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Efficient, Cost Effective Electrification of the Automobile vs. the Diesel Alternative

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Issues to Consider Regarding Best Use of PHEVs

- Need to consistently use all of the capacity of a battery pack in order to get best return on investment in the PHEV – this means usually driving further than the distance-to-battery-pack-charge-depletion.

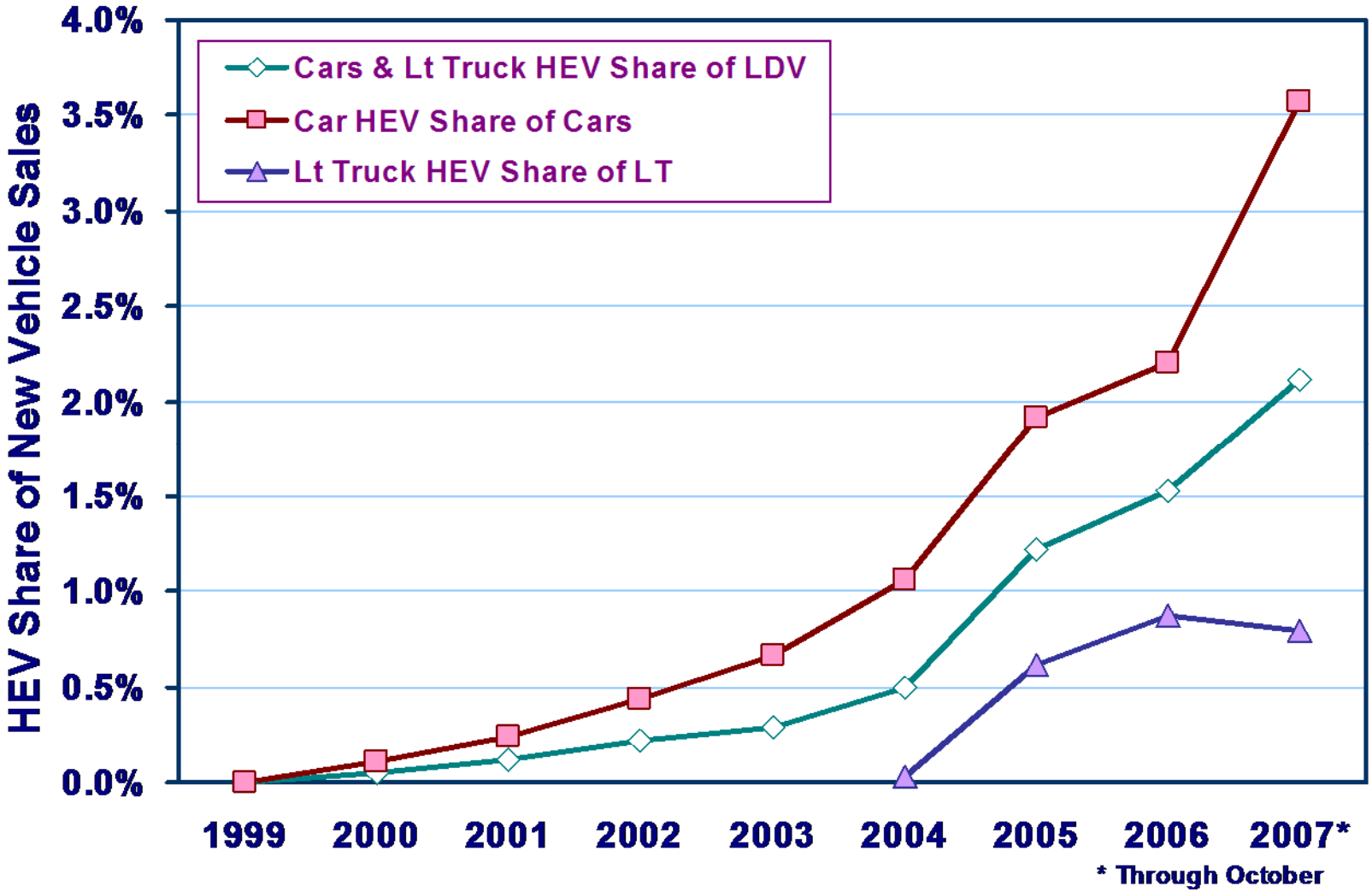
- Early PHEVs are likely to use blended mode charge depletion (intermittent engine operation). "Blended mode" depletion takes longer than all electric mode depletion – but how much? This pushes the initial market a bit toward those driving faster and further.

- Speed of driving is related to usual distance driven (faster means further), since vehicles on average are driven about the same number of hours per day.

- Fuel savings effectiveness of PHEVs per kWh will be related to the kind of driving done – neighborhood, urban arterial, urban interstate, rural interstate.

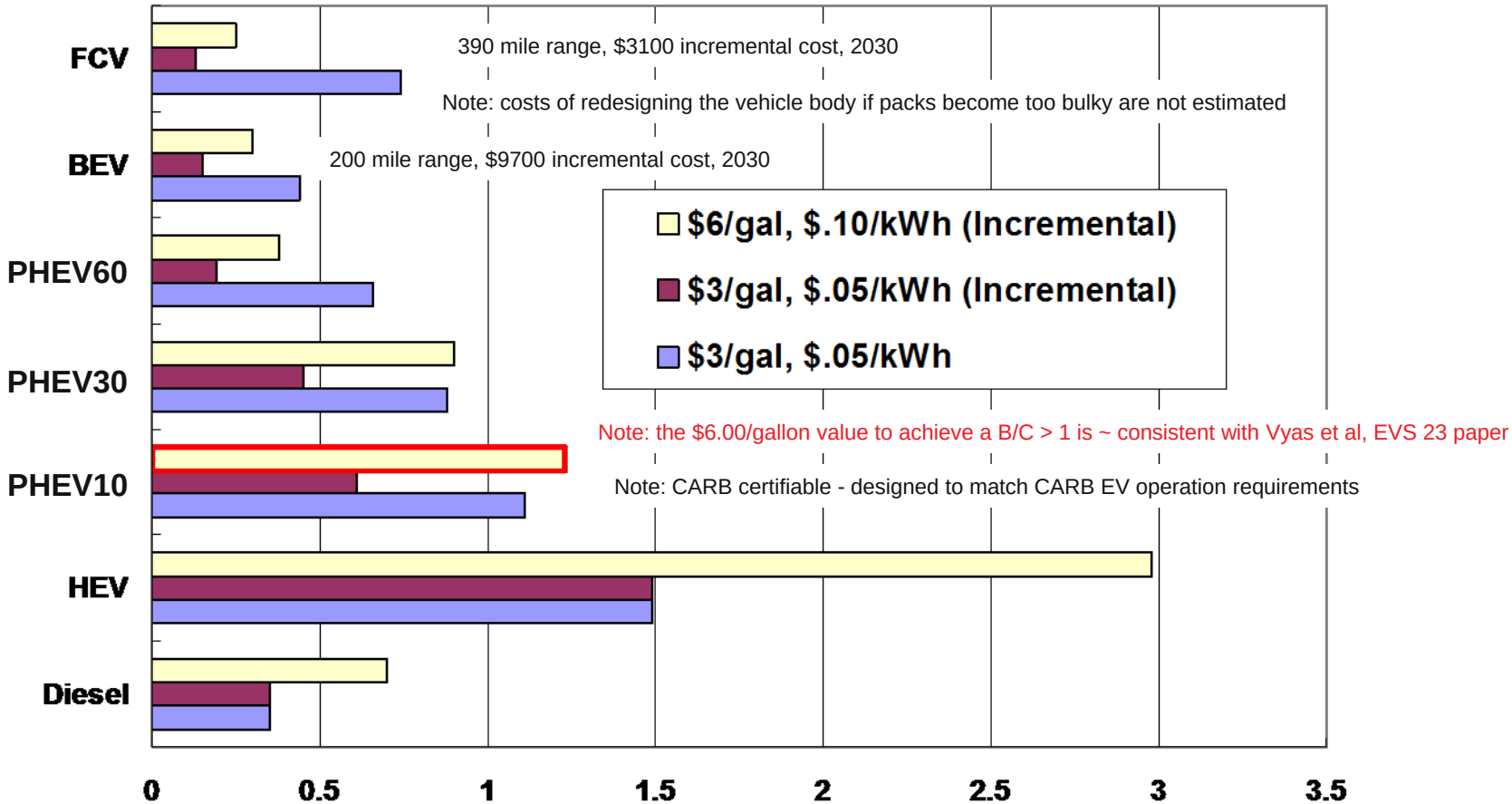
- Driving fast depletes a battery pack quickly, so, if typical driving is at high speed a significant portion of driving may be in "charge sustaining" mode (HEV mode) rather than "charge depleting" mode (electric drive). Diesels beat hybrids for fuel savings when driven at higher speeds.

For HEVs, Cars Designed for Efficiency (smaller engines) are Outselling Trucks Designed for Power (bigger engines)



Change in share of HEVs within U.S. new vehicle sales, 3856 kg GVW and below

For Average Driving, MIT's Recent Study Implies 2030 HEVs, PHEV10s, and PHEV30s will Better the Diesel



2030 Advanced, R&D Success, Benefit to Cost Ratio (> 1.0 desirable)

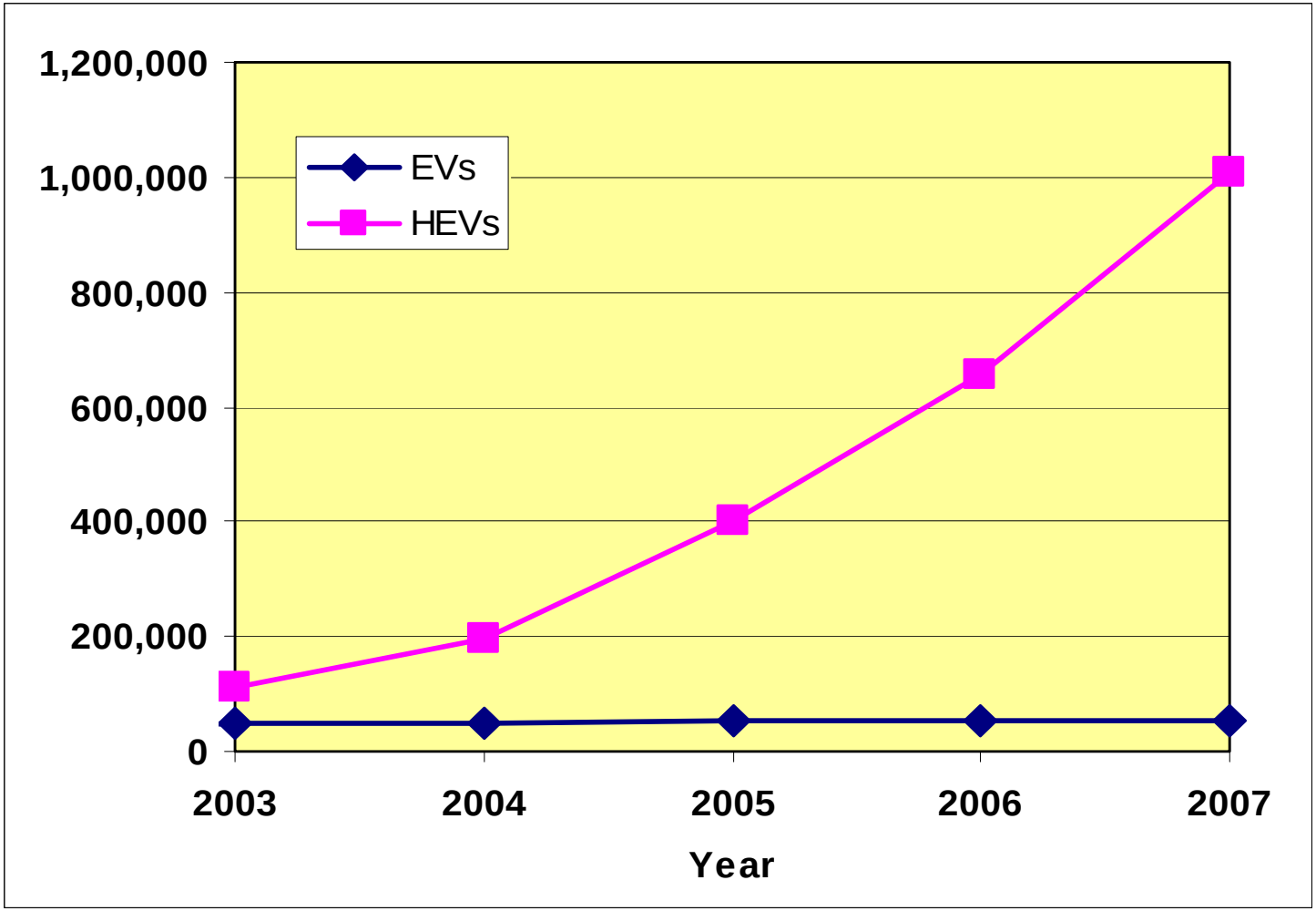
Base = Relative to best 2030 Conventional Powertrain

Incremental for PHEVs is vs. PowertrainType Below, FCV BEV vs. Conventional

Note: the PHEVs characterized are designed to operate all electrically on the UDDS. Blended mode should be more cost effective, will be studied in '08

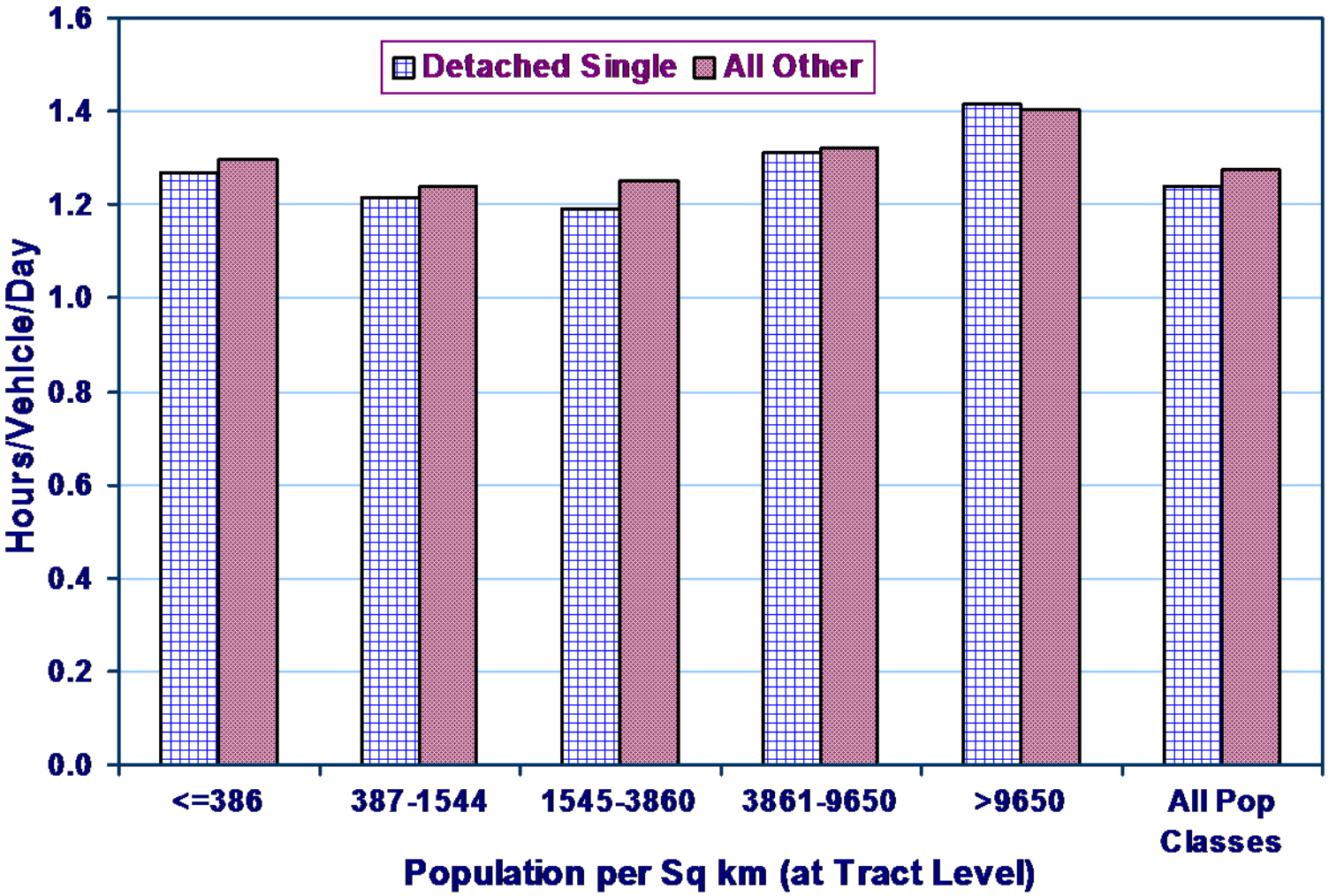
From "Where is the Early Market for PHEVs" presentation given at EVS-23 (corrected) by D. Santini, Dec. 2007. Derived from data in Kromer and Heywood, 2007 "Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet. MIT LFEE-2007 03 RP.

The Kromer and Heywood B/C Ratios for HEVs vs. EVs for 2030 are Consistent with Recent Electric Drive Market Trends



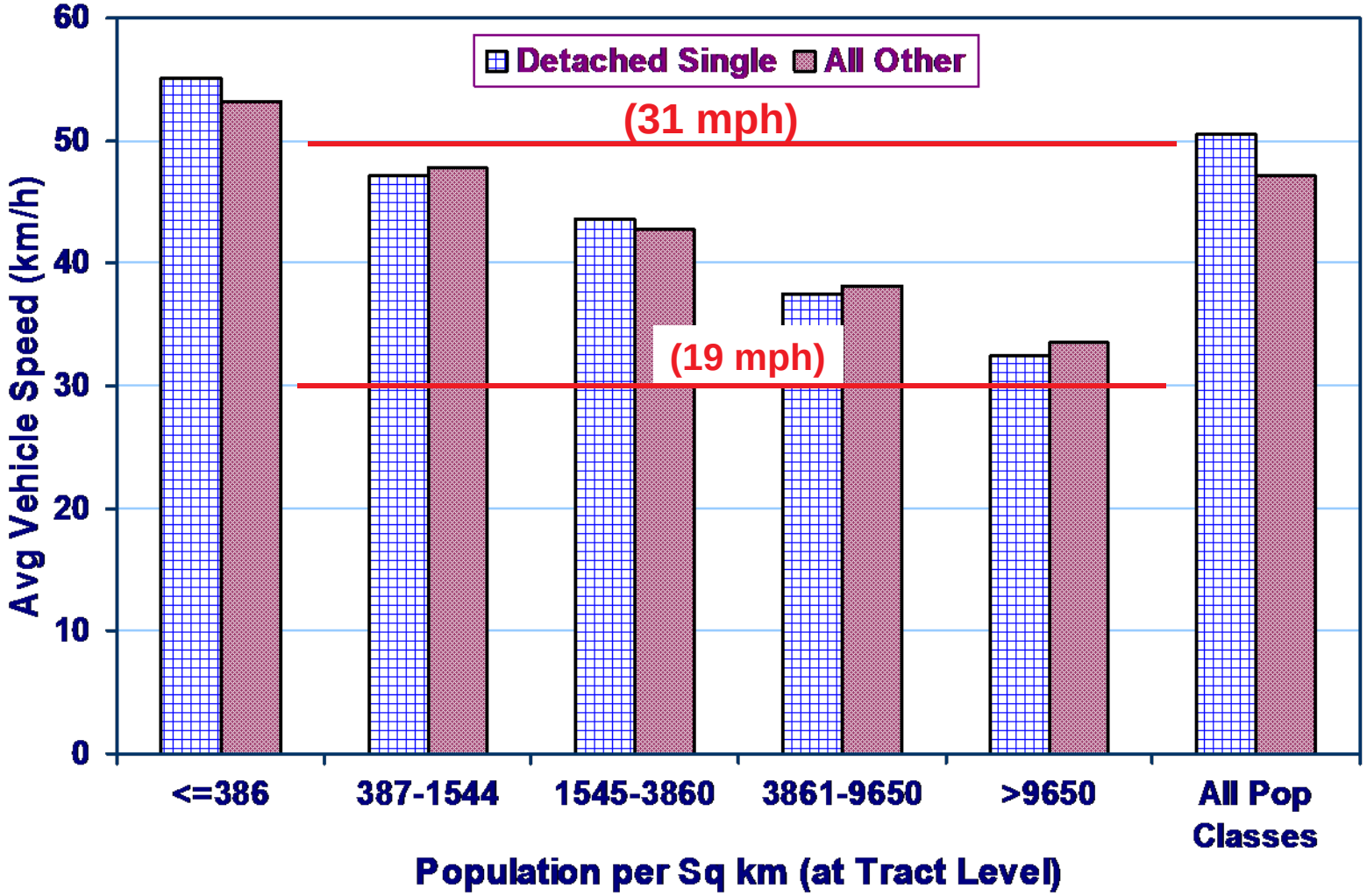
Cumulative Total of HEVs vs. EVs in the U.S. Fleet

On Average, Vehicles are Driven ~ 1.25 Hours/Day, Regardless of Population Density



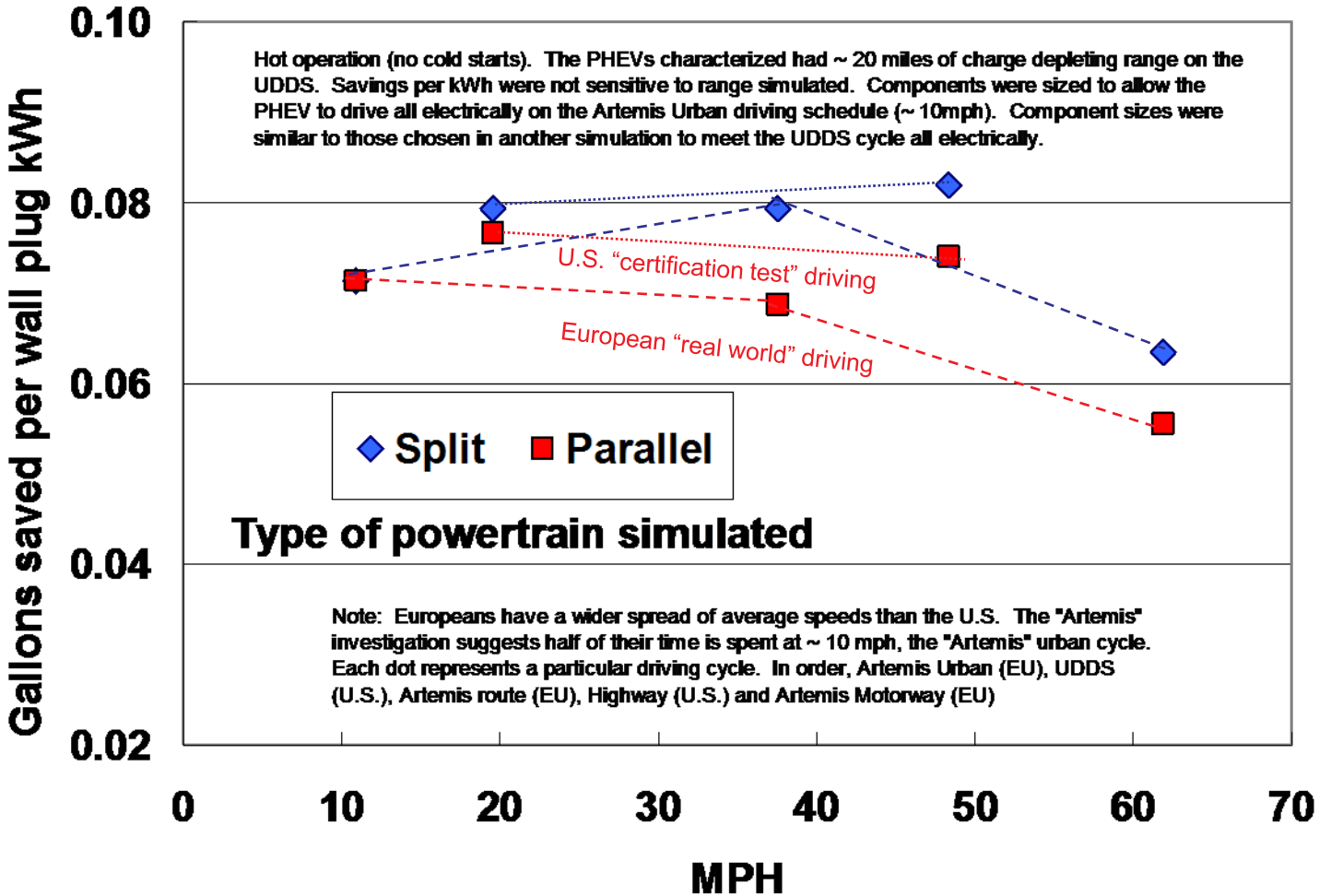
Hours per vehicle per day vs. population density, U.S. [Vyas et al, 2007]

Average Speed (& Distance Traveled per Day) Increases as Population Density Decreases

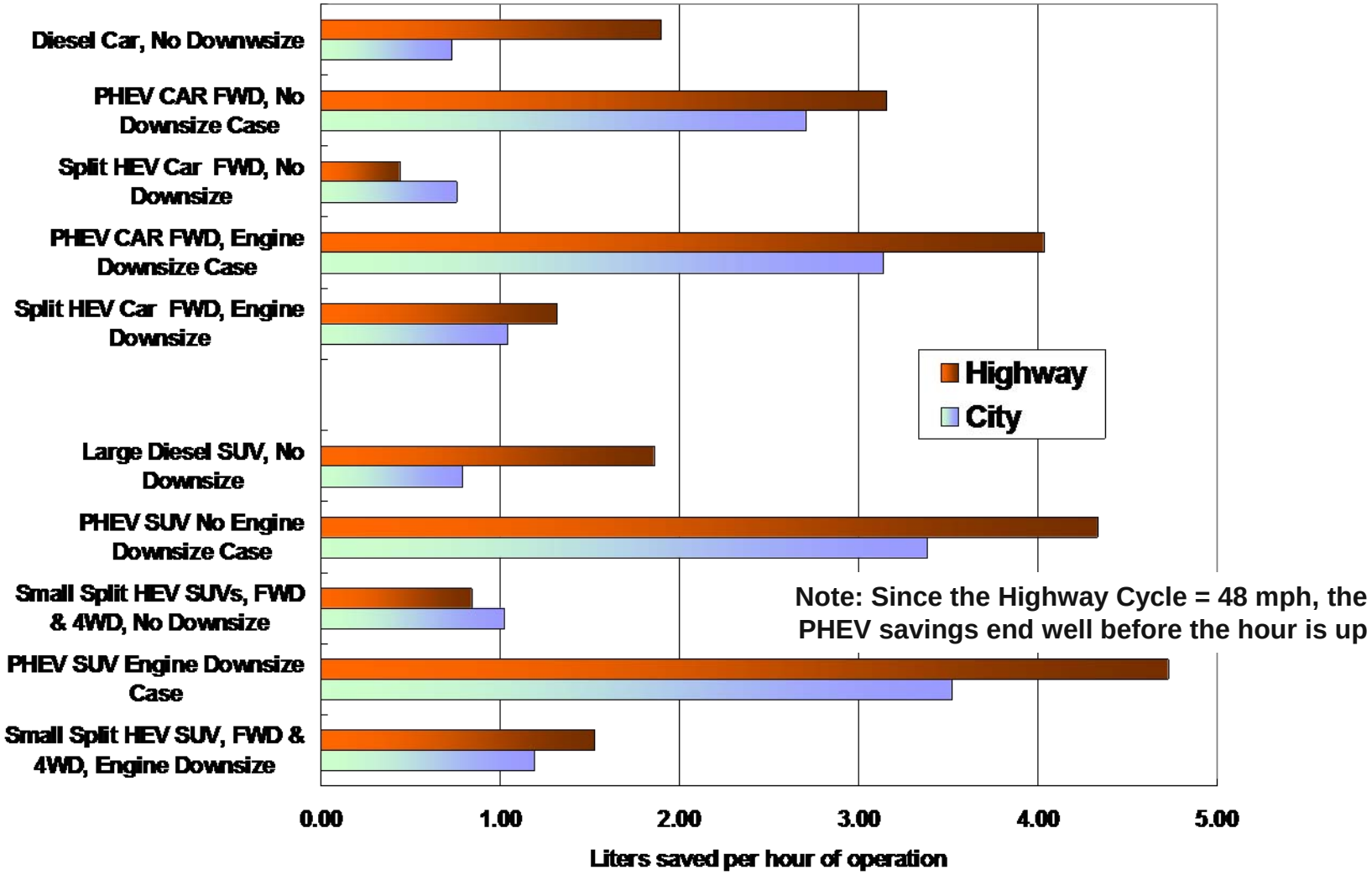


Variation in average speed as a function of population density and dwelling unit type [Vyas et al, 2007]

For Some of the Likely Early "Split-HEV-Powertrain" PHEVs (i.e. Prius, Escape), Recent Argonne/EPRI Study Simulations Imply Best Savings at Typical Daily U.S. Driving Speeds

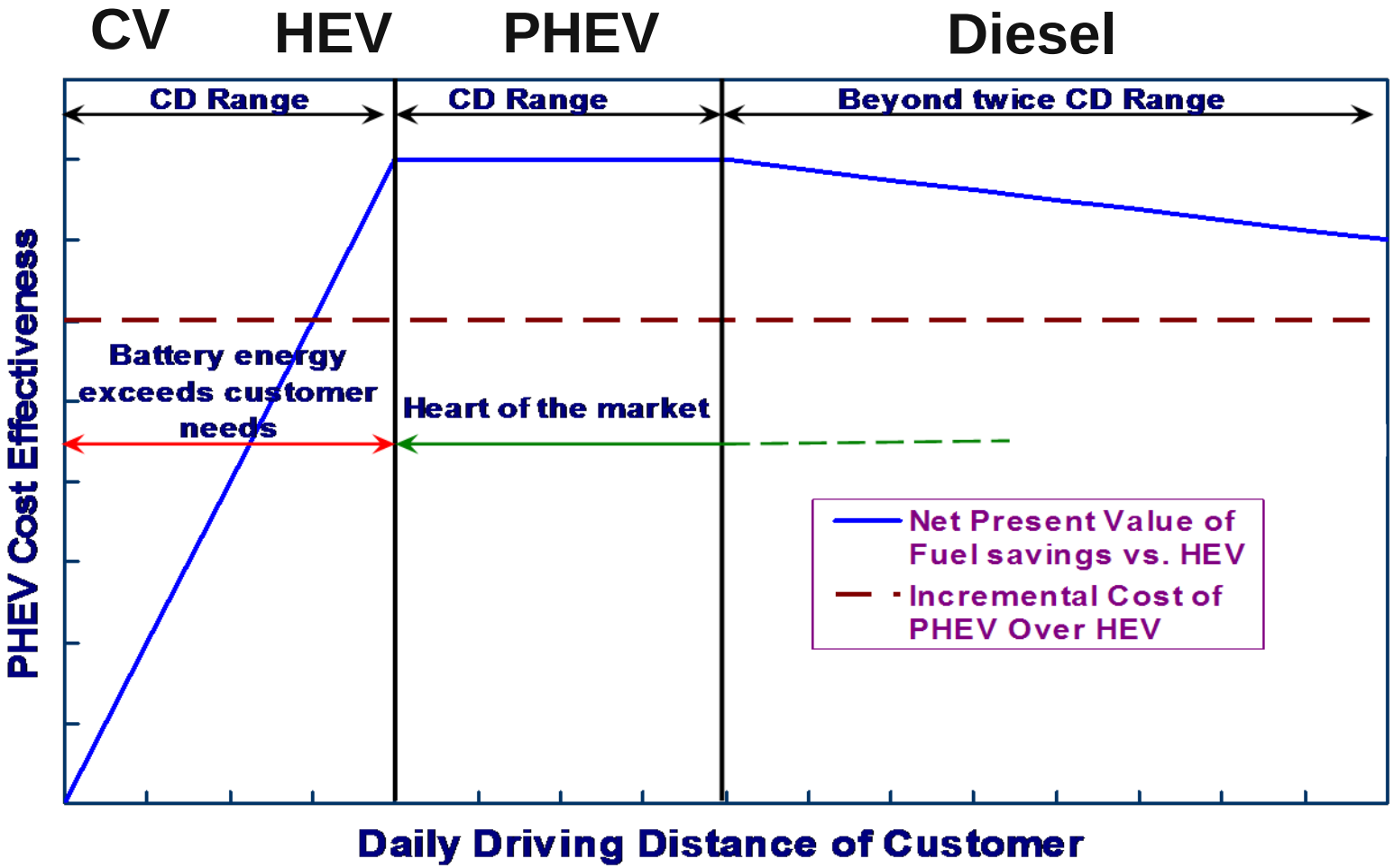


No One is an Average Driver: The Diesel Might Still Be Best for Drivers Traveling Longer Distances at Highway Speed



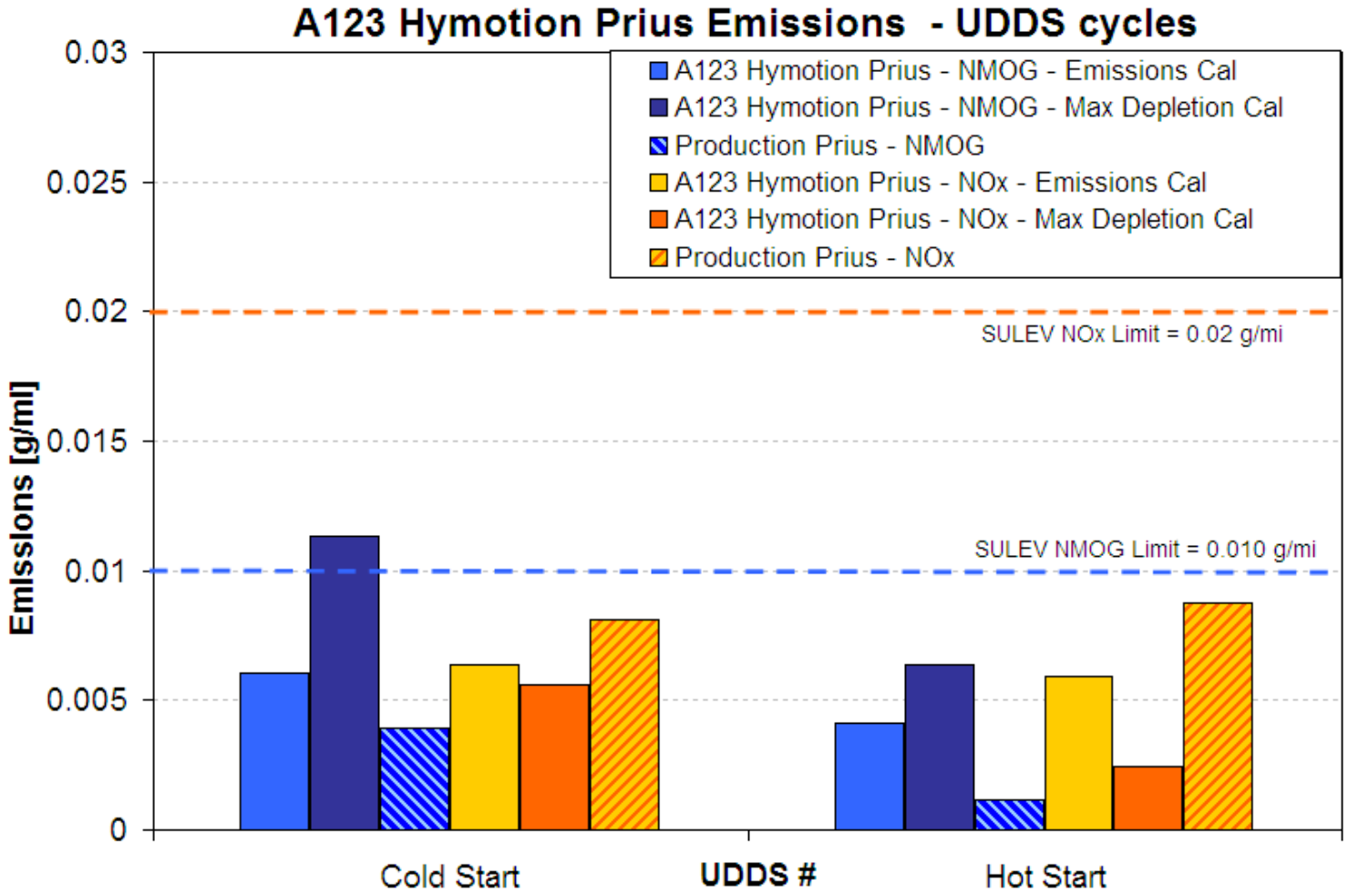
Fuel savings of a "modest" PHEV, or HEV, or Diesel vs. conventional Petrol

Best Powertrains Will Depend on Usual Distance



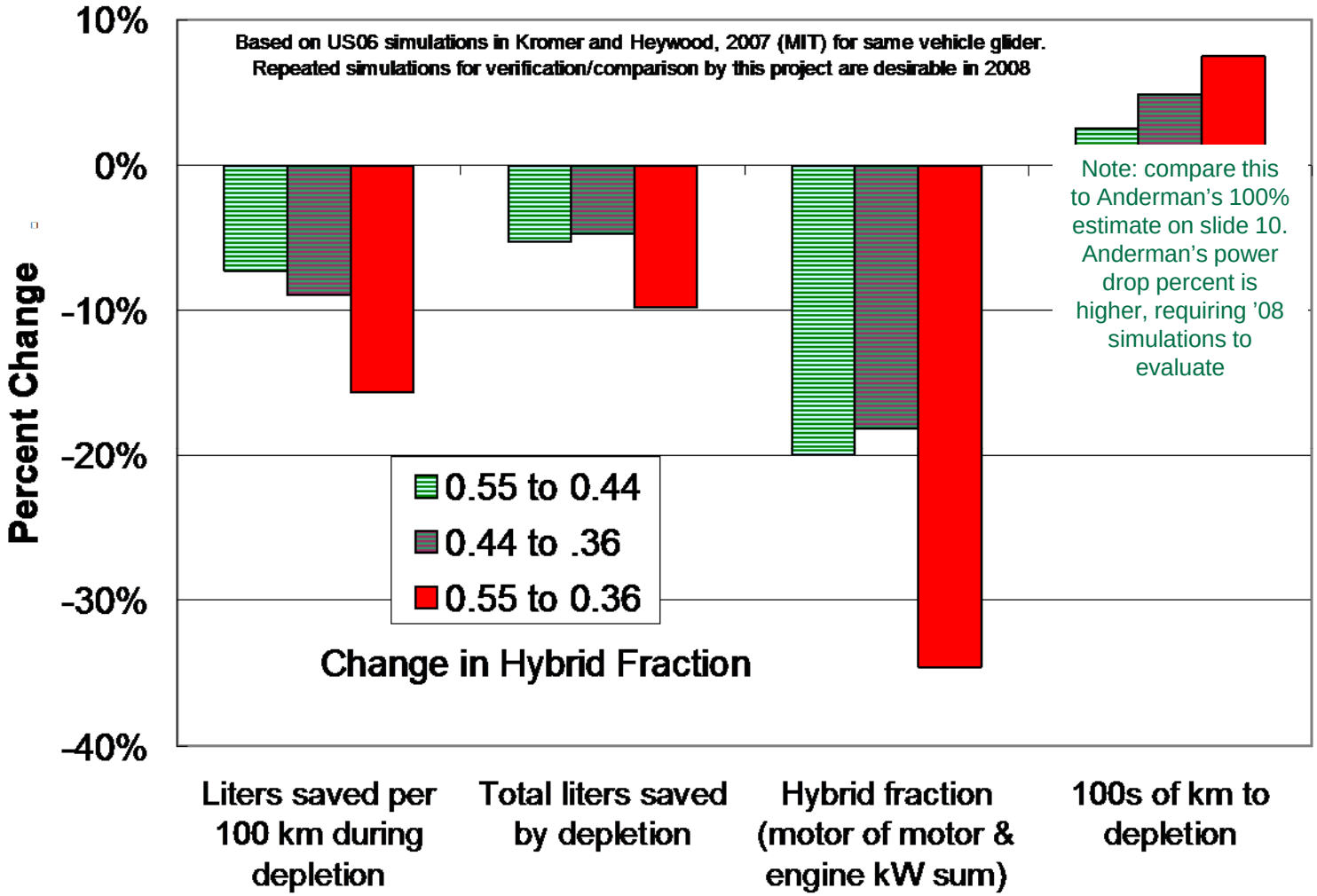
Conceptual match of daily driving distance to PHEV capabilities and "Best" Advanced Powertrain

Past PHEV Evaluations Assumed All Electric (Zero Emissions) Driving: First Generation PHEVs Will Likely use "Blended" Mode; Still May Have Very Low Tailpipe Emissions



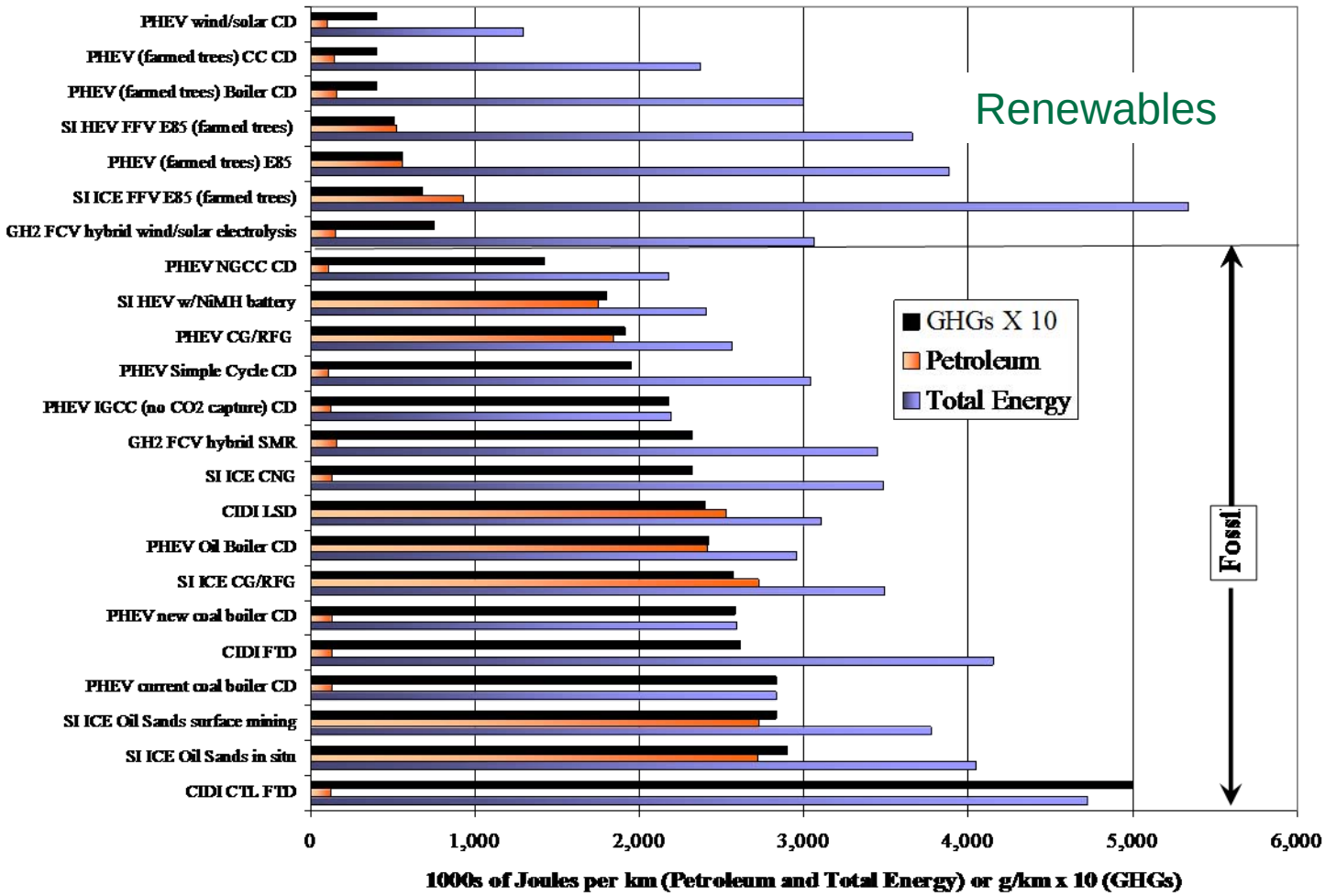
Hymotion Prius emission during the UDDS drive cycle [Duoba and Carlson, 2007]

According to Kromer and Heywood, a 35% Reduction in PHEV Battery Power Causes a Drop of Fuel Saved of ~ 10%, and an Increase in Distance to Depletion of < 10%



Derived from data in Kromer and Heywood, 2007 "Electric Powertrains: Opportunities and Challenges in the U.S. Light-Duty Vehicle Fleet. MIT LFEE-2007 03 RP.

Second Generation? For PHEVs Driven All Electrically, Initial Life Cycle Emissions per km Estimates Imply Large GHG and Oil Use Benefits via Various Renewable Pathways



Total energy, petroleum, and GHGs per kilometer driven [Gaines et al, 2007], various fuel paths

From subtask 2 on PHEVs from 2008 IEA Annex VII report, forthcoming, led by Argonne and EPRI.

Implications for the PHEV Marketplace

- The economic desirability of depletion of each daily charge argues for sales to customers where average daily distance driven is several miles beyond the PHEV charge depleting range.

- However, customer daily distances driven that are too great imply driving at high speed on Interstates where PHEVs will not be as effective

- Since typical U.S. driving is about 30 miles/day, a PHEV with less range than this is desirable, assuring that most consumers would routinely deplete battery pack charge

- The early “sweet spot” appears to be a PHEV with ~ 10 to 20 miles usual distance to charge depletion, in the suburbs of typical U.S. cities. This, fortunately is where most garages are found.