U.S. Department of Energy, Vehicle Technologies Program, Advanced Vehicle Testing Activity (AVTA)

Plug-in Hybrid Electric Vehicles (PHEVs) Overview

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Local Climate Leadership Summit
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AVTA Background and Goals

- The Advanced Vehicle Testing Activity (AVTA) is part of DOE's Vehicle Technologies Program
- The AVTA goals:
  - Provide benchmark data to DOE, technology modelers, research and development programs, vehicle manufacturers (via VSATT), and target and goal setters
  - Assist fleet managers in making informed early adaptor vehicle purchase, deployment and operating decisions
- The AVTA is conducted by DOE's Idaho National Laboratory and Electric Transportation Engineering Corporation

AVTA Testing History

- **Plug-in hybrid electric vehicles (PHEV)**
  - **12 models, ~150 vehicles, 600,000 fleet test miles**
- **Hybrid electric vehicles (HEV)**
  - **14 models, 39 vehicles, 5 million test miles**
- **Hydrogen ICE (internal combustion engine) vehicles**
  - **7 models, 400,000 test miles**
- **Full-size battery electric vehicles (BEVs)**
  - **40 EV models, 5+ million test miles**
- **Neighborhood electric vehicles**
  - **21 models, 200,000 test miles**
- **Urban electric vehicles**
  - **3 models, 1 million test miles**

PHEV Advantages

- Reduced petroleum consumption and emissions
- Recover energy during regenerative braking
- Use existing gas station infrastructure
- Minimal electric grid changes needed - add connector and electric vehicle supply equipment (EVSE)
- At home battery charging, well below cost of gasoline
- Zero emission potential (local)
- Lower fuel costs compared to HEVs
- Energy security by displacing imported petroleum with domestically generated electricity
- Potential for off-peak charging

Primary Source Electric Drive Transportation Association (EDTA)
http://www.electricdrive.org/index.php?ht=d/Articles/cat_id/5599/pid/9673

PHEV Challenges

- Cost and complexity of two powertrains
- Drivers adapting to dual-fueling scenario
- Component availability - batteries, powertrains, power electronics (early challenge)
- Higher initial capital cost
- Cost of batteries and potential battery replacements
- Added weight
- Probable need for public recharging infrastructure
- Challenge to move charging to off-peak times
- If large PHEV batteries are successful, will BEVs replace PHEVs?

Primary source EDTA
http://www.electricdrive.org/index.php?ht=d/Articles/cat_id/5599/pid/9673

12 PHEVs Models in AVTA Testing / Demos

- Hymotion Prius (A123Systems) – only PHEV conversion crash tested and limited CARB exemption
- Hymotion Escape (A123Systems)
- Ford E85 Escape (Johnson Controls/Saft)
- EnergyCS Prius, 2 models (Valance and Altair Nano)
- Electrovaya Escape (Electrovaya)
- Hybrids Plus Escape, 2 models (Hybrids Plus and K2 Energy Solutions)
- Hybrids Plus Prius (Hybrids Plus)
- Manzanita types of Prius (lead acid)
- Manzanita Prius (Thunder Sky)
- Renault Kangoo (Saft NiCad)
- All Lithium unless

PHEV Testing

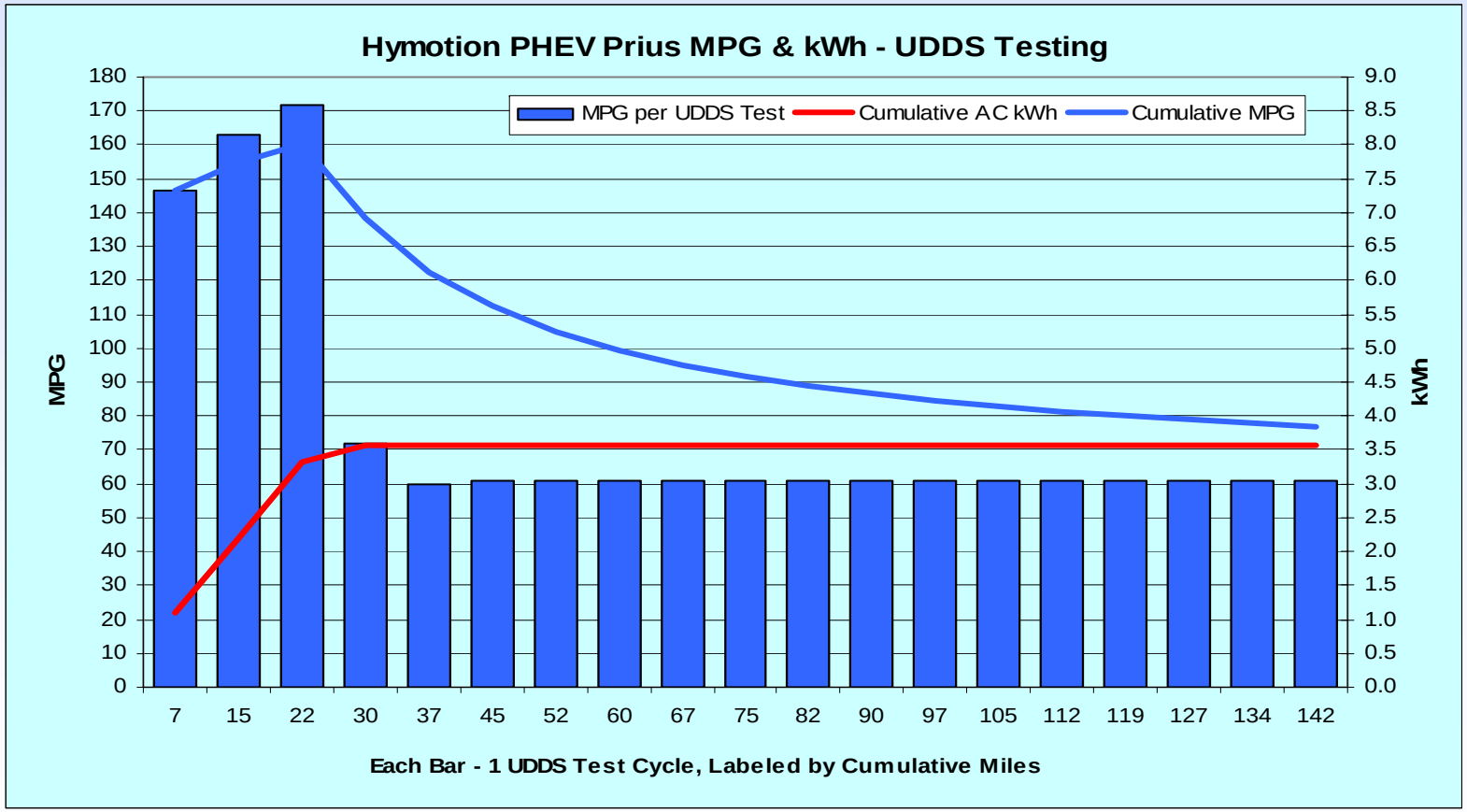
- **Testing used to document:**
  - **Battery life, charging patterns and profiles**
  - **Vehicle operations, fuel use (electricity and gasoline) and infrastructure requirements**
  - **Driver influences on fuel use**
  - **Individual PHEV models and PHEV concepts**
  - **PHEV life-cycle costs**

PHEV Battery and Operating Modes

- **Today's PHEVs either have a single battery pack, or a HEV battery and a PHEV pony battery pack**
- **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. Therefore, 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 electric drive propulsion in the PHEV battery. Therefore, the battery SOC is being depleted during the trip**
- **Mixed CD/CS mode – there is energy in the battery pack at the start of a single trip, but the battery is fully depleted before the trip ends**
- **Electric propulsion is either in the form of all-electric or electric-assist (ICE is also providing propulsion power)**

Hymotion Prius Gen I – UDDS Fuel Use

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



Hymotion Prius Gen I – 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	2340	3100	1404	167	5,440	Weighted Average		79.5

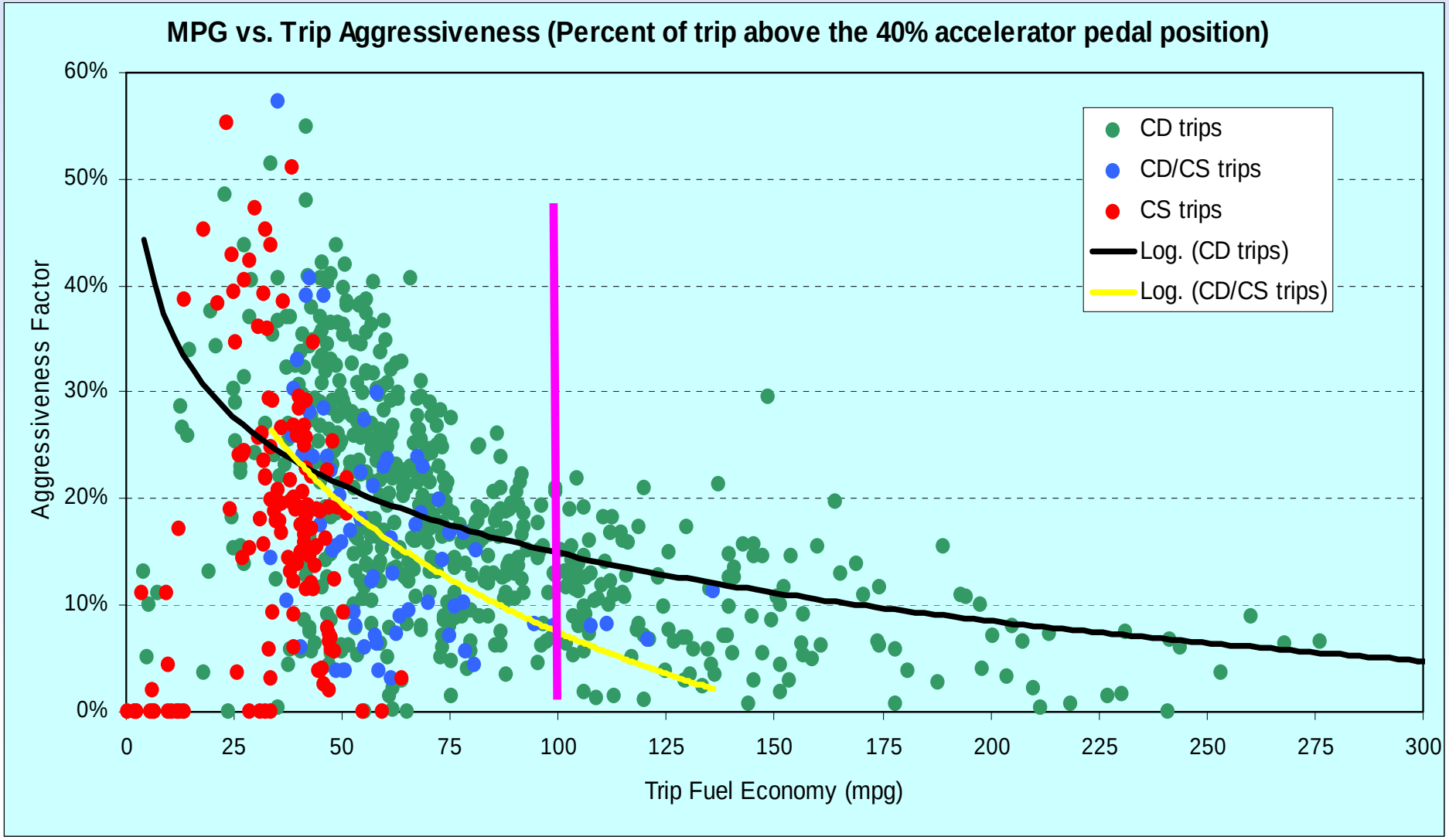
Each total distance slightly greater than 600 and 640 miles. HEV version = 44 mpg

Why Does PHEV MPG Vary So Much?

- 13 Hymotion Prius - May 2008

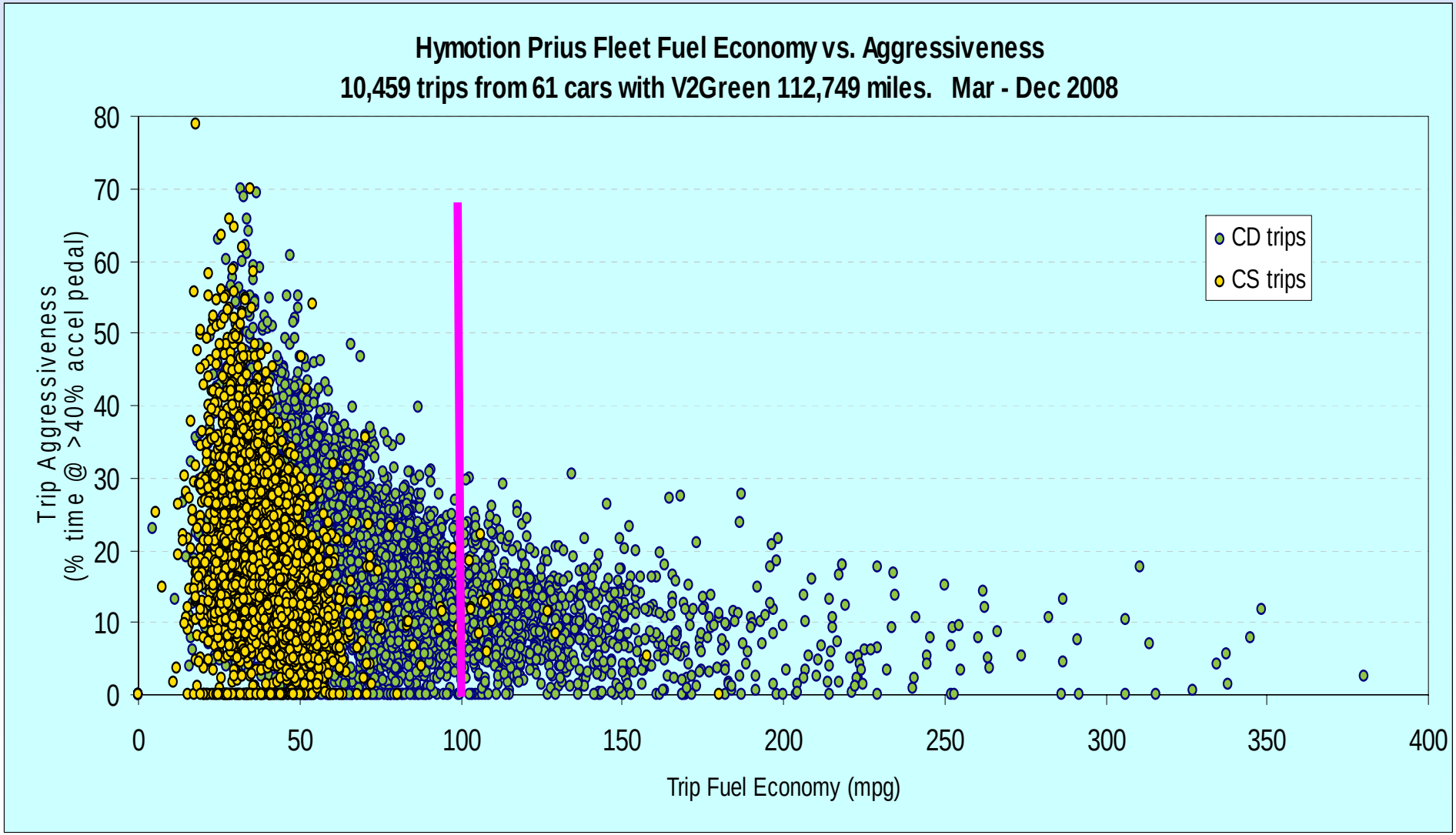
Charge / Operating Mode	# Trips	Total Distance (mi.)	Average Trip (mi.)	MPG	DC kWh\mi.
Charge Depleting (CD)	575	3,040	5.3	72.0	0.138
Mixed CD / CS	67	1,840	27.5	52.1	0.050
Charge Sustaining (CS)	133	1,411	10.6	40.2	
Electric vehicle only (EV)	137	127	0.9		0.236
Total	912	6,417	7.0		
CD, CS, CD/CS results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

PHEV MPG and Aggressive Driving



13 Hymotion Prius, 775 trips, 6,291 miles, May 2008

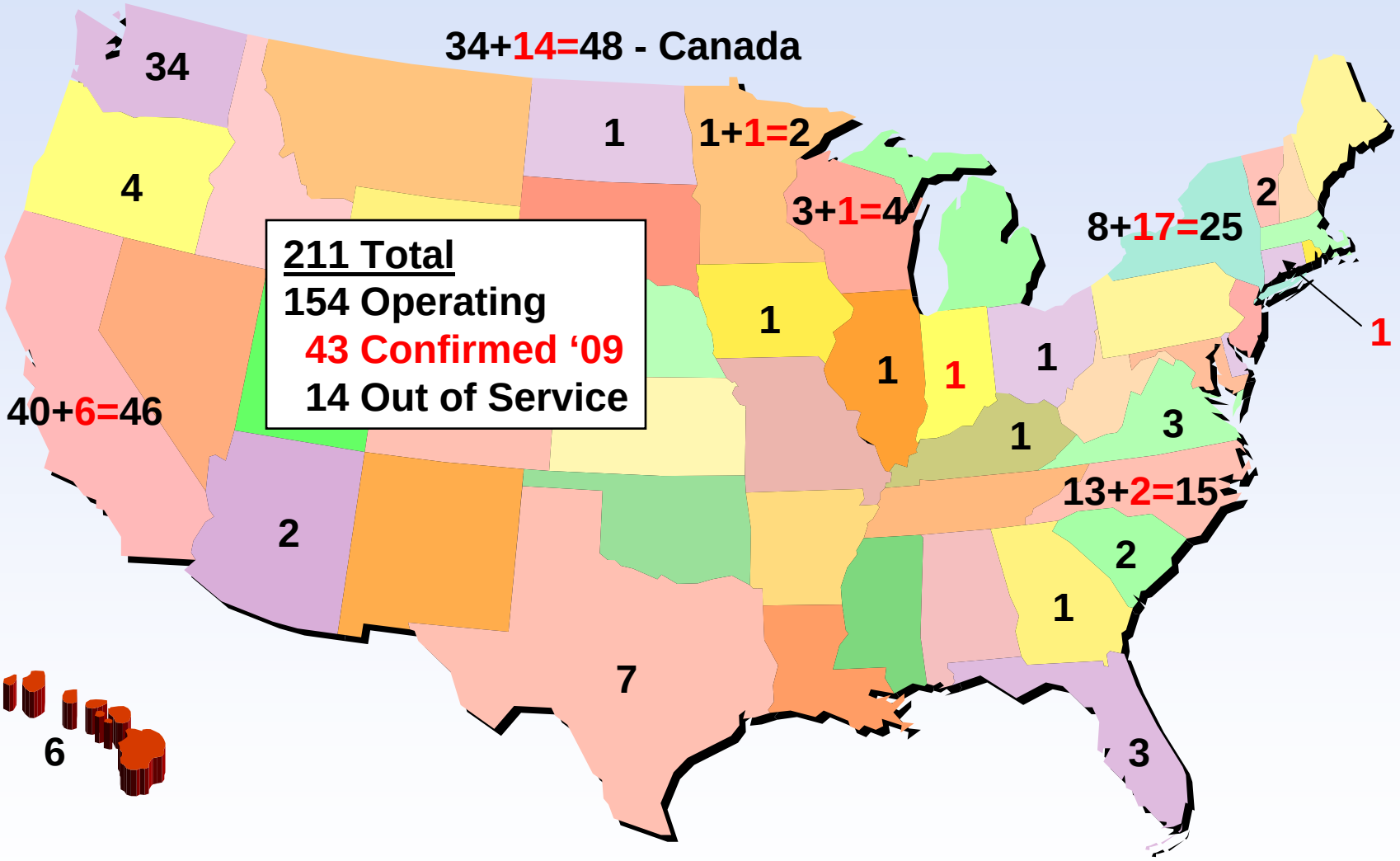
PHEV MPG and Aggressive Driving



PHEV Fleet Testing Partners

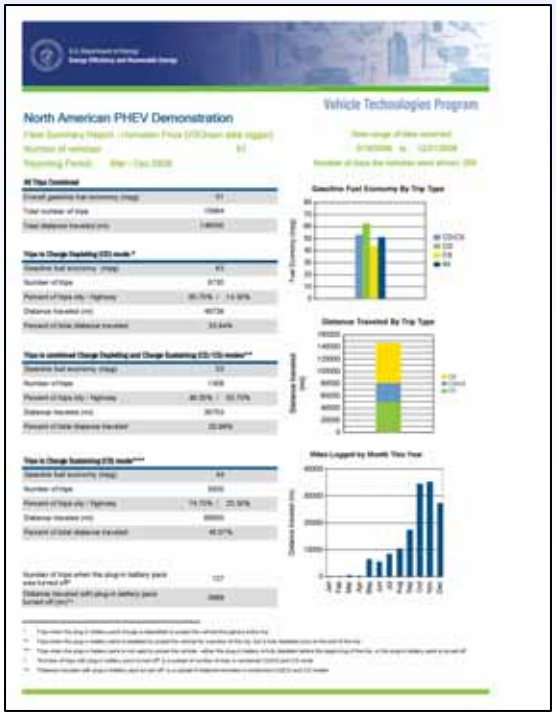
- 75+ testing partners in the U.S. and Canada:
  - 36 Electric utilities and 2 clean-air agencies
  - 10 City, county and state governments
  - 7 Private companies and advocacy organizations
  - 8 Universities and colleges and 4 Canadian provinces
  - 2 PHEV companies 1 sea port and 1 DOD facility
- Testing partners include:
  - A123Systems, EnergyCS, NYSERDA, NRECA, UC Davis, Fairfax County, Google.org, Austin Energy, Central Vt PSC, Duke Energy, Advanced Energy, Progress Energy, SDGE, Basin Electric, Buckeye Power, WI Public Power Inc., Madison GE, SCANA Corp., Port of Seattle, Seattle City Lights, HCATT

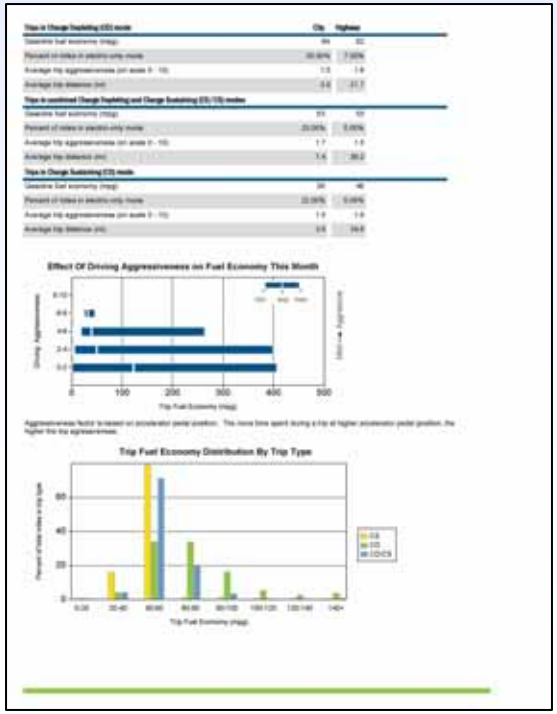
PHEV Fleet Testing

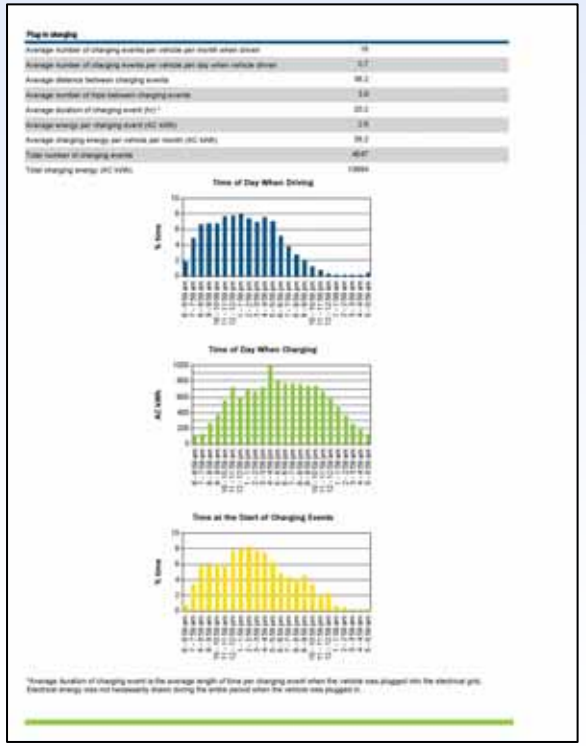


PHEV Fleet Testing Reports

- **Summary reports posted monthly on web**
- **Individual vehicle reports only go to the respective fleets each month, 740+ reports to date**
- **115 Hymotion Prius PHEVs, 484,682 miles, 50,501 trips, 12,754 charging events, 28,663 kWh used. V2Green and Kvaser data logger reports**

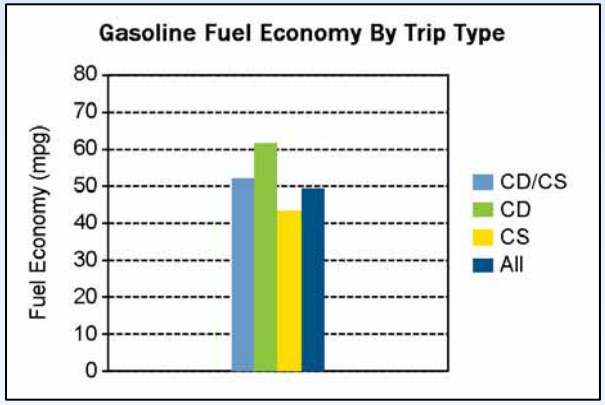


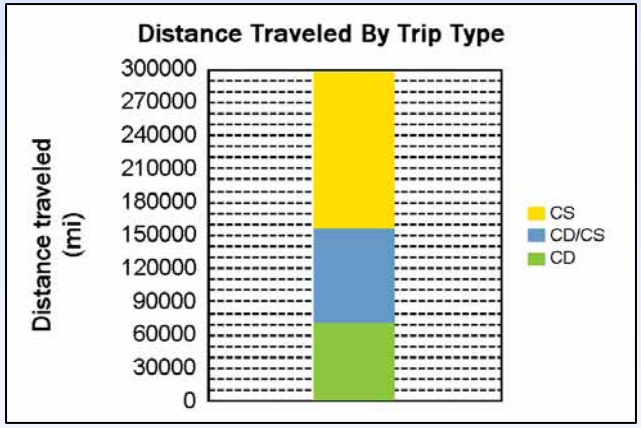


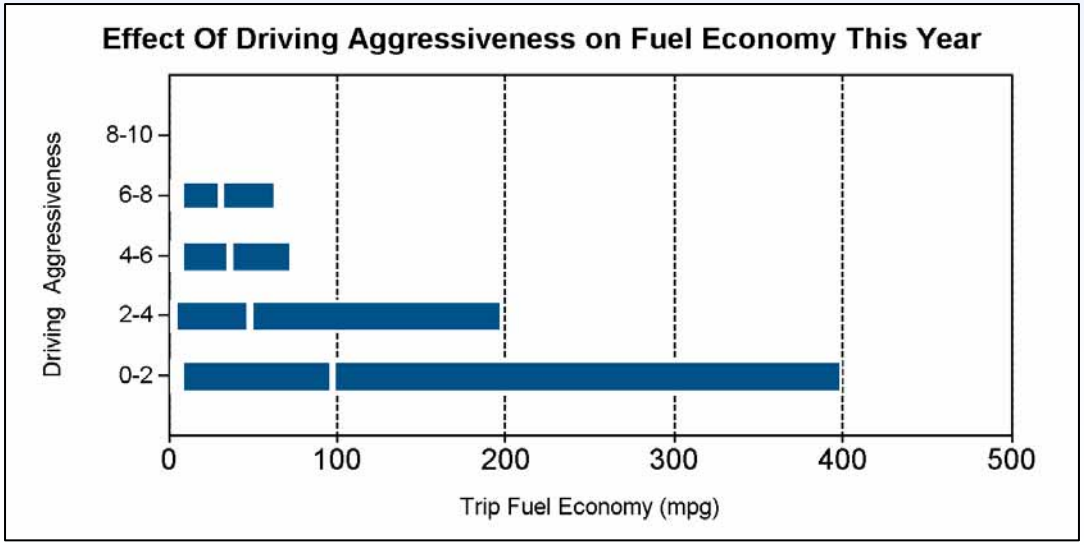


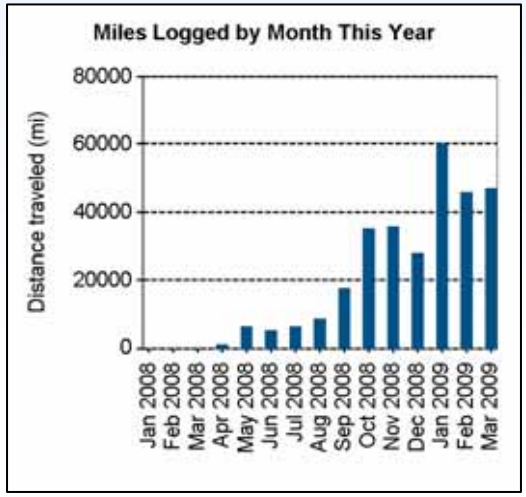
Fleet Testing Results

- **Hymotion Prius, with V2Green Data Logger. 03/08 to 03/09. 65 PHEVs, 296,558 miles, 30.099 trips, 7,290 charging events and 118,755 kWh used**

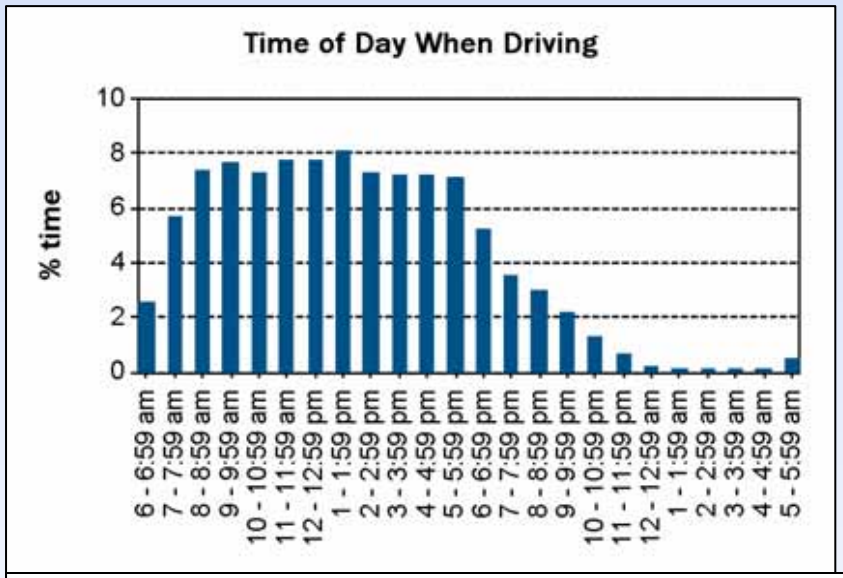


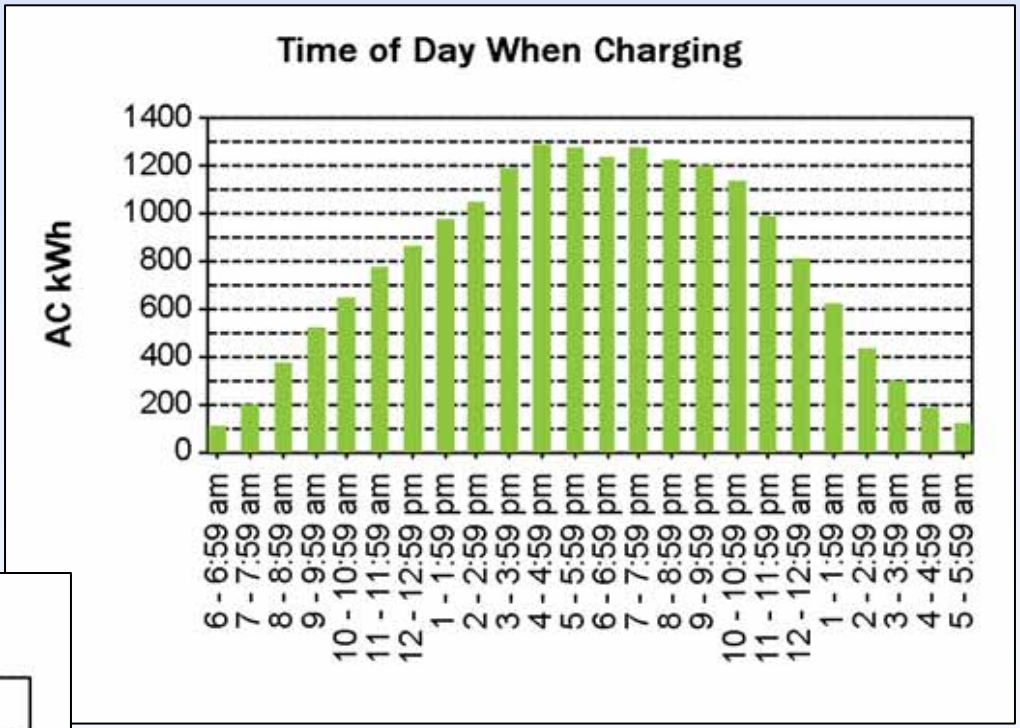


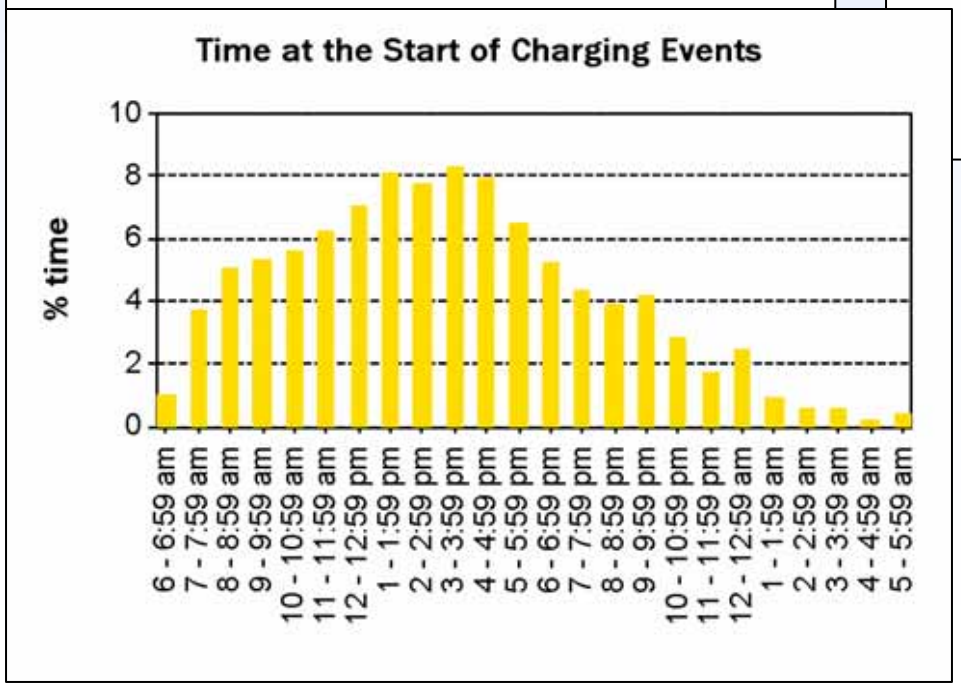




Fleet Testing Results – cont'd







Charging Infrastructure Terms

- **Level I – 110 / 120 VAC, 15 amp (12 amp continuous). Maximum 1.44 kW continuous. Onboard charger. NEMA5-15R receptacle, with GFCI**
- **Level II – 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. EVSE, mated to AC input and SAE J1722 connector to vehicle (the "plug")**
- **Level III – greater than Level II, generally off-board charger supporting more than one vehicle. Energy to vehicle can be 440 VDC or higher**
- **Fast Charge – Returns 50% of a battery's capacity in under 30 minutes. For large batteries, usually at Level III**
- **SAE J1722 – scheduled June 2009 vote. Defines standard connector up to ~70 amps**

PHEV Purchase Considerations

- Has the vehicle emissions been certified by CARB or the EPA, or received an exemption?
- Has the vehicle been crashed testing and FMVSS certified per NHTSA reporting requirements?
- Have truly independent testing results been published, such as DOE's AVTA testing?
- "Rich" charging environment may be less costly than increasing per vehicle battery size
- Current PHEVs have the potential to provide greater than 100 mpg – but maybe need a "better" PHEV driver
- Future PHEVs may provide controlled response to power demands
- Match mission to PHEV capabilities
- Consider the vehicle's ambient operating temperature
- Conversions need crash testing – Don't believe "its just another piece of luggage in the trunk"

Lithium Battery Performance

- **Applicable to NiMH and Lithium chemistries, the DOE / USABC HEV and PHEV battery goals are listed below**
- **Most lithium batteries are performing to or near the goals**

Temperature	Capacity based on performance at 30°C
0°C (32°F)	50%
-10°C (14°F)	30%
-30°C (-22°F)	10%
+50°C (122°F)	>100%

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 BEV
- 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

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 (maybe 2009)
- 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)

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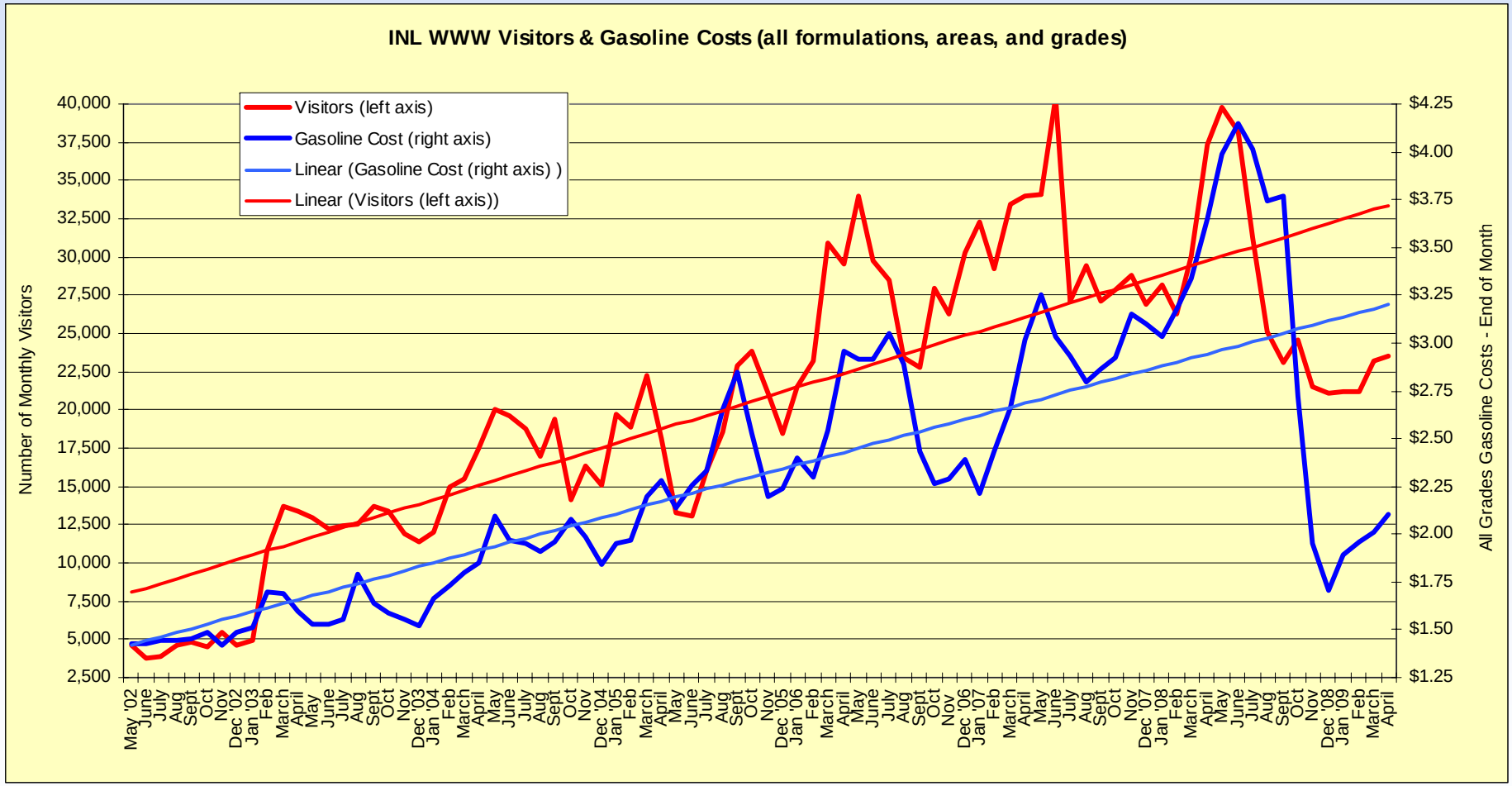
AVTA Webpage Use and Gasoline Costs



Acknowledgement

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Additional Information

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

INL/CON-09-15989