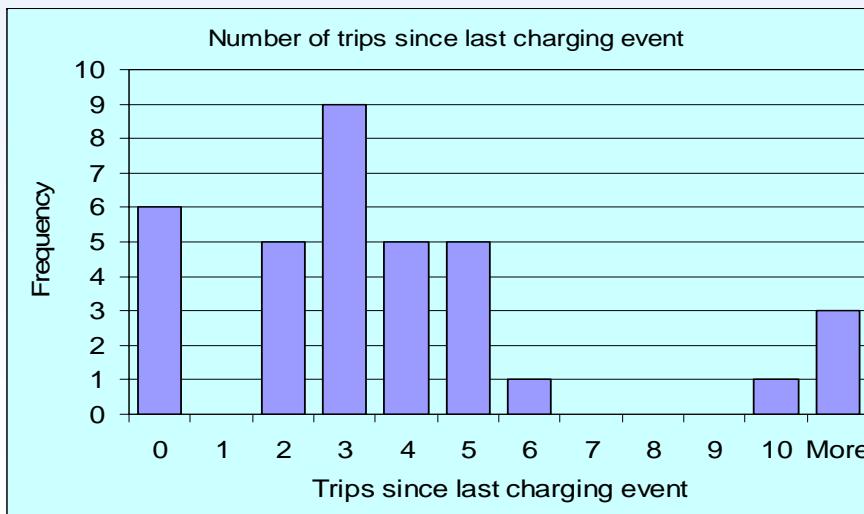
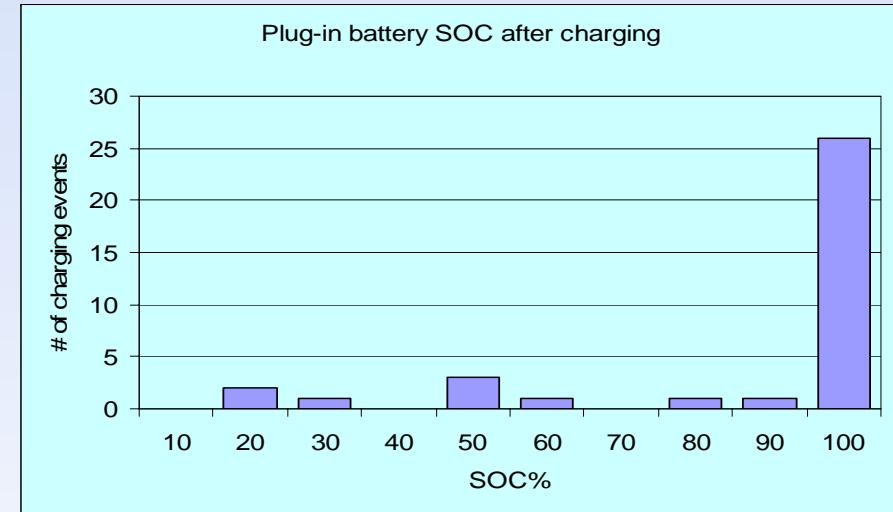
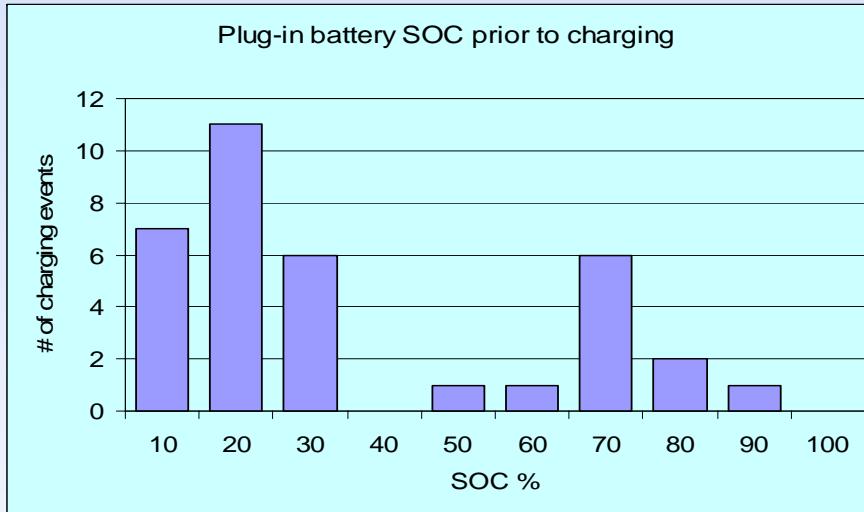
Hymotion Prius Charging Profiles

- 3 months, 2212 miles, 35 charges (single PHEV)



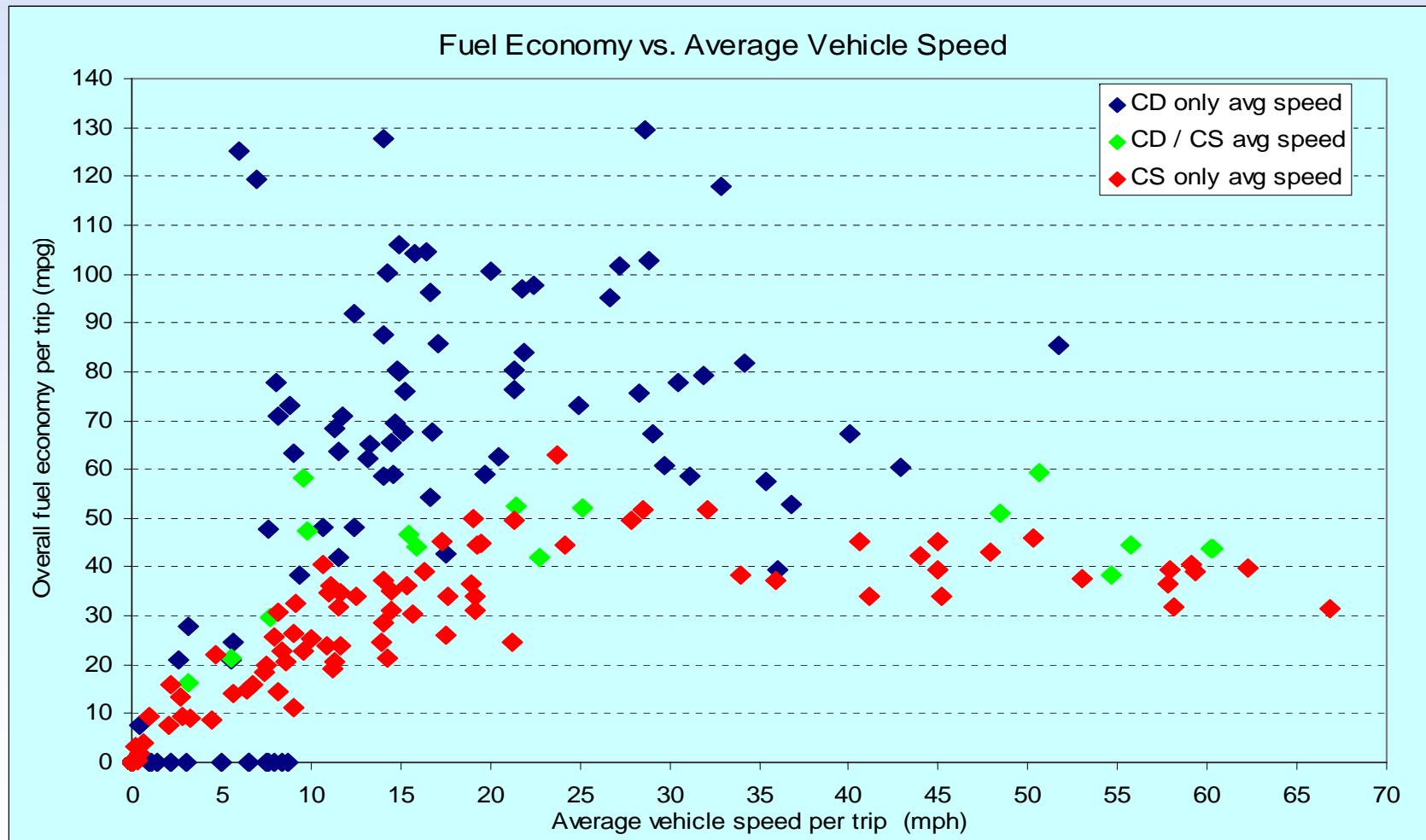
Hymotion Prius Charging Profiles

- 3 months, 2212 miles, 35 charges (single PHEV)



Hymotion Prius MPG Vs. Speed

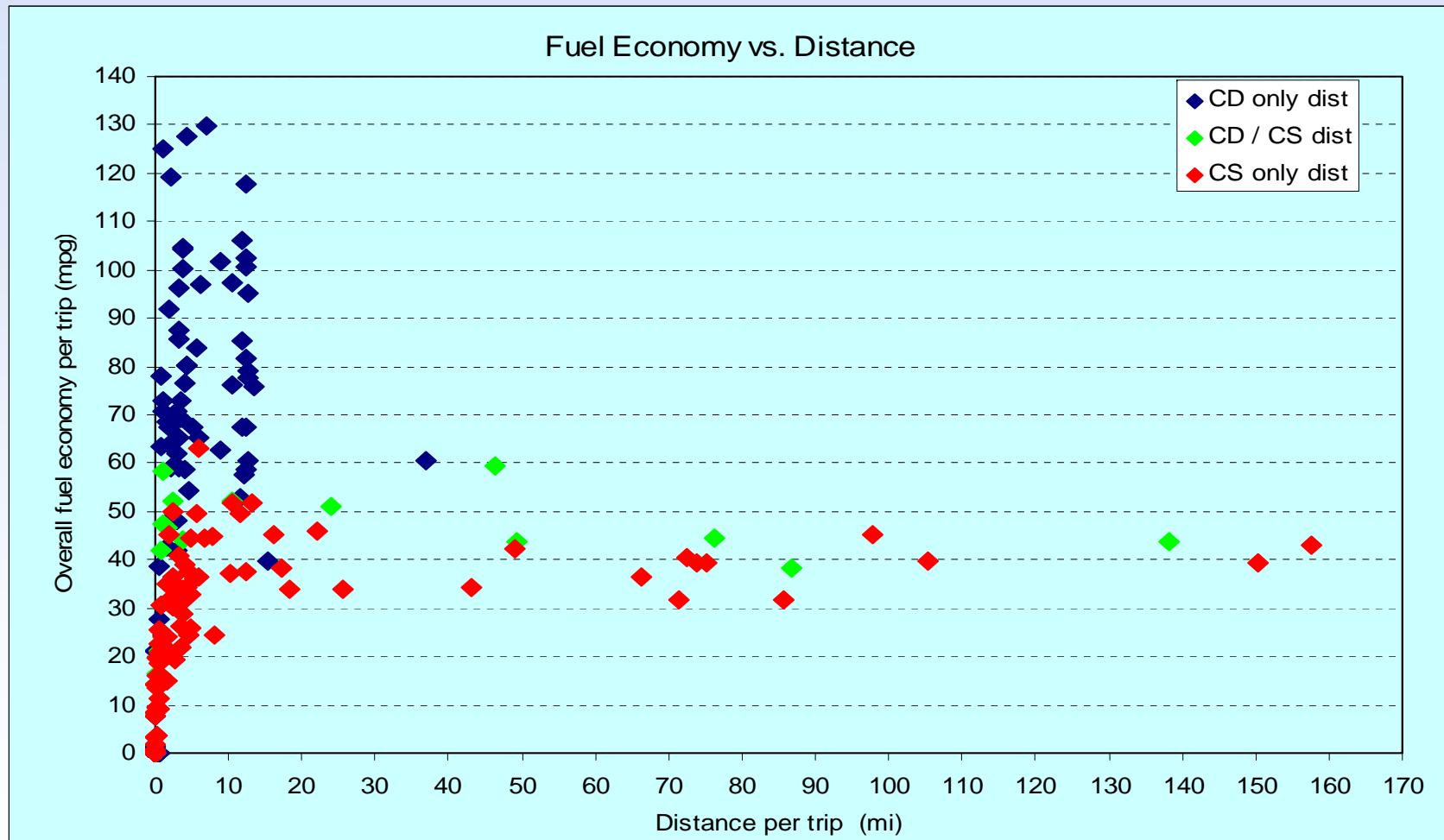
- 3 months, 2212 miles (single PHEV)



CD – charge depleting, S - sustaining

Hymotion Prius MPG Vs. Trip Distance

- 3 months, 2212 miles (single PHEV)



CD – charge depleting, S - sustaining

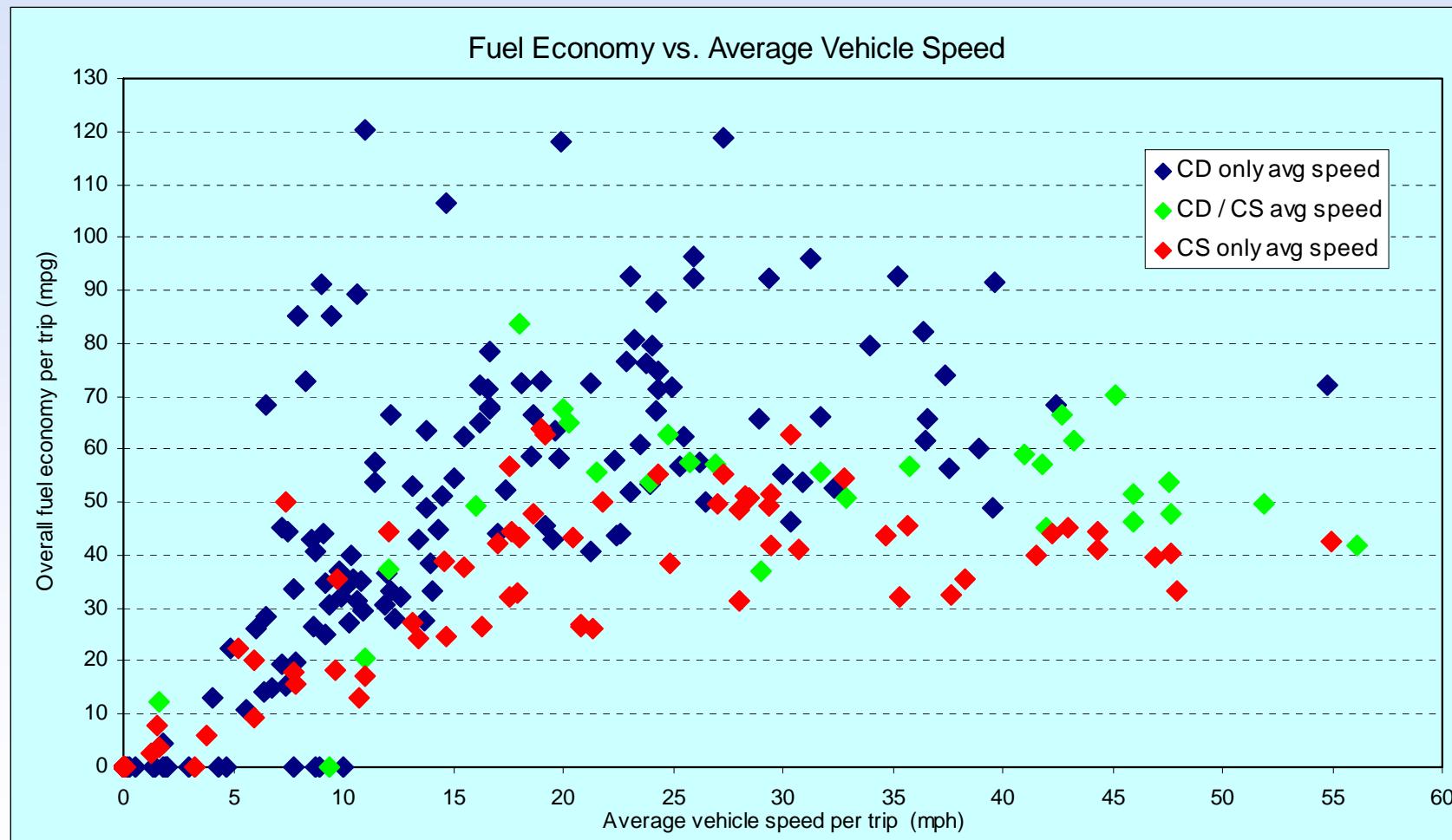
Hymotion Prius – Different Fleet

- 1/2/08 – 1/31/08, 12 charging events, single vehicle

| | All Trips | CD-only mode | Combined modes | CS-only mode |
|----------------------|-----------|--------------|----------------|--------------|
| Average MPG | 43 | 76 | 45 | 40 |
| # of Trips | 77 | 12 | 12 | 53 |
| % Total Trips | - | 16% | 16% | 69% |
| Miles | 1,999 | 86 | 1,047 | 866 |
| Average Miles / Trip | 26 | 7 | 87 | 16 |
| % Total Miles | - | 4% | 52% | 43% |

Hymotion Prius 5 PHEVs MPG Vs. Speed

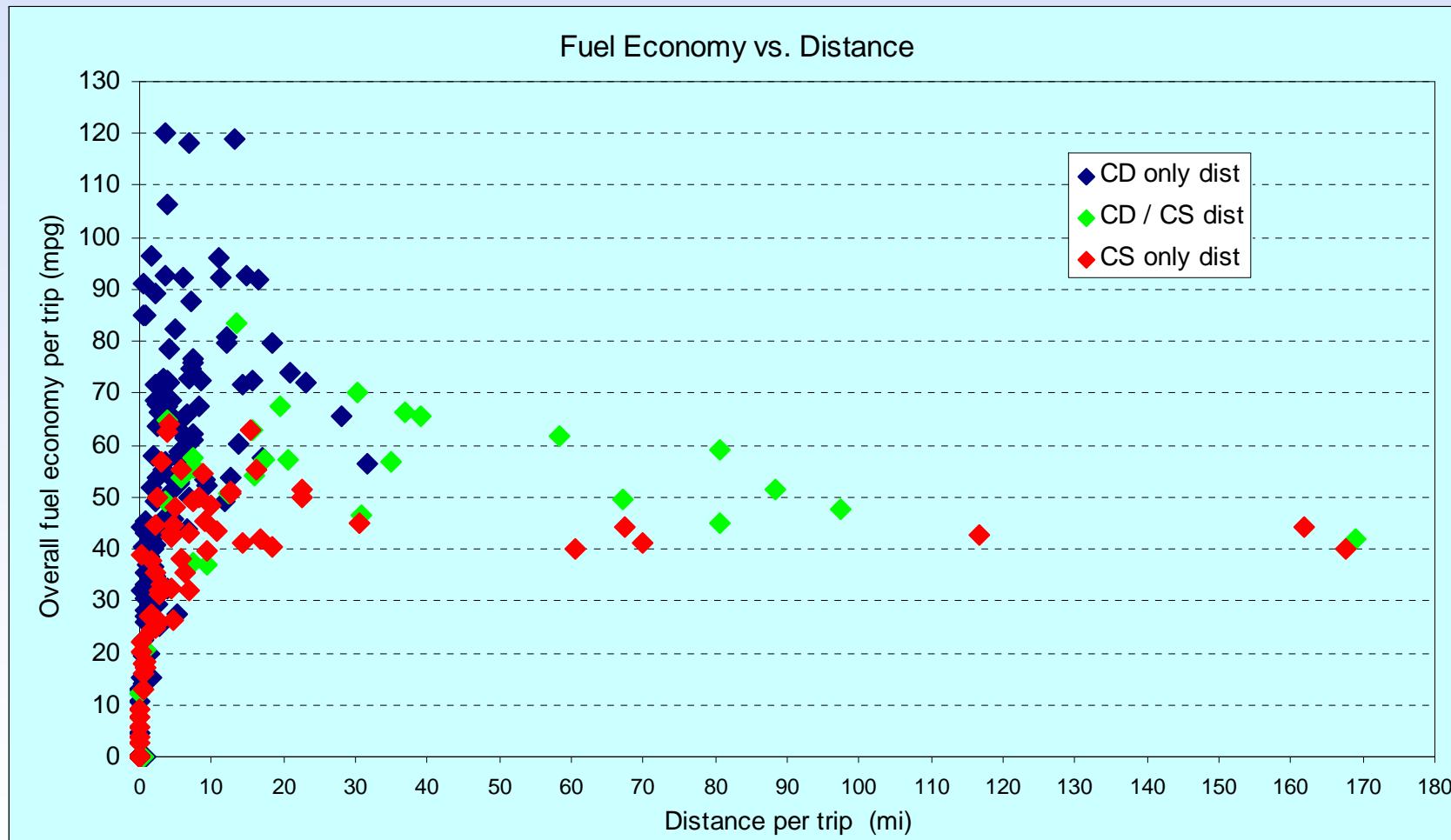
- TX, VT, and CA, 2800 miles, 206 trips, January 2008



CD – charge depleting, S - sustaining

Hymotion Prius 5 PHEVs MPG Vs. Distance

- TX, VT, and CA, 2800 miles, 206 trips, January 2008



CD – charge depleting, S - sustaining

EnergyCS Joint Data Collection

- EnergyCS provided onboard data for seven vehicles operating in fleets in Canada, Arizona, and California
- Modifying data collection to allow EnergyCS and INL server-to-server interface and wireless communication
- EnergyCS using different battery manufacturers
- 36 vehicles deployed (16 North America and 20 Europe)
- Started 2007



NYSERDA

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

| Model | Baseline Testing | Accelerated Testing | Delivery Status |
|--------------------|----------------------|---------------------------|-----------------------|
| EnergyCS Prius | Completed | Problem – near completion | 1 delivery |
| Hymotion Prius | Completed | Completed | 1 delivery |
| Hymotion Escape | Completed | Ongoing | 1 delivery |
| Electrovaya Escape | Problems – completed | Waiting to start | 4 deliveries required |
| HybridsPlus Escape | Waiting to start | Ongoing | 3 deliveries required |



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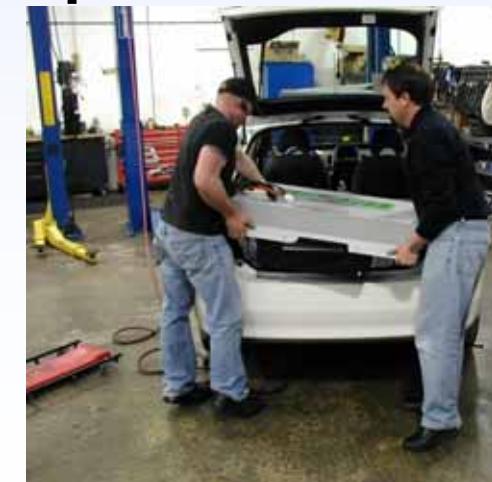
Tacoma Power

- Two lead acid battery Prius PHEVs from the Green Car Company
- Two Hymotion Prius on order
- Testing includes charging and driving profiles as well as charging infrastructure analysis
- Using V2Green cellular data loggers and GPS units
- Started 1st quarter CY08



Seattle-Area Demonstration

- 13 Hymotion Prius PHEV demonstration with:
 - The City of Seattle (4)
 - King County (4)
 - Port of Seattle (2)
 - Puget Sound Clean Air Agency (3)
- 1 Green Car Company lead acid Prius at King County
- Using V2Green cellular data loggers and GPS units
- Offboard fuel use and maintenance requirements
- Time-of-day charge demand study
- Started April 2008



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National Rural Electric Cooperative Association (NRECA)

- Total of ten Prius and Escape PHEVs from Hymotion, EnergyCS, and HybridsPlus will be / are operated by rural electric coop (4 delivered)
- Collect and process onboard data from the fleets, and provide individual vehicle and fleet operations data to NRECA and fleets
- Started 2007



University of California Davis

- **UCDavis will use 13 Hymotion Prius for public fleet demonstration**
- **Demonstration will include up to 70 drivers that are identified by AAA of California**
- **Each public driver will operate a vehicle for ~2 months**
- **Use V2Green cellular data loggers and GPS units**
- **AVTA provides data collection, handling, analysis and dissemination support**
- **AVTA, UCDavis and AAA partnering to capture first study of public use of PHEVs, including charging practices and locations**
- **Started April 2008**

Washington State PHEV Demonstration

- Demonstrate 14 Hymotion Prius in coastal, desert, and island areas
- Testing partners include:
 - Port of Chelan (lead)
 - State of Washington
 - Five utilities and three colleges
 - Port agencies, cities and counties
 - Private company
- Will include daily solar (photovoltaic array) charging of up to three PHEVs
- Electricity costs as low as 2.5 cents/kWh (hydropower)
- Using V2Green cellular data loggers and GPS units
- Started April of 2008



Hawaii PHEV Demonstration

- Demonstrate six Hymotion Prius on Maui and Oahu
- Testing partners:
 - State of Hawaii
 - University of Hawaii
 - Hawaiian Electric Company
 - Maui Electric Company
 - Maui County
 - U.S. Air Force
- Will use V2Green cellular data loggers and GPS units
- Start late summer 2008



Charging Infrastructure



Charging Infrastructure



Other Upcoming PHEV Testing

- Status of End of Life Battery Studies
 - EnergyCS Valance battery repaired and finishing accelerated testing
 - Hymotion Prius pack near completion of accelerated testing
- Charging demand study awaiting critical mass of PHEVs at one location
- Track, dynamometer and accelerated testing of PHEV Sprinter
- Testing data loggers
- Defining bi-directional charging study
 - Likely at ~6 kW and ~20 kW levels
 - Includes V2Grid on two lithium battery PHEVs
 - Includes cellular modem charging control

Acknowledgement

This work is supported by the U.S. Department of 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-08-14176

