



# U.S. Department of Energy - Advanced Vehicle Testing Activity

## PHEV Field Test Plans and Testing Results

DOE PHEV Annual Review Meeting -  
Washington DC. June 2007

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# Presentation

- Background & goal
- Test plan development
- Test methods
- PHEVs in testing
- Testing results to date
  - Gasoline & electricity use
  - Combined fuel costs on a per mile basis
- PHEV payback based on fuel cost savings
- PHEV potential petroleum reductions
- Future PHEV activities

# AVTA Background & Goal

- The Advanced Vehicle Testing Activity (AVTA) is part of the U.S. Department of Energy's FreedomCAR & Vehicle Technologies Program
- The AVTA is primarily conducted by the Idaho National Laboratory (INL) & Electric Transportation Applications (ETA - Phoenix, AZ), with Argonne National Laboratory performing dynamometer testing
- AVTA Goal
  - Provide benchmark data to technology modelers, & research & development programs
  - Also assist fleet managers in making informed vehicle purchase, deployment & operating decisions

# AVTA Testing History

- **Hybrid electric vehicles**
  - 12 models, 3 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**
  - 15 models, 200,000 test miles
- **Urban electric vehicles**
  - 3 models, 1 million test miles
- **Oil bypass filters**
  - 2 models, 1.3 million test miles

# PHEV Test Plan Development

- **Developed 400-page vehicle specifications & test procedures document for:**
  - **Baseline performance testing (closed track & dyno)**
  - **Accelerated testing (defined onroad testing)**
  - **Battery testing (after baseline & accelerated testing)**
  - **Fleet testing**
- **Developed with the anticipation of testing PHEVs from converters & OEMs**
  - **Initial draft reviewed by ANL & NREL, with two PHEVs tested to validate procedures**
  - **Second draft being commented on by OEMs, PHEV converters, FreedomCAR Tech Teams, & others**
  - **Third draft to be distributed all PHEV Stakeholders**

# PHEV Baseline Performance Testing

- Initial track testing conducted by ETA near Phoenix
  - Testing includes coastdown (determination of dynamometer coefficients), acceleration, top speed, charging, & durability
- Five day dynamometer testing regime performed at Argonne
  - Testing includes at least 26 drive cycle tests
  - Charge depleting & sustaining test cycles
  - UDDS, HWFEDs & US06 cycles
  - Includes air conditioning (AC) off & on cycles

# PHEV Baseline Performance Testing – cont'd

- If vehicle option, conduct Rechargeable Energy Storage System (RESS) Only mode baseline performance testing with & without A/C:
  - Day 1, RESS Only mode – A/C off
    - UDDS, UDDS, HWFEDS, HWFEDS
    - UDDS, UDDS, HWFEDS, HWFEDS
    - Repeat as able, than charge traction battery
  - Day 2, RESS Only mode – A/C on
    - UDDS, UDDS, HWFEDS, HWFEDS
    - UDDS, UDDS, HWFEDS, HWFEDS
    - Repeat as able



# PHEV Accelerated Testing

- Accelerated testing in Phoenix over 4,240 miles
- GPS units track distance, average & maximum speeds

Cycle (mi)	Urban (10 mi)	Highway (10 mi)	Charge (hr)	Reps (N)	Total (mi)	Reps (%)	Miles (%)	Cum. (mi)
10	1	0	4	60	600	45%	14%	600
20	1	1	8	30	600	23%	14%	1200
40	4	0	12	5	200	4%	5%	1400
40	2	2	12	5	200	4%	5%	1600
40	0	4	12	5	200	4%	5%	1800
60	2	4	12	10	600	8%	14%	2400
80	2	6	12	8	640	6%	15%	3040
100	2	8	12	6	600	5%	14%	3640
200	2	18	12	3	600	2%	14%	4240
<b>Total</b>	<b>1740</b>	<b>2500</b>	<b>984</b>	<b>132</b>	<b>4240</b>			<b>4240</b>
<b>Average</b>	<b>41%</b>	<b>59%</b>	<b>7.5</b>	<b>32.1</b>				



# AVTA PHEVs Currently Being Tested

- EnergyCS Prius – 9 kWh Valence lithium pack
  - Completed baseline performance testing
  - Completed 1,000 miles of accelerated testing
- Hymotion Prius – 5 kWh A123 lithium (& Prius pack)
  - Completed baseline performance testing
  - Started accelerated testing
- Renault Kangoo - 9.6 kWh (measured usable) NiCad pack & 650 cc gasoline engine (series hybrid)
  - Completed baseline performance testing
  - Completed 600 miles of accelerated testing
- Additional vehicles in cooperation with NYSERDA



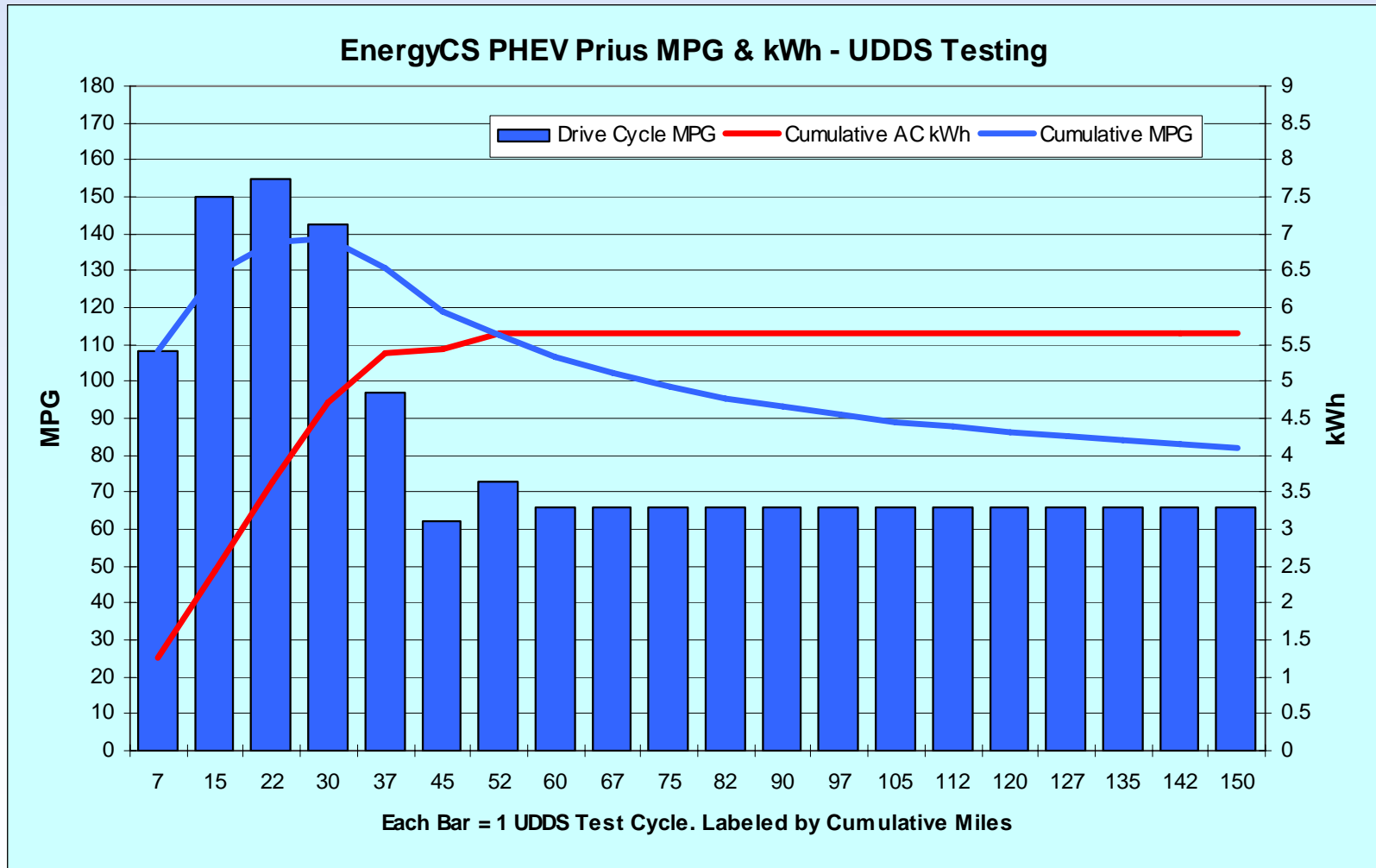
# NYSERDA PHEVs Testing Status

- Support NYSERDA's PHEV deployment by conducting baseline performance & accelerated testing on six PHEV conversion models
  - EnergyCS Prius: testing AVTA vehicle as surrogate. Vehicle delivered to New York
  - Hymotion Prius: testing AVTA vehicle as surrogate. Vehicle delivered to New York
  - Hymotion Civic: June delivery
  - Hymotion Escape: June delivery
  - Electovaya Escape: June delivery
  - HybridsPlus Prius: July delivery
  - Some rolling delivery delays



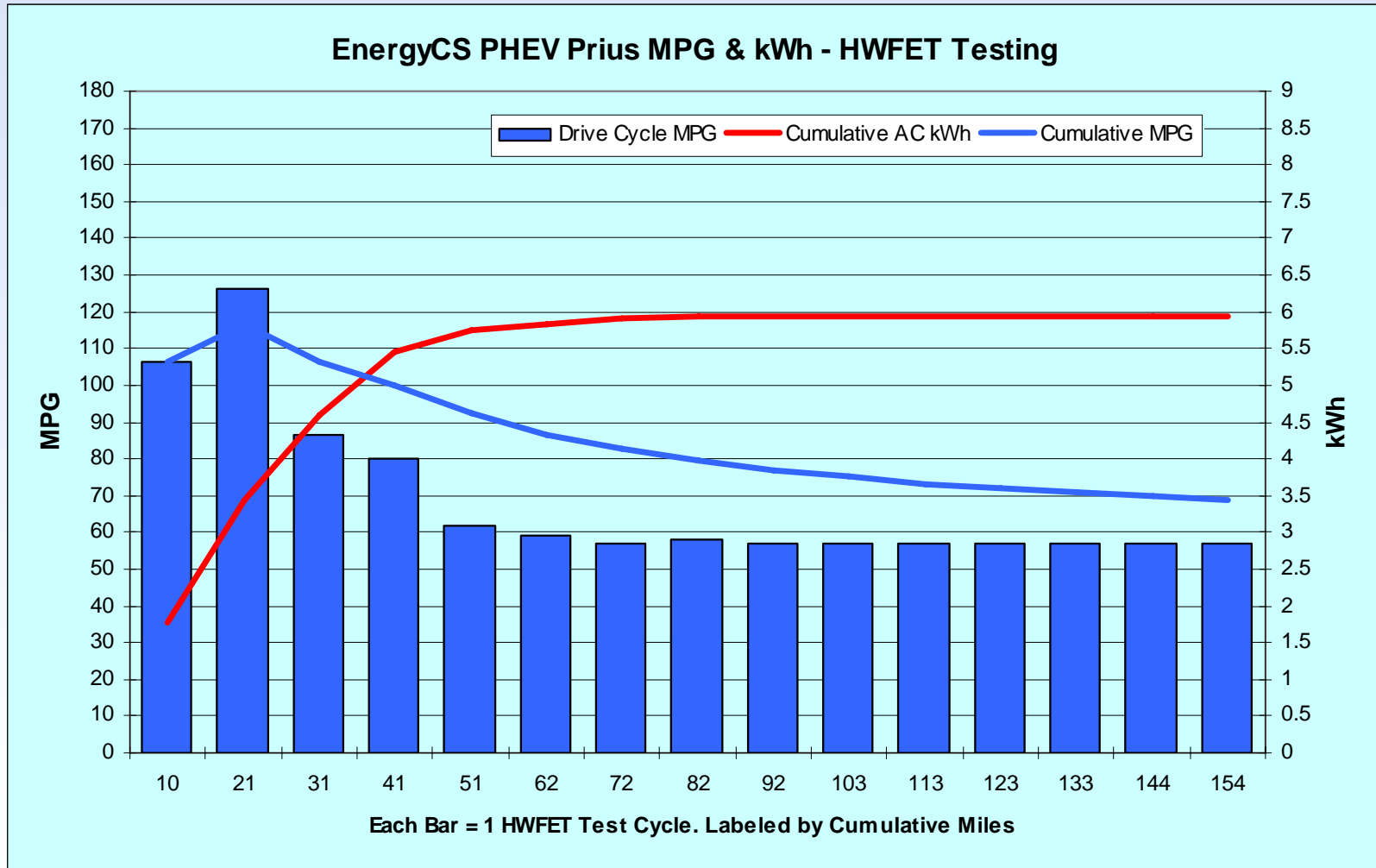
# EnergyCS Prius – UDDS Fuel Use

- kWh – A/C at the wall



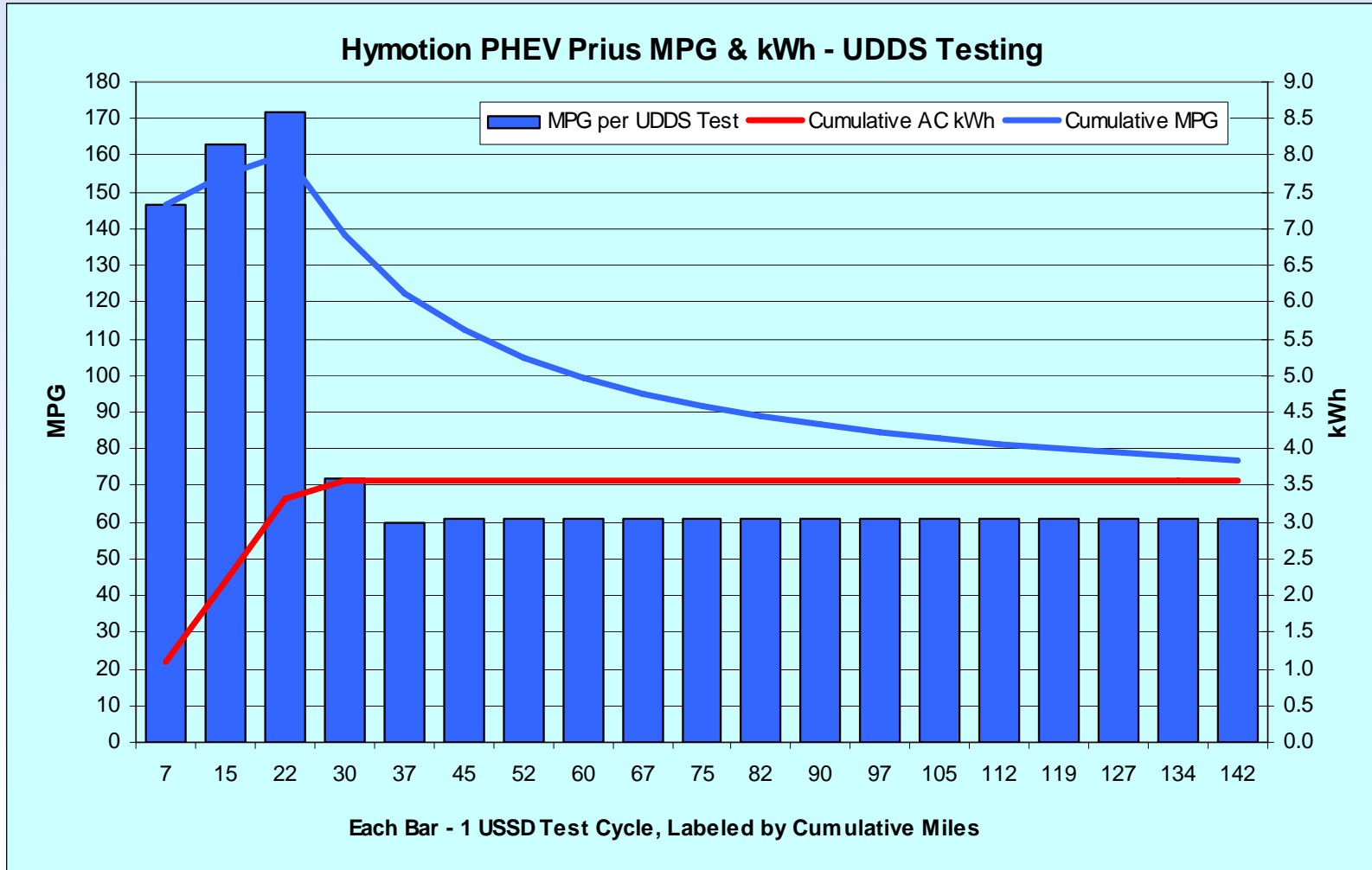
# EnergyCS Prius – HWFET Fuel Use

- kWh – A/C at the wall



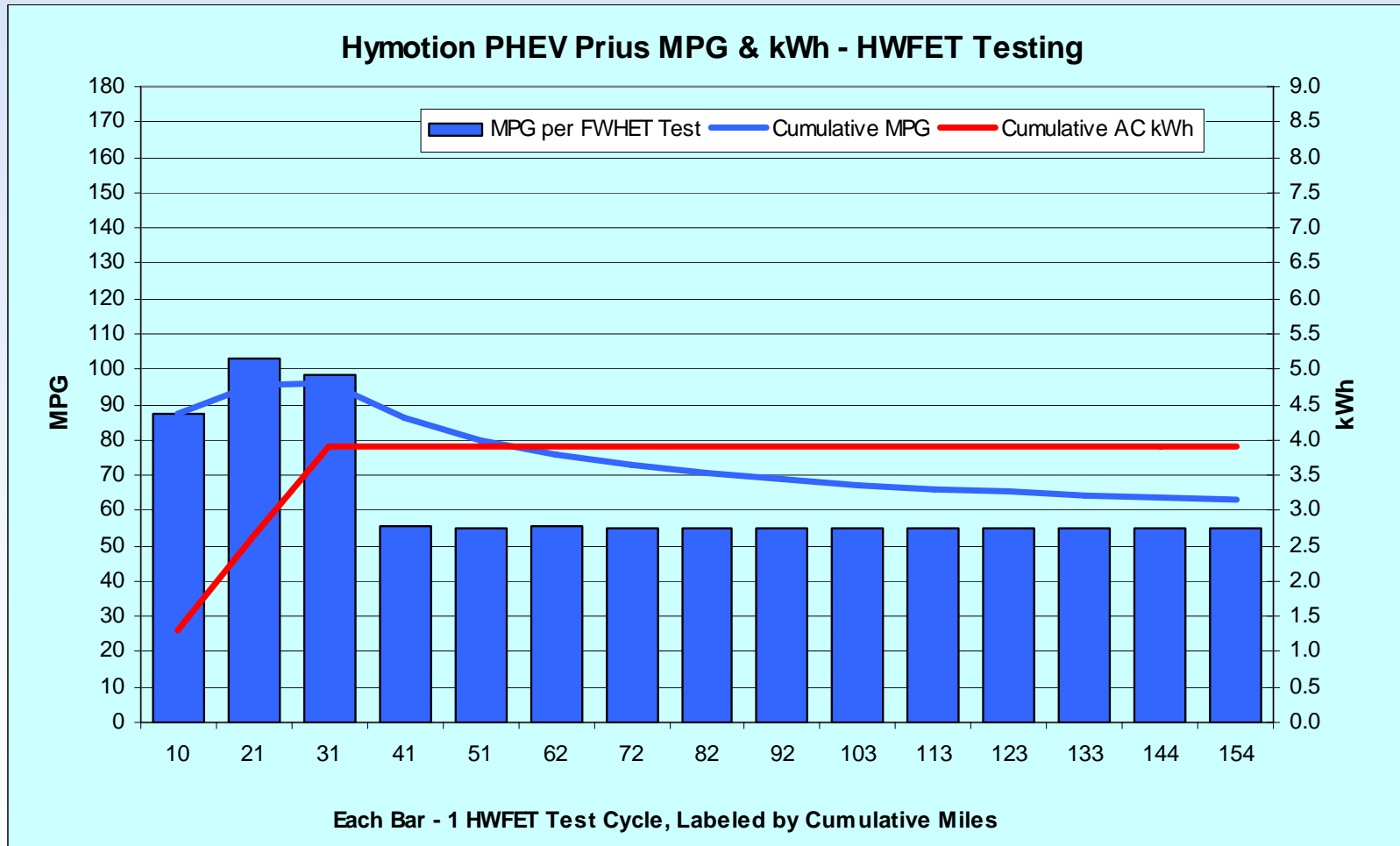
# Hymotion Prius – UDDS Fuel Use

- kWh – A/C at the wall



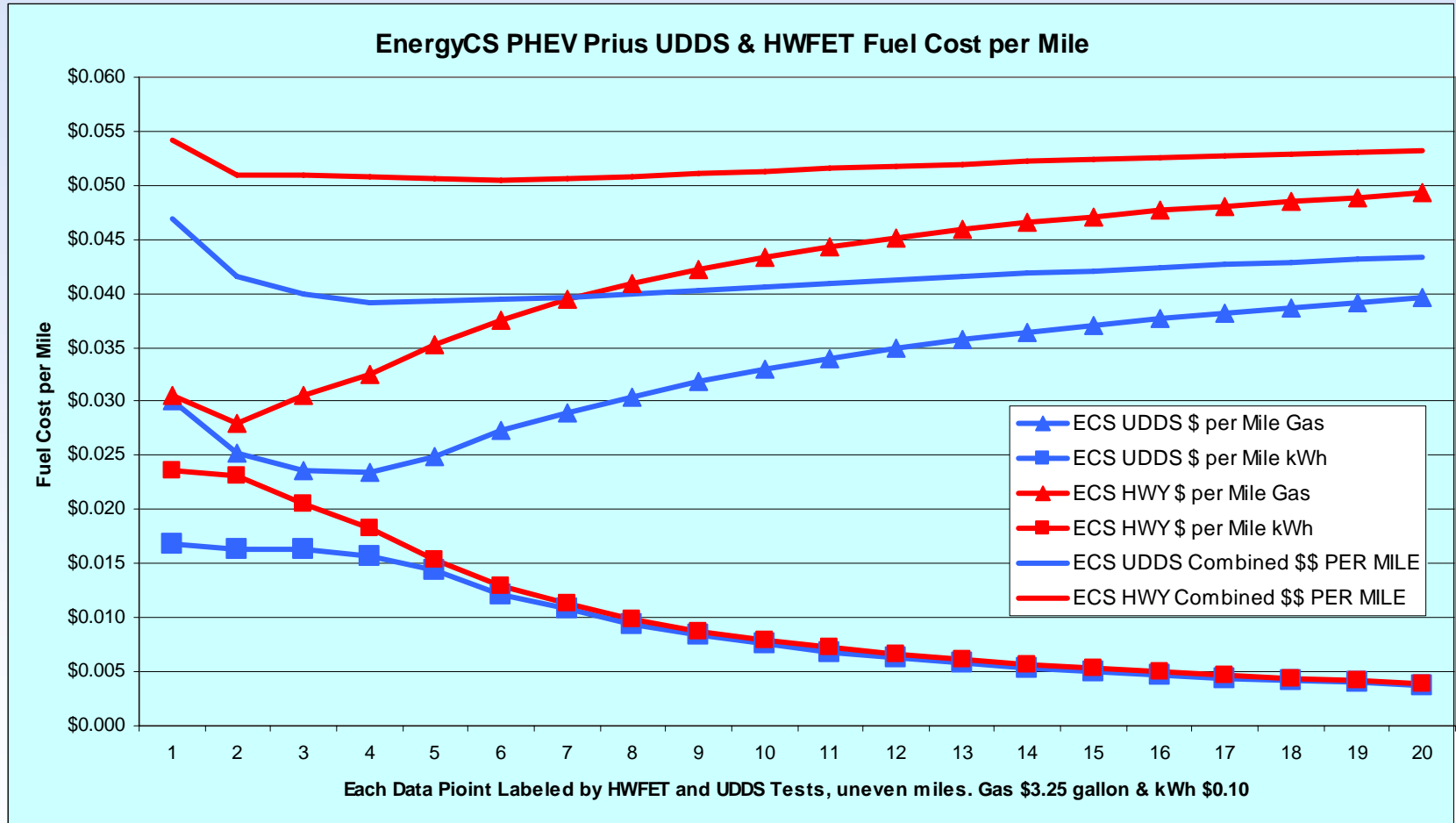
# Hymotion Prius – HWFET Fuel Use

- kWh – A/C at the wall



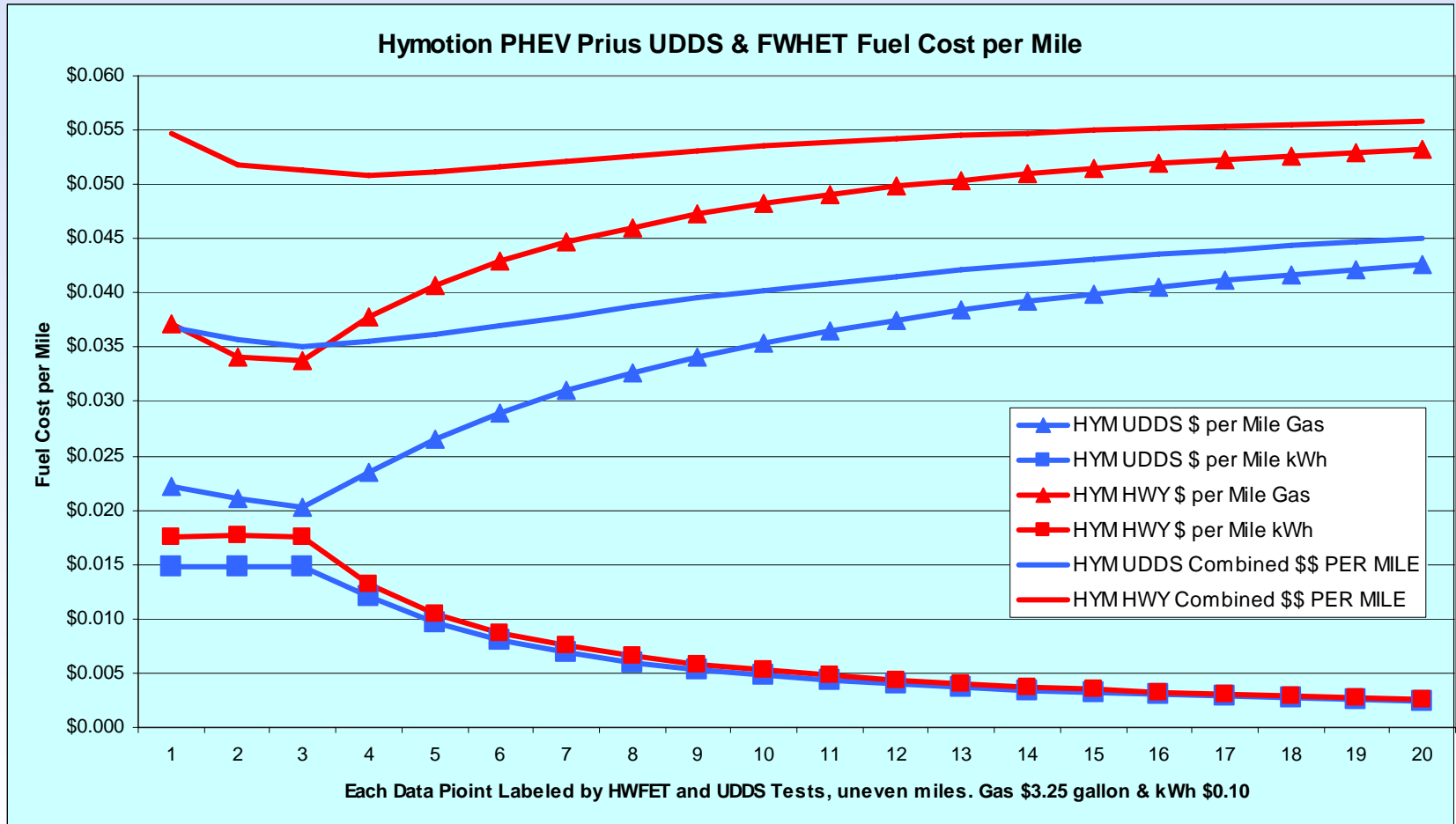
# EnergyCS Prius – Fuel Costs

- kWh – A/C at the wall



# Hymotion Prius – Fuel Costs

- kWh – A/C at the wall





# EnergyCS Prius Accelerated Testing

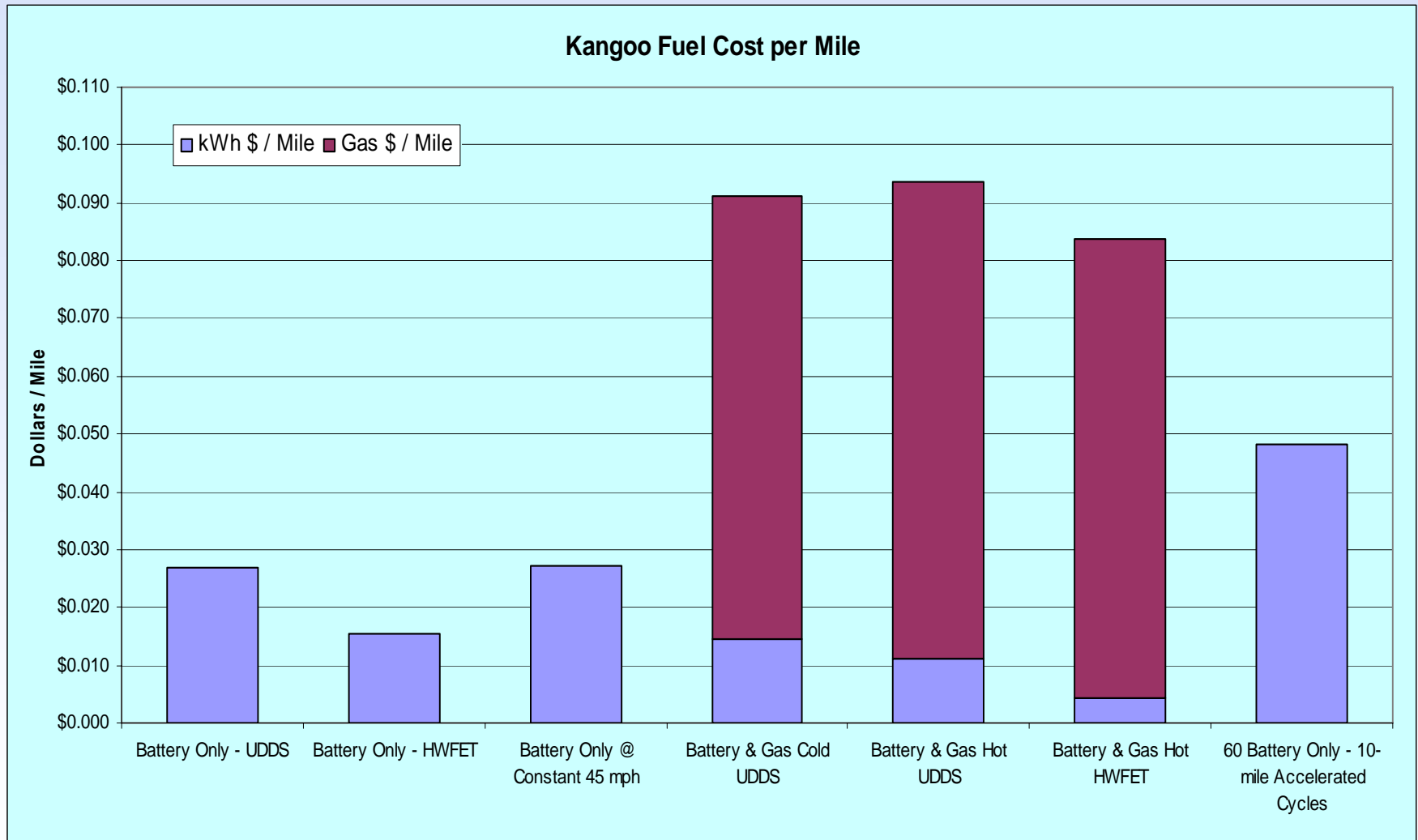
Cycle (mi)	Urban (10 mi)	HWY (10 mi)	Charge (hr)	Reps (N)	Total (mi)	Actual (mi)	MPG	Miles / kWh
40	2	2	12	5	200	206	144.3	6.87
40	0	4	12	5	200	208	85.5	7.17
60	2	4	12	10	600	621	103.7	10.02
<b>Total</b>	<b>4</b>	<b>10</b>	<b>240</b>	<b>20</b>	<b>1,000</b>	<b>1,035</b>	<b>109.1</b>	<b>8.82</b>
					<b>Gas \$ / Mile</b>	<b>kWh \$ / Mile</b>	<b>Total Fuel \$ / Mile</b>	
40	2	2	12		\$0.023	\$0.015	\$0.037	
40	0	4	12		\$0.038	\$0.014	\$0.052	
60	2	4	12		\$0.031	\$0.010	\$0.041	
<b>Weighted Average - (miles)</b>					<b>\$0.031</b>	<b>\$0.012</b>	<b>\$0.043</b>	

- Assumes gasoline \$3.25 / gallon & \$0.10 kWh

# Kangoo – Test Results

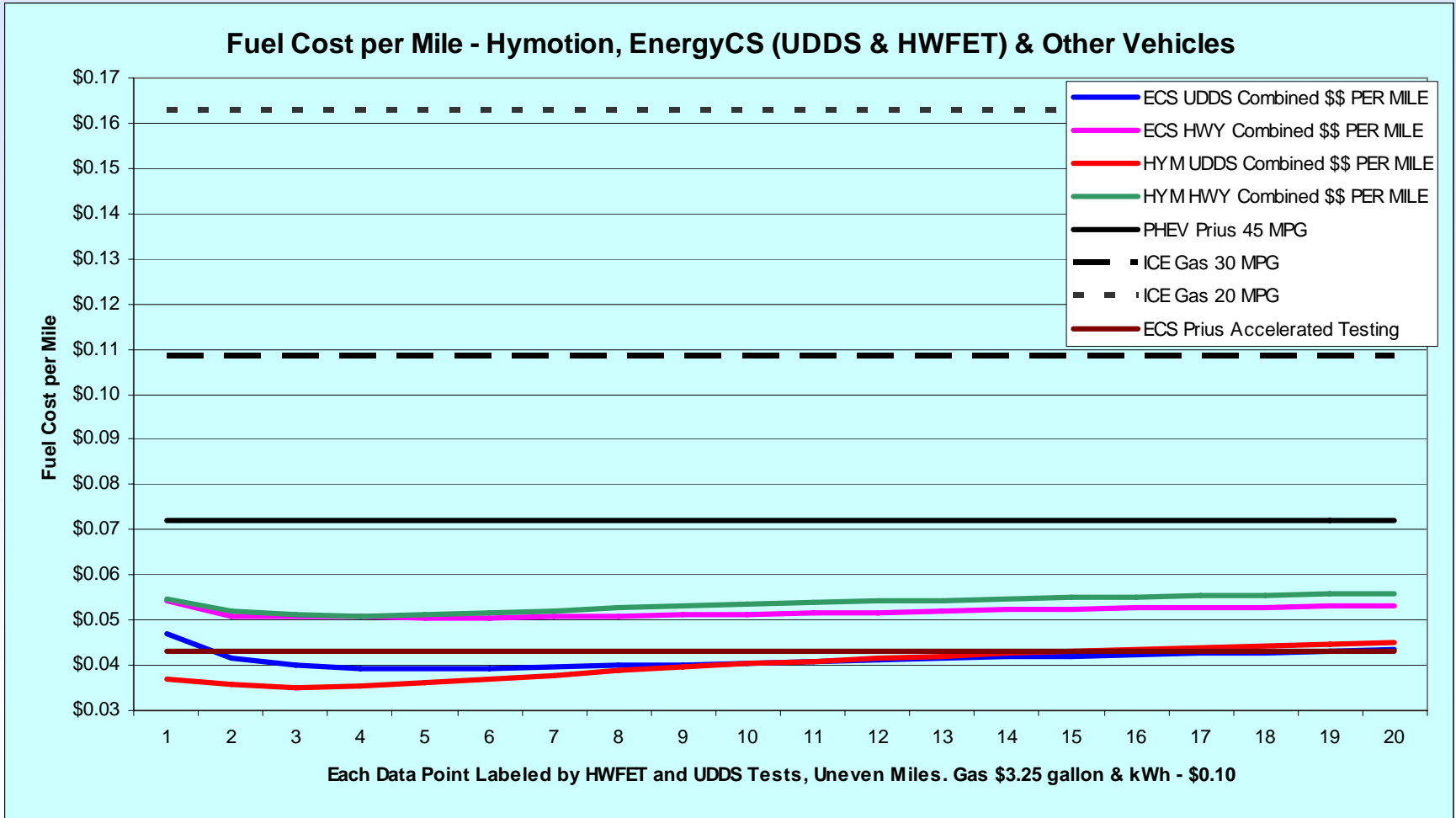
Test Cycle	A/C kWh per Mile	Miles per Gallon
Battery Only - UDDS	0.268	
Battery Only - HWFET	0.155	
Battery Only @ Constant 45 mpg	0.271	
Battery & Gas Cold UDDS	0.144	42.3
Battery & Gas Hot UDDS	0.110	39.4
Battery & Gas Hot HWFET	0.042	40.9
60 Battery Only 10-mile Accelerated Cycles	0.481	

# Kangoo – Fuel Cost per Mile



# Combined ECS & Hymotion Fuel Costs

- kWh – A/C at the wall



# PHEV (ECS/HYM) Payback Assumptions

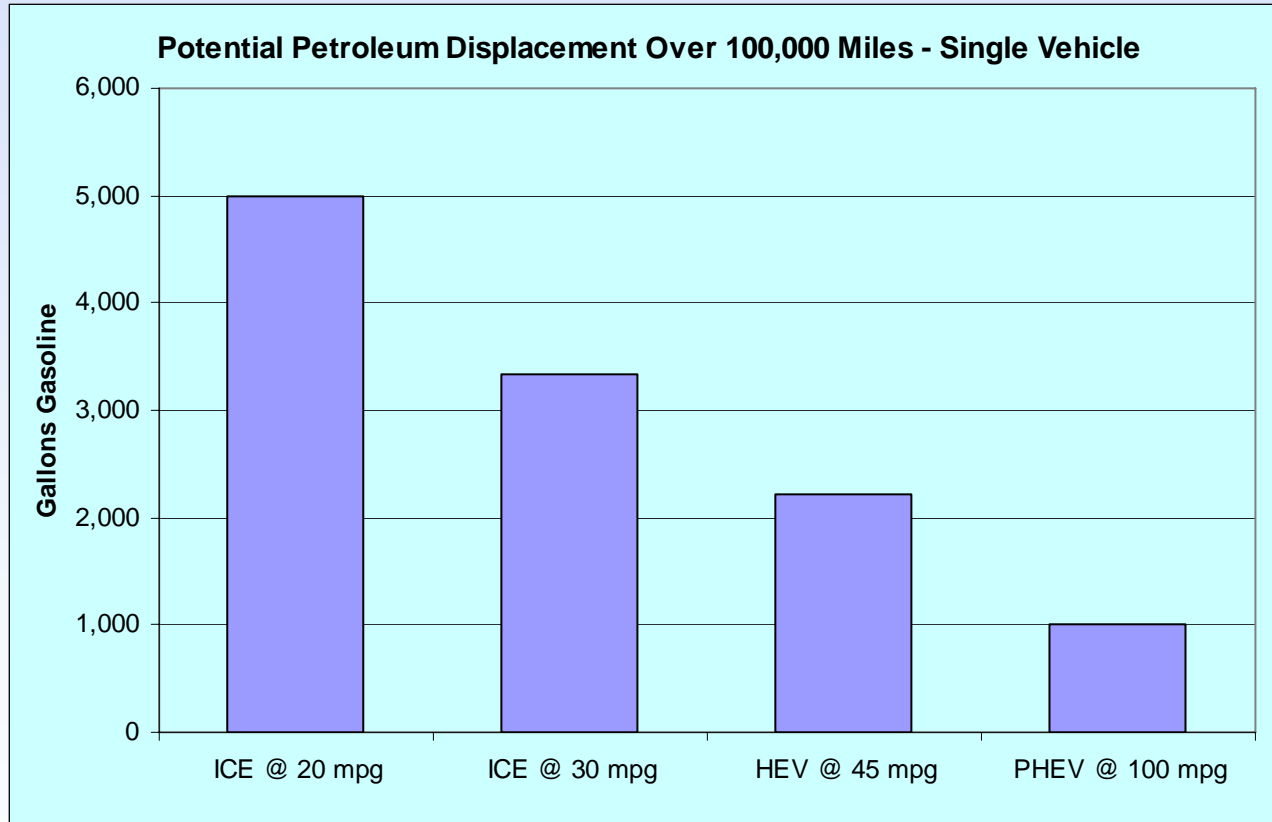
- Average gas & kWh costs - driving 40 & 60 miles / day
  - Both PHEVs in UDDS average: ~\$0.039 / mile
  - Both PHEVs in HWFET average: ~\$0.051 / mile
  - EnergyCS accelerated test: ~\$0.043 / mile
- Versus HEV Prius @ 45 mpg: \$0.072
- AVTA's PHEVs cost from \$15k to \$40k (\$40k includes data logger). Using \$15 and \$30k (assumes no data logger), average incremental PHEV cost is \$22.5k
- Ignores additional battery replacement costs & any additional costs if a vehicle warranty is voided
- Payback = PHEV incremental cost compared to lower PHEV fuel cost per mile than HEV fuel cost per mile

# PHEV (ECS/HYM) Payback

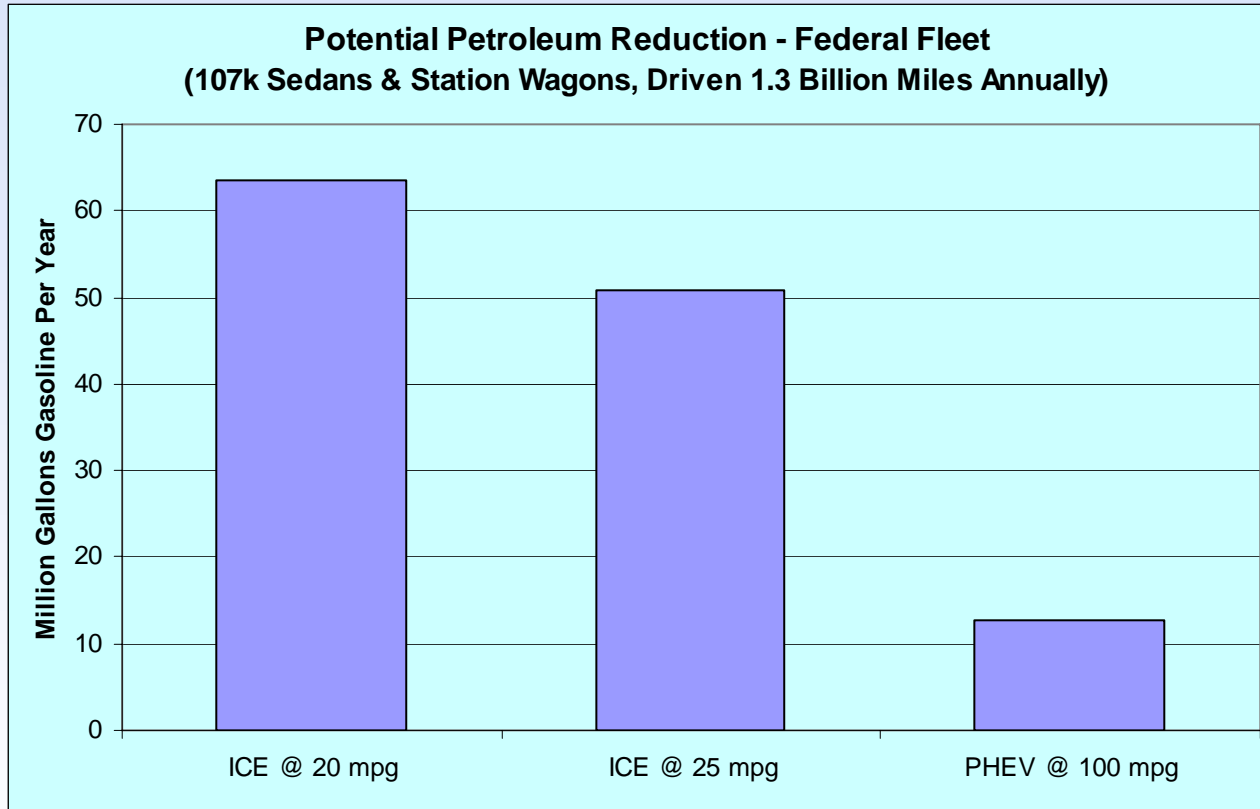
	Miles Driven Per Day	Fuel Savings Per Mile	Conversion Cost	Miles to Payback	Years to Payback
HWFET	40	\$0.021	\$22,500	1,071,429	73
HWFET	60	\$0.021	\$22,500	1,071,429	49
UDDS	40	\$0.033	\$22,500	681,818	47
UDDS	60	\$0.033	\$22,500	681,818	31

- 40 miles / day = 14.6k miles / year. 60 miles / per day = 21.9k miles / year
- PHEV incremental cost = \$22.5k. \$3.25 gasoline & \$0.10 kWh
- **Based on UDDS fuel savings & PHEV DC kWh use**
  - **A 100,000-mile, 5-year payback, ~60 miles / day, = \$3,300 battery with 3.1 to 4.7 usable DC kWh**
  - **Assuming 70% maximum DOD, no life-time capacity loss, = battery with 4.4 to 6.7 DC kWh at \$3,300**

# Potential Petroleum Displacement for a Single Vehicle, Over 100,000 Miles

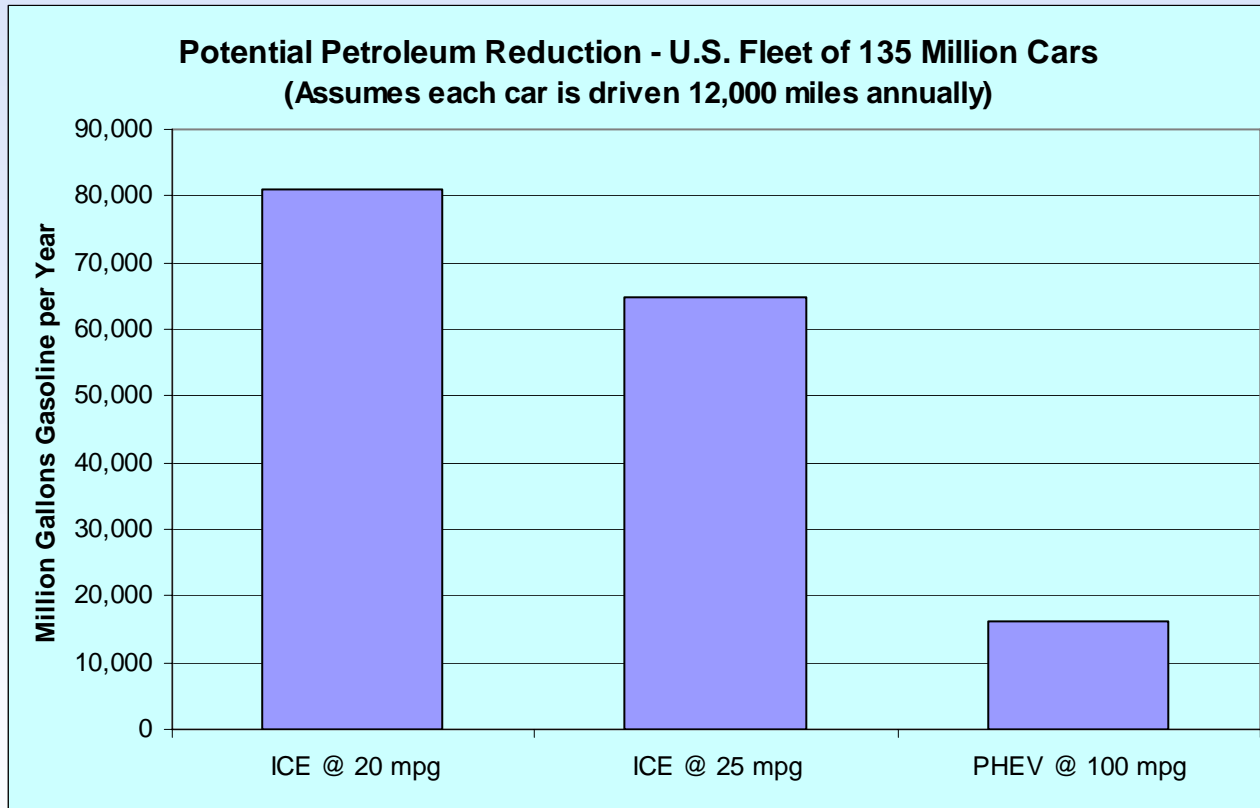


# Potential Annual Petroleum Displacement For Entire Federal Fleet of Passenger Cars





# Potential Annual Petroleum Displacement For Entire U.S. Fleet of Passenger Cars



# PHEV Additional / Future Testing

- Working with EnergyCS to collect onboard fleet data for vehicles operating in California, Canada & Arizona
- Working with Hymotion to collect fleet data on their 30+ vehicles already deployed
- Work with NYSERDA to collect fleet data on PHEVs introduced into New York State fleets
- Collect fleet data on any AVTA-operated PHEVs
- Possibly collect fleet data with SCAQMD
- Exploring other PHEV data collection opportunities
- The AVTA will continue to obtain viable PHEVs for baseline performance, accelerated, fleet & battery testing

# Acknowledgement

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Vehicle Systems Team Leader, Tien Duong  
Project Leader and VSATT Lead, Lee Slezak

## Additional Information

<http://avt.inl.gov>

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