Plug-in Hybrid Electric Vehicles

Current Status, Long-Term Prospects and Key Challenges

Presented at Clean Cities Congress and Expo

by

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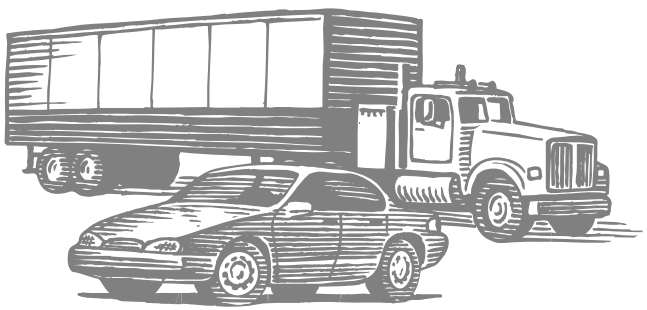
May 8th, 2006



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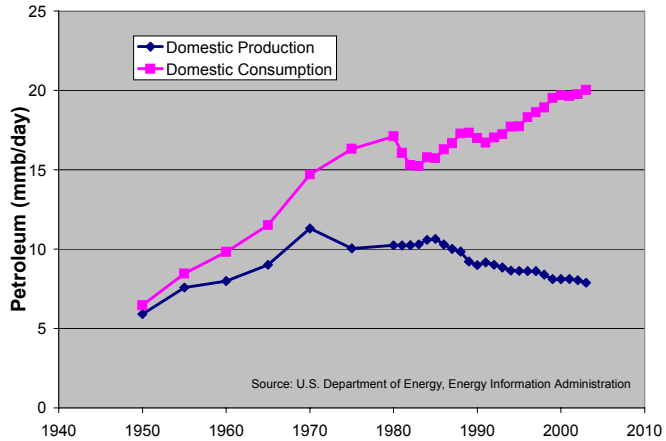
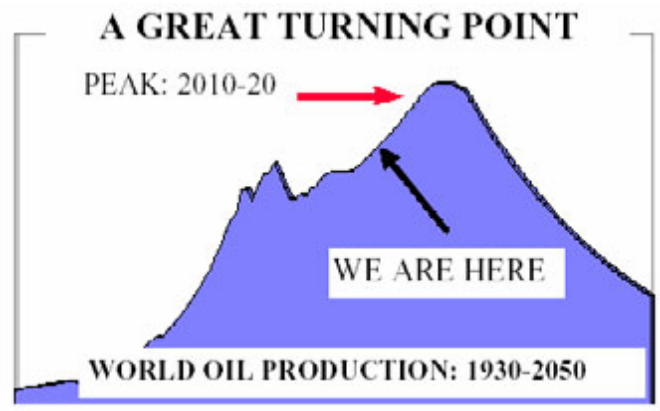
The Perfect Storm

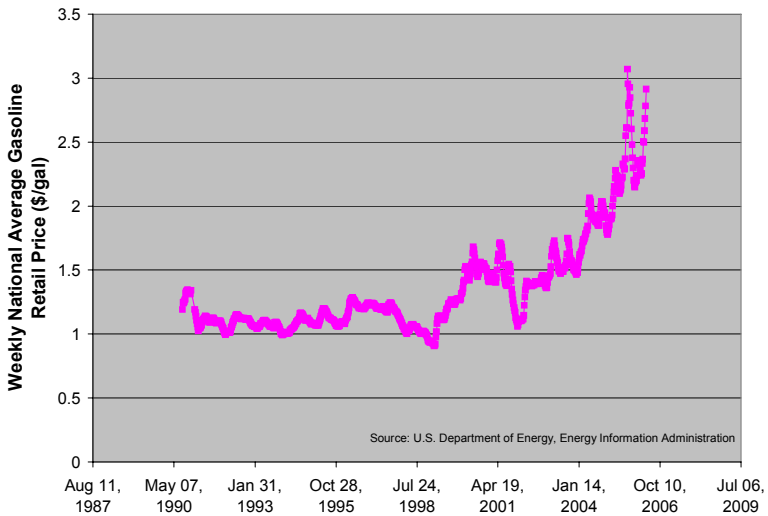
- Petroleum consumption has steadily increased while domestic production has continued to decline
- World oil production predicted to peak within the next 5-15 years
- Recent increase in gasoline price is indicator of growing tension between supply and demand





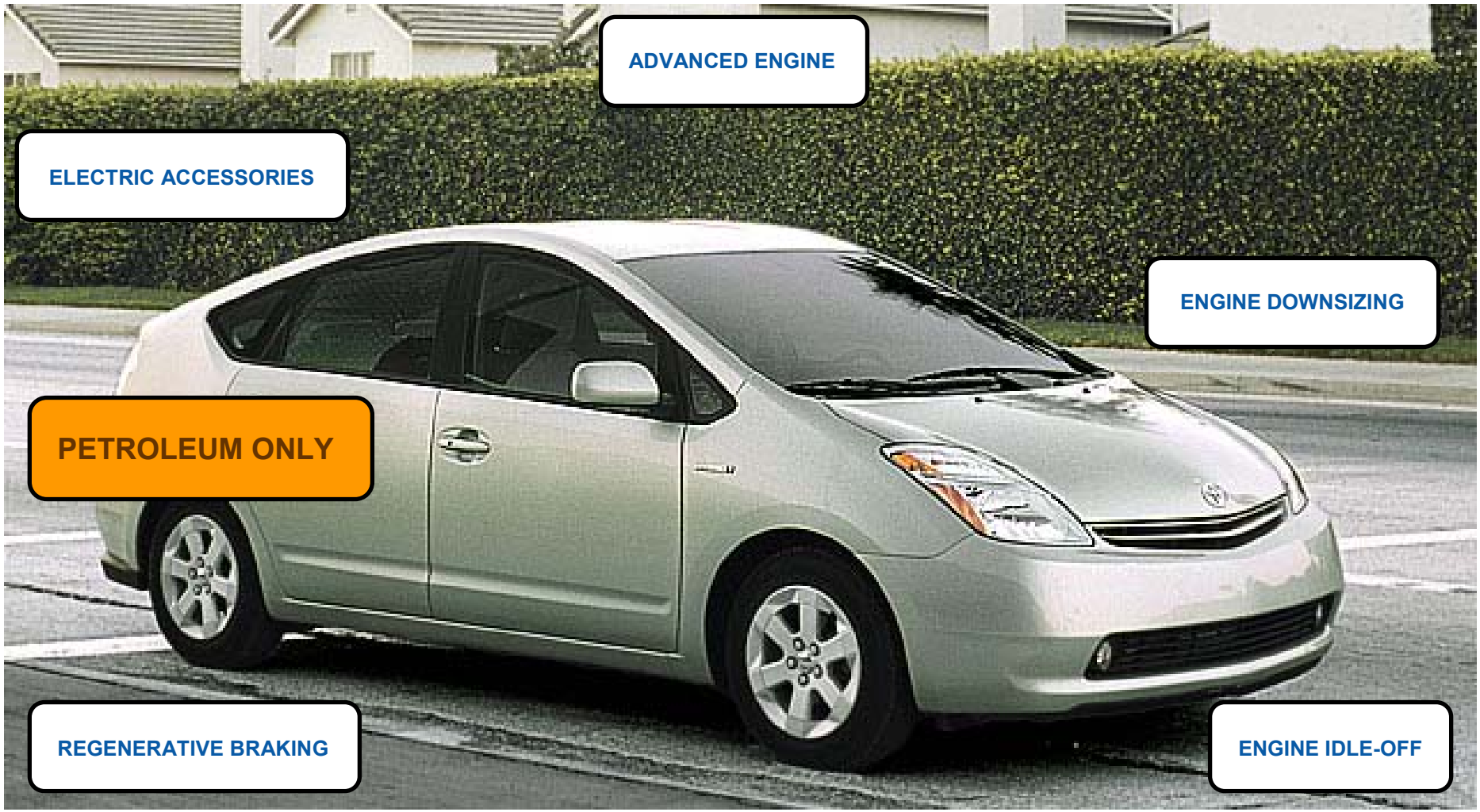
Source: Hubbert Center Newsletter #99/1 R. Udall and S. Andrews

Gasoline price - 85% rise in 5 years!



WHAT'S OUR PLAN?

A “Full” Hybrid



76hp gasoline engine, 67hp electric motor, 1.5kWh battery

A Plug-In Hybrid

ADVANCED ENGINE

Fuel Flexibility

ENGINE DOWNSIZING

ELECTRIC ACCESSORIES

PETROLEUM

AND/OR

ELECTRICITY

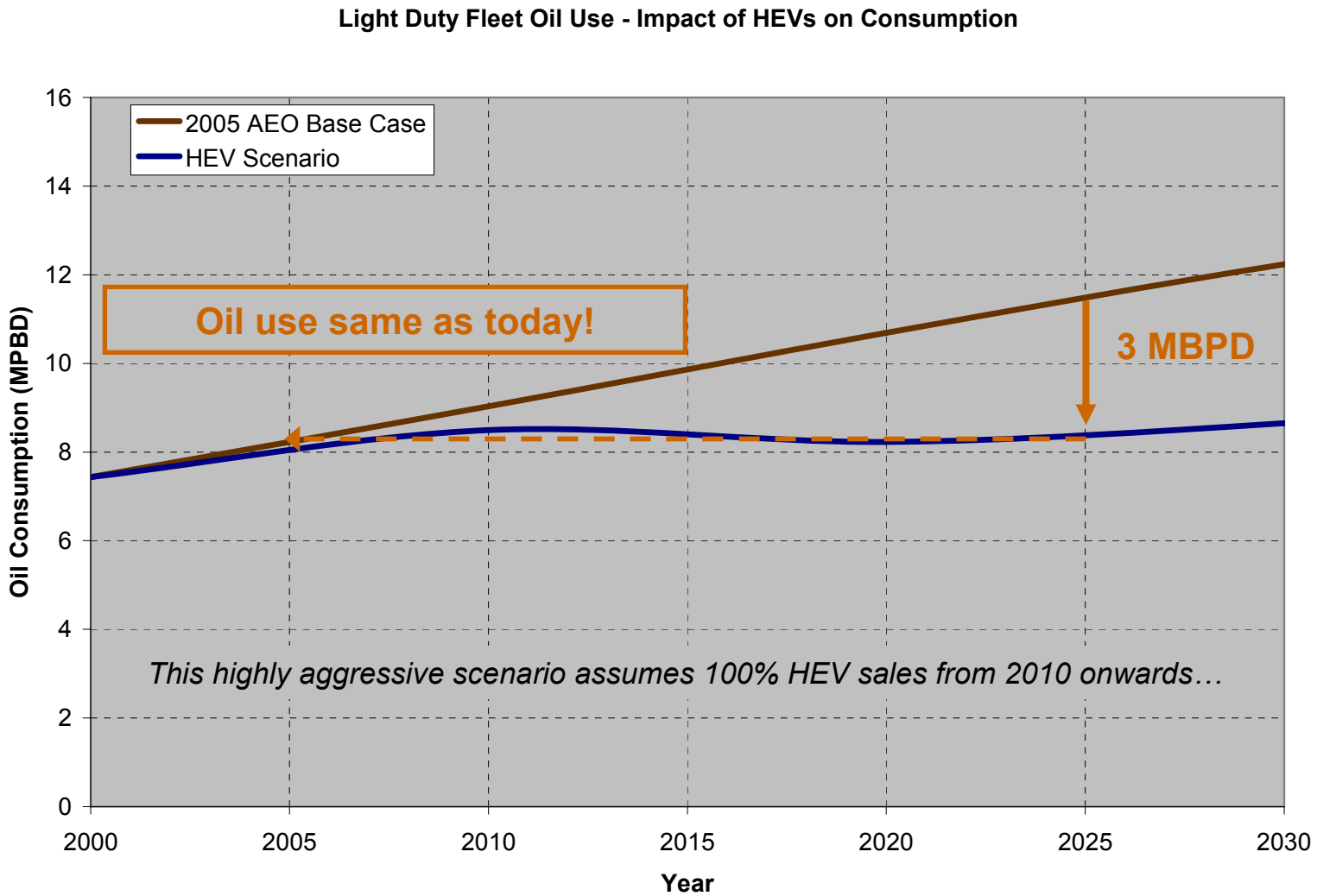
ENGINE IDLE-OFF

REGENERATIVE BRAKING

BATTERY RECHARGE

76hp gasoline engine, 67hp electric motor, 9.0kWh battery (30mi)

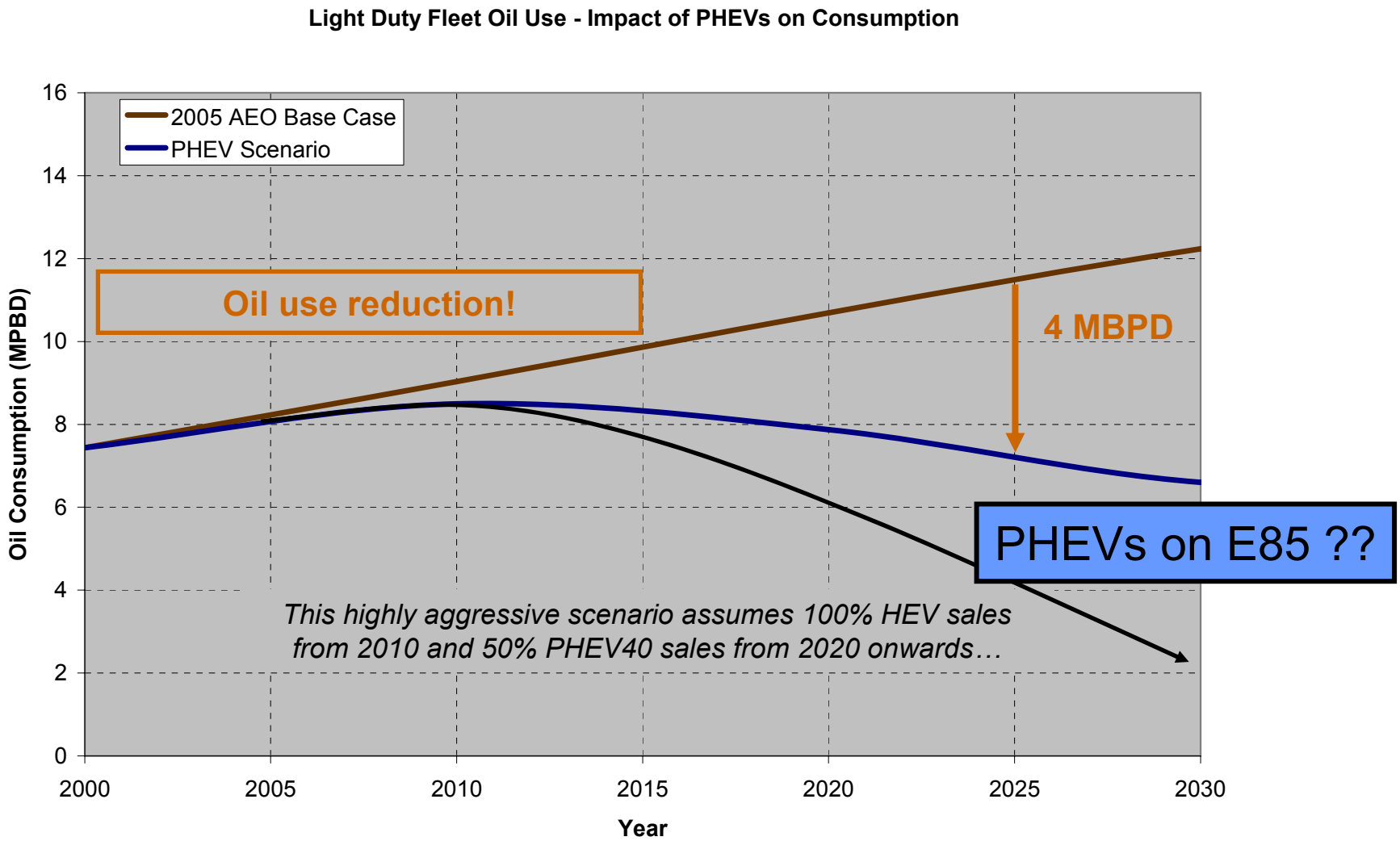
Oil Use Reduction with HEVs



HEVs unable to reduce consumption below today's consumption level

Produced using VISION model, MBPD = million barrels per day

Oil Use Reduction with PHEVs



PHEVs reduce oil consumption with a transition to electricity

Produced using VISION model, MBPD = million barrels per day

OEM Plug-In Hybrids

2003 Renault Kangoo Elect'road

- up to 50mi electric range

- approximately 500 sold in Europe

DaimlerChrysler Sprinter PHEV

- 15 prototypes being produced for testing in various locations in Europe and North America

- up to 20mi electric range

Other PHEV Prototypes - Industry

EnergyCS Plug-In Prius

HyMotion Escape PHEV

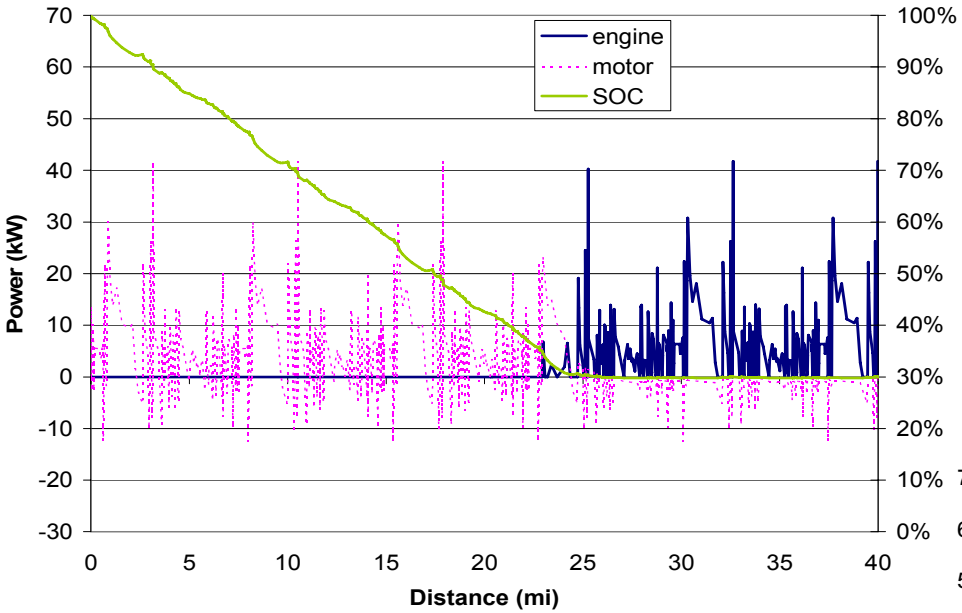
AFS Trinity Extreme Hybrid™

AC Propulsion Jetta PHEV

Esoro AG H301

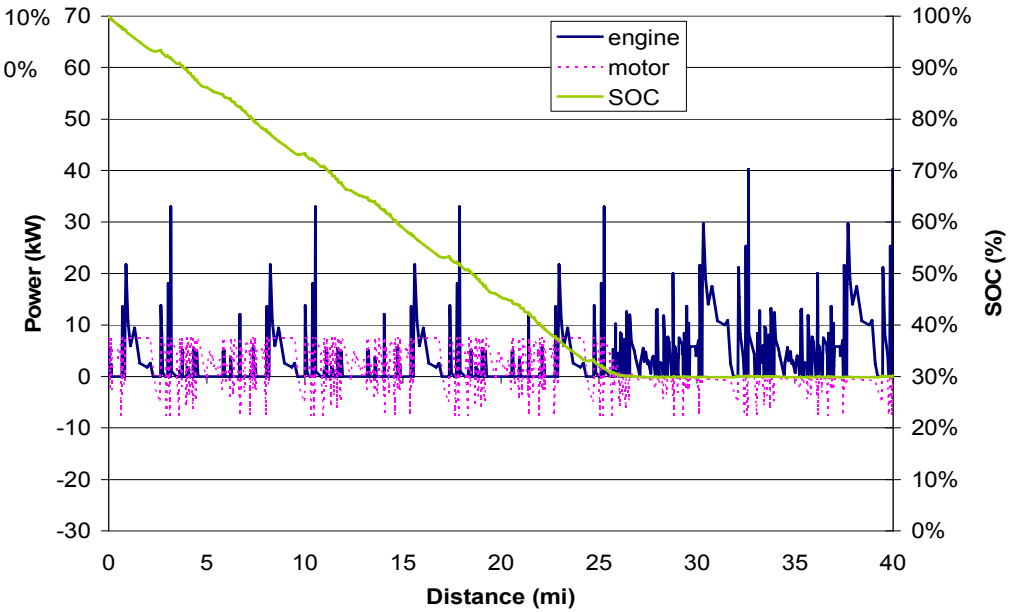
Design Options
All-Electric vs Blended Strategy

All-Electric



- Engine turns on when battery reaches low state of charge
- Requires high power battery and motor

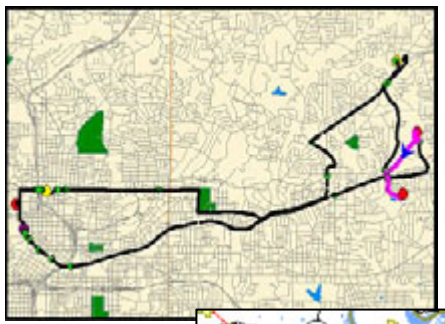
Blended

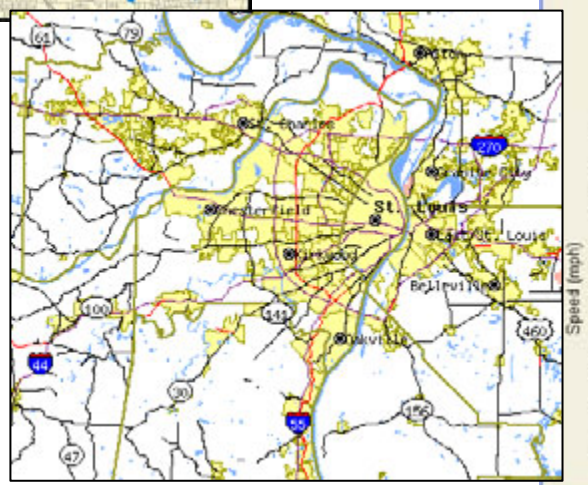


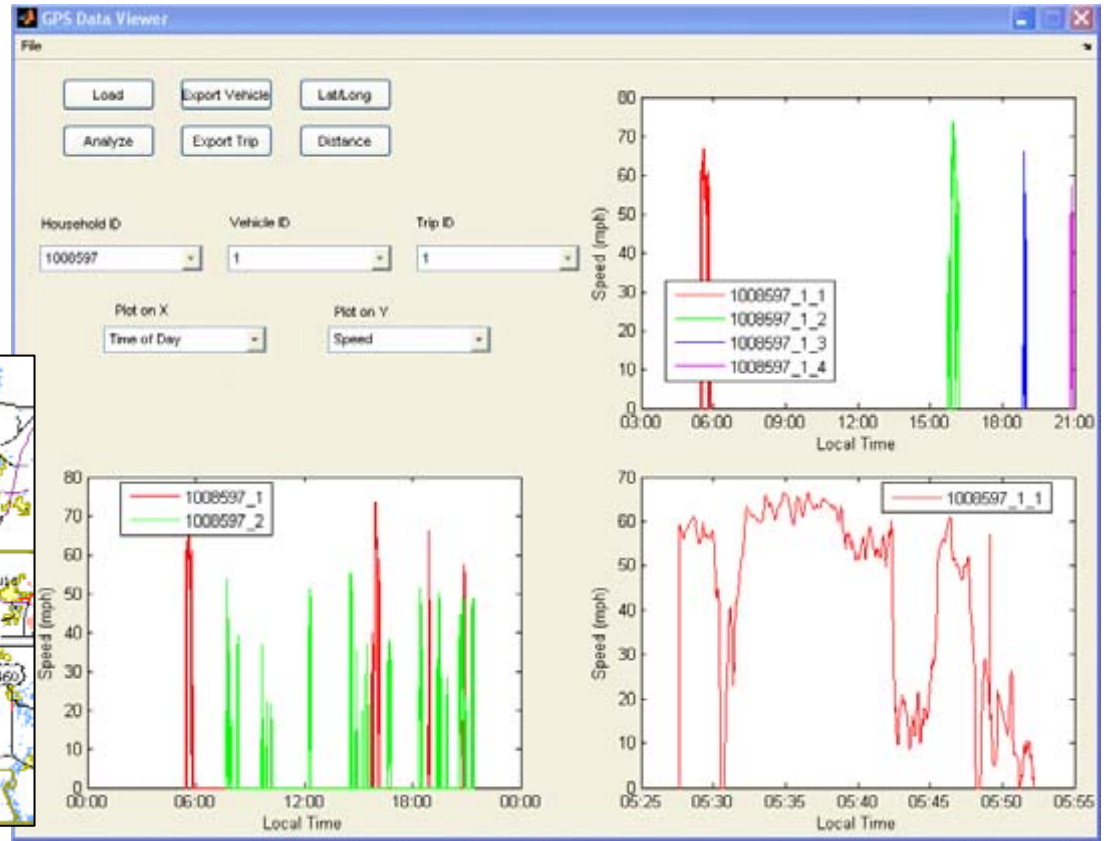
- Engine turns on when power exceeds battery power capability
- Engine only provides load that exceeds battery power capability

Household Travel Survey Data Can be Used to Predict Real-World Benefits of Advanced Technologies

- Provides valuable insight into travel behavior
- GPS augmented surveys supply details needed for vehicle simulation

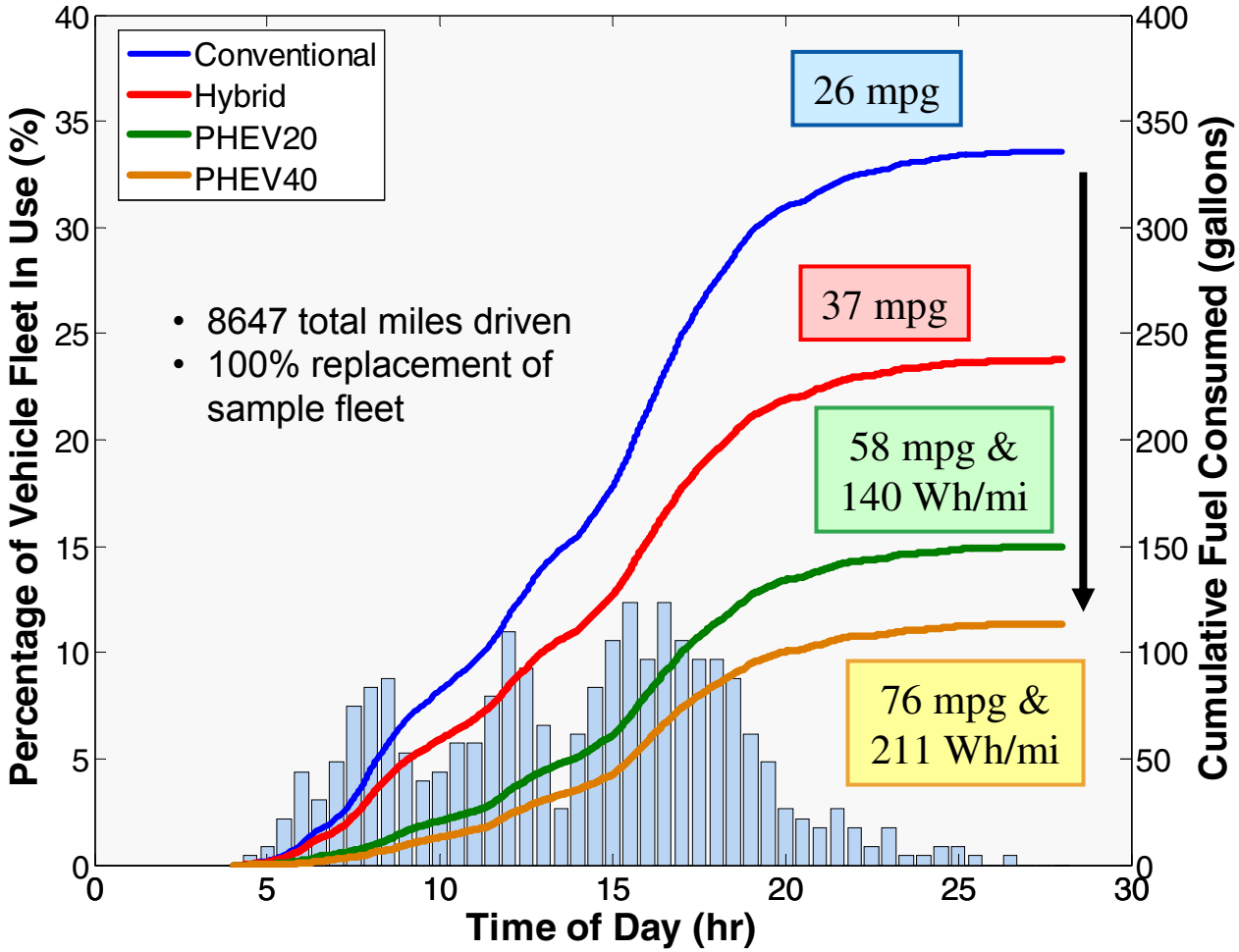






PHEVs Reduce Fuel Consumption By 50% On Real- World Driving Cycles

227 vehicles from St. Louis each modeled as a conventional, hybrid and PHEV



	Average Daily Costs		
	Gas.	Elec.	¢/mi
CV	$3.15	---	8.3
HEV	$2.21	---	5.8
PHEV20	$1.41	$0.48	5.0
PHEV40	$1.08	$0.72	4.7

Assumes $2.15/gal and 9¢/kWh

PHEVs:
~40% reduction in operating costs
~$460 annual savings

HEVs and PHEVs Likely to Reduce Greenhouse Emissions

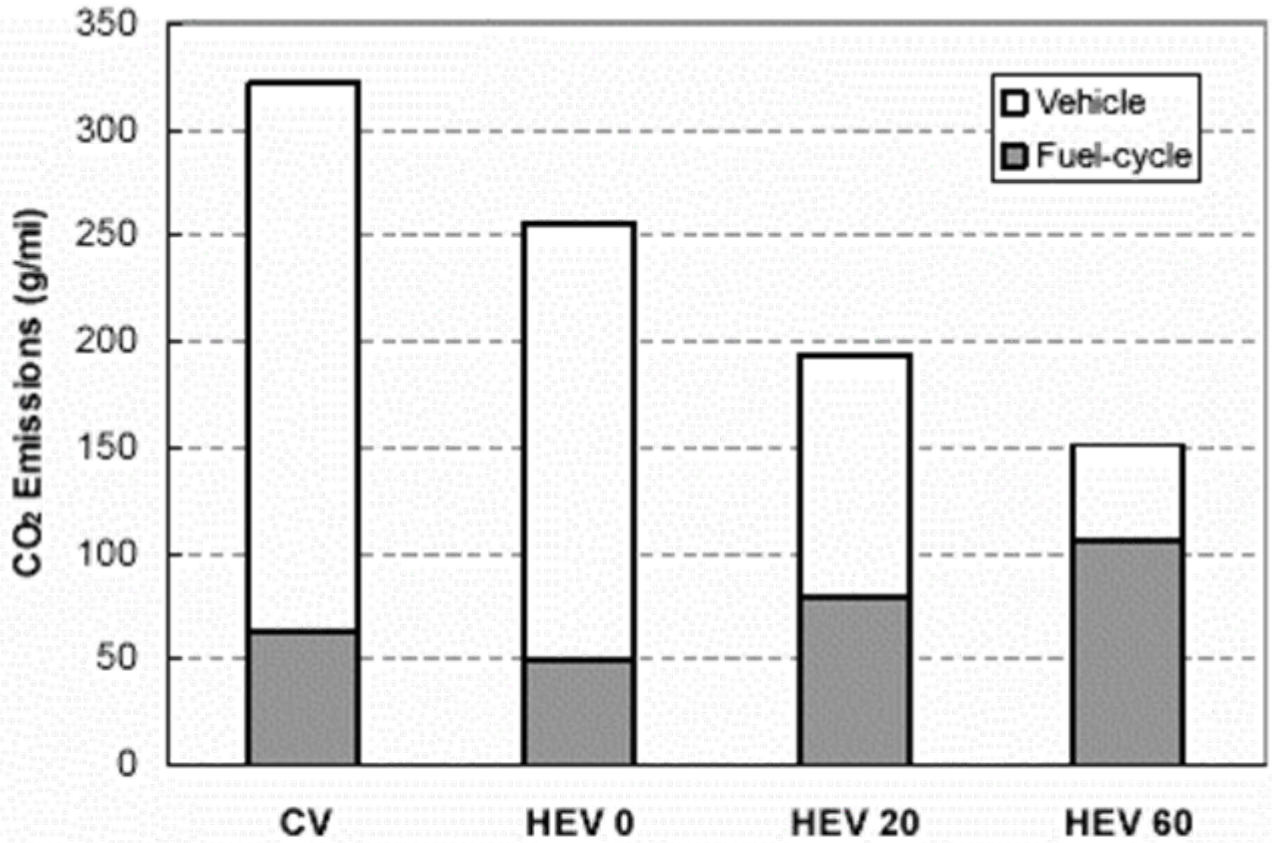


Figure 2-10
Greenhouse Gas Emissions (CO_2) "Well-to-Wheels" for the Compact Car for the Average Driving Schedule and Charging Nightly

Source: Hybrid Electric Vehicle Working Group, www.epri.com

Electrified Miles May Lead to Cleaner Operation

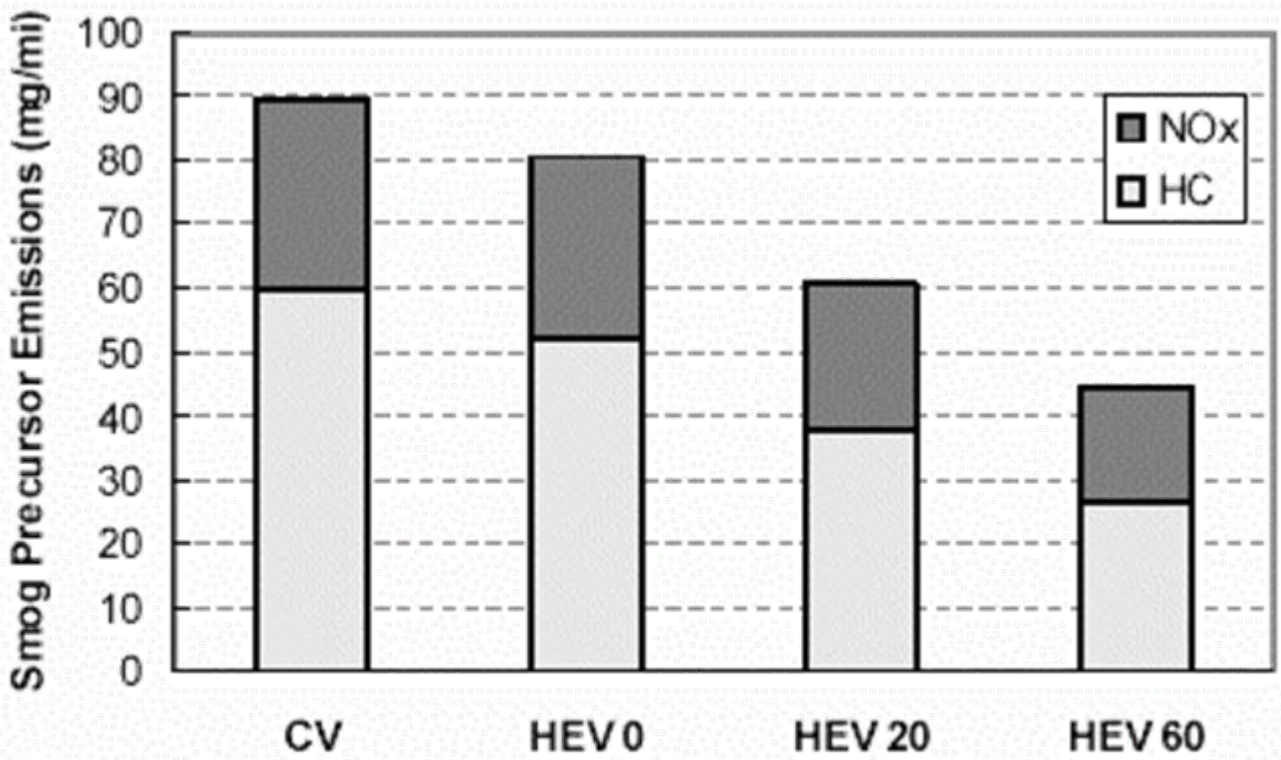
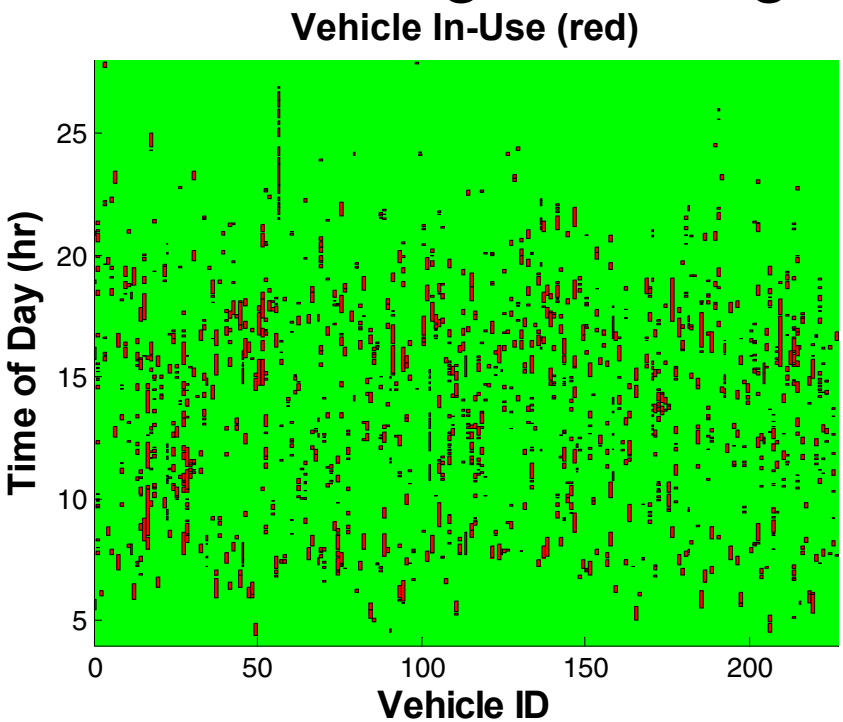


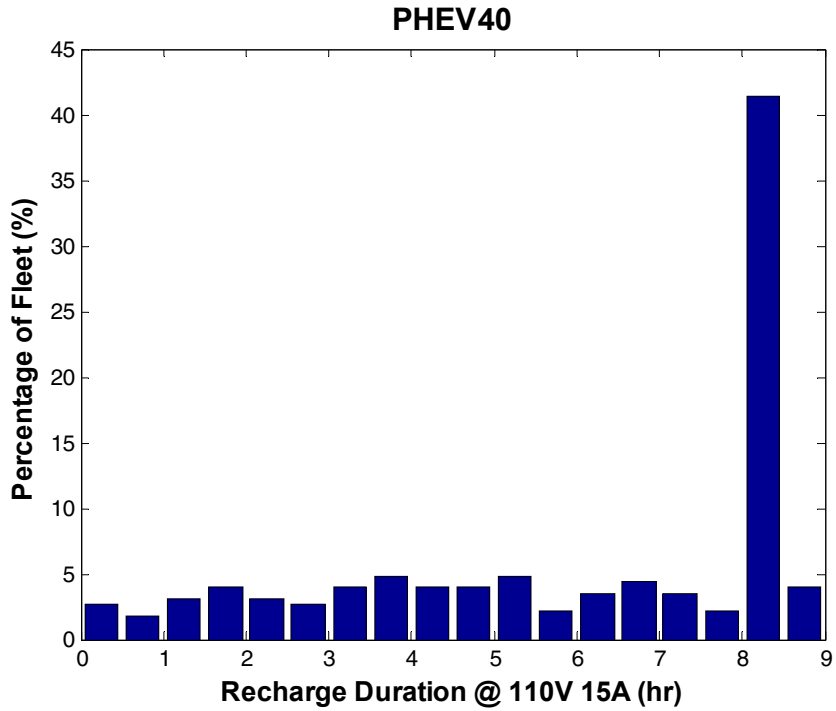
Figure 2-7
NOx Plus HC (Smog) "Well-to-Wheels" Emissions for the Compact Car for the Average Driving Schedule and Charging Nightly

Source: Hybrid Electric Vehicle Working Group, www.epri.com

In-Use Simulations Show Reasonable Recharge Times with Standard Household Outlet

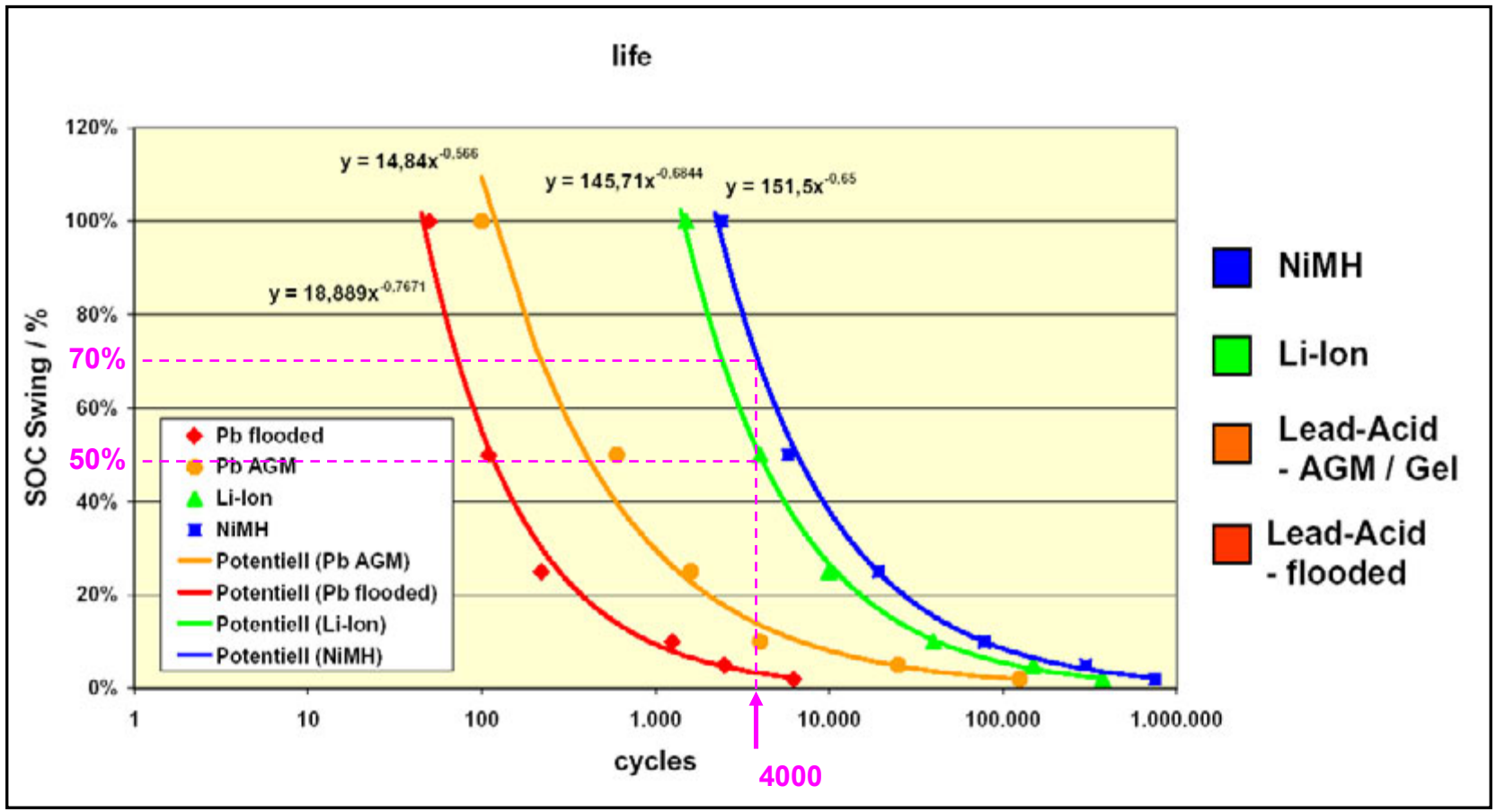
- Typical vehicle is used less than 5% of the time
  - Lots of opportunity for recharging
- Both PHEV20 and PHEV40 owners likely to get full recharge overnight with standard outlet





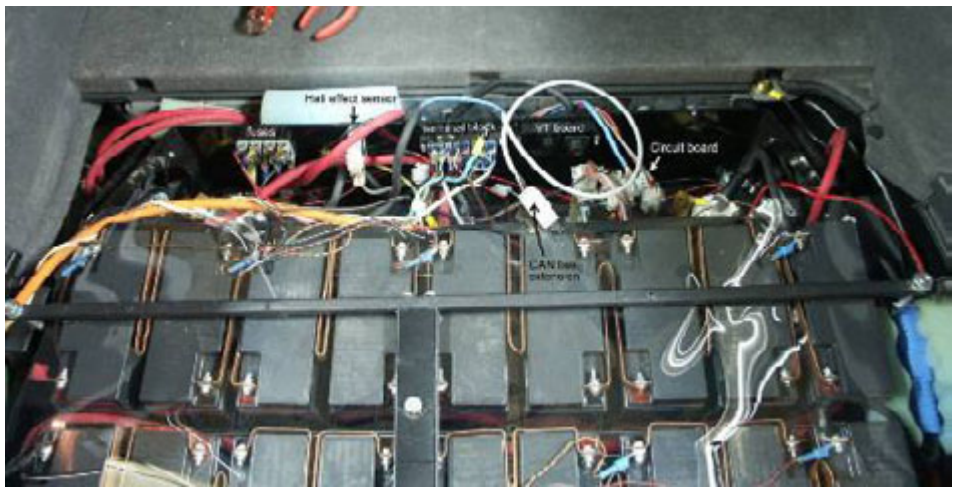
Technical Challenges
Battery Life

- PHEV battery likely to deep-cycle each day driven: 15 yrs equates to 4000-5000 deep cycles
- Also need to consider combination of high and low frequency cycling

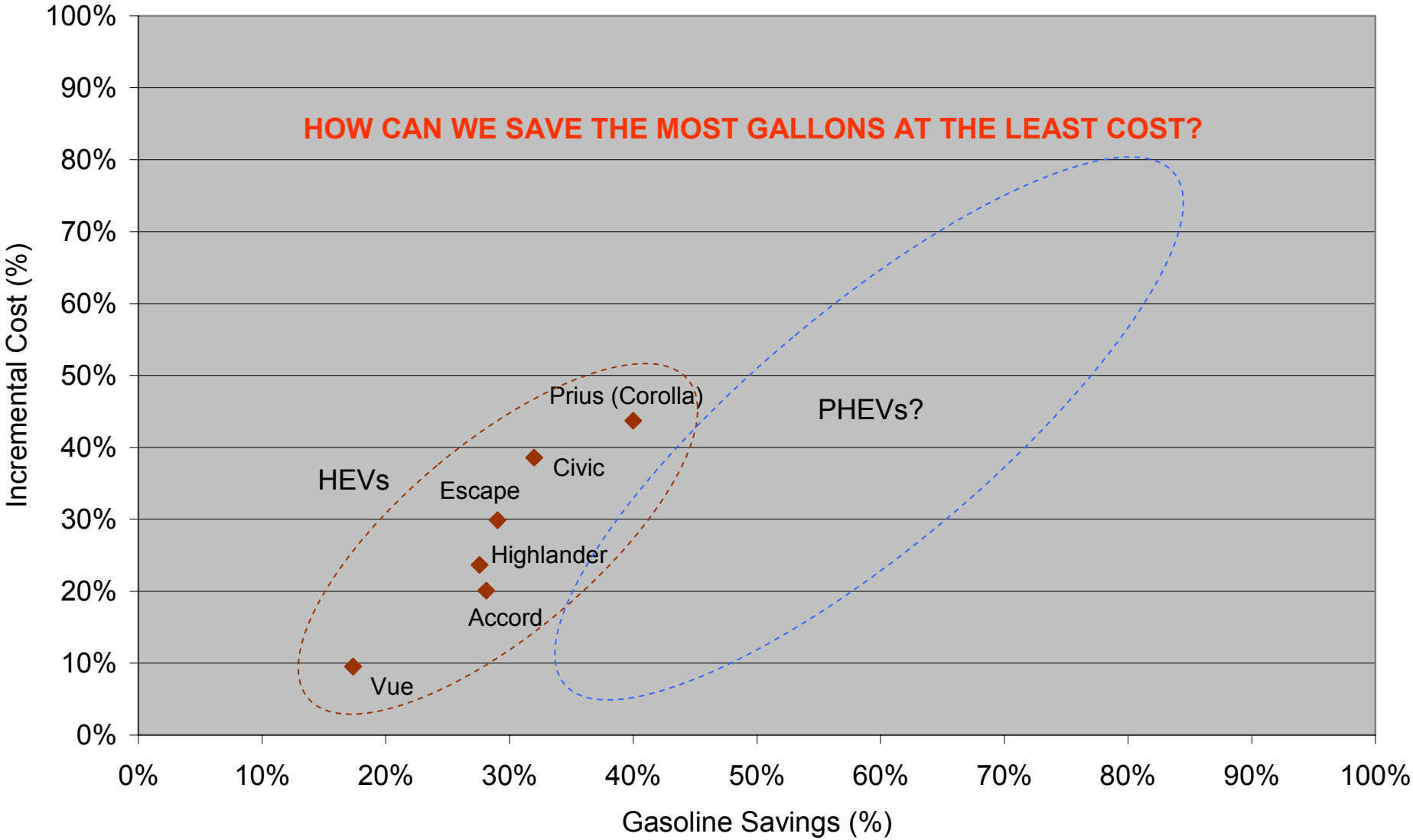


Data presented by Christian Rosenkranz (Johnson Controls) at EVS 20

Technical Challenges
Battery Packaging



Technical Challenges
Vehicle Costs



Conclusions

- Plug-in hybrid technology uses electricity from the utility grid to reduce petroleum consumption beyond that of HEV technology
  - Predicted 50% reduction in in-use consumption based on simulations using travel survey data
- Industry interest is growing and some prototypes have been built
  - Collaboration between labs and industry will likely lead to innovative systems solutions
- The U.S. Department of Energy is expanding its research portfolio to include PHEVs
  - Research will address key remaining barriers to commercial PHEVs including battery life, packaging, and cost