A Methodology for Calculating eVMT in PHEVs Based on Second by Second Logged Data

Christopher Nitta, Vaishnavi Chaitanya Karanam, Matthew Favetti and Gil Tal

Institute of Transportation Studies, University of California, Davis | January 2020

Background

Since the introduction of Plug-In Electric Vehicles (PEVs) to the market, researchers and policy makers have been interested in understanding the portion of Vehicle Miles Travelled (VMT) on electricity, also known as electric VMT (eVMT). Understanding the eVMT share of the total VMT for vehicles is critical for researchers and policymakers as 30% of Greenhouse Gas (GHG) emissions come from the transportation sector in the U.S., 60% of these emissions stem from Light Duty Vehicles (LDV).

Since PHEVs have two energy sources i.e. the battery and the gasoline engine, it is challenging to estimate eVMT when both sources are used to propel a vehicle within a single trip. Previous research classified trips based on the energy sources used, before calculating eVMT. As a part of the Electric Vehicle Miles Traveled On-Road Analysis Project ID VSS171[?], Richard "Barney" Carlson at INL proposed such a method. Carlson's approach classifies PHEV trips into three different categories: All-Electric, Blended, and Charge Sustaining (CS). In All-Electric trips, the eVMT is equal to the VMT, and in CS mode the eVMT is assumed to be zero. For blended trips, eVMT is calculated by multiplying the trip VMT by the ratio of gallons displaced by electricity to the displaced gallons plus consumed gallons of fuel.

This study builds on Carlson's proposed methodology to estimate the eVMT of PHEV trips, while not requiring trip classification based on energy source used.

Research Implications

The proposed methodology does not require the classification of each trip into one of three categories but is based on second by second logged data. The key insight that all miles travelled prior to first engine on are eVMT enables the removal of the classification. This methodology is important when considering future policies such as geofencing that may delay the use of the PHEV battery or when analyzing the regional impact of PHEVs.

Data

The data used in this study is a fragment of a much larger dataset compiled for the eVMT study. The Electric Vehicle Miles Traveled (eVMT) project is a California-wide study involving over 400 California households that aims to understand the day-to-day driving and charging behavior of PEVs under real world conditions. We're actively collecting real-time data from on-board loggers installed in various PHEVs, BEVs, and ICEs.

For this project, we narrow our scope by strictly focusing on the driving data of PHEVs. In total 189 PHEVs with over 275,000 trips were analyzed.

PHEV eVMT Calculation

Our key observation is that all miles traveled prior to the first engine on event are actually eVMT, where the miles travelled after the first engine on are a blend of pVMT and eVMT. This observation prompted the development of Eq. (3). Eq. (3) attributes 100% of miles traveled to eVMT prior to the first engine on event, and the fraction of the miles after to eVMT based upon the fraction of energy.

$$\boldsymbol{eVMT = VMT_{EngOn} + \left(VMT - VMT_{EngOn}\right)\frac{E_{ElecPEAEO}}{E_{ElecPEAEO}+E_{Petroleum}}} \quad 3)$$

In Eq. (3), VMT is the total trip VMT, VMT_{EngOn} is the VMT at the first engine on, and $E_{ElecPEAEO}$ is the petroleum equivalent electrical energy consumption after the engine is first turned on (see Eq. (4)), and $E_{Petroleum}$ is the the measured petroleum energy consumption. An advantage of this approach is that the single equation can incorporate All-Electric trips and those that are hybrid, since the VMT before first engine on will be equal to VMT.

$$\boldsymbol{E_{ElecPEAEO} = EER \cdot \left(E_{Elec} + \frac{E_{Kin}}{Eff_{Motor}}\right)} \quad (4)$$

Eq. (4) incorporates the Energy Efficiency Ration (EER) or the petroleum equivalent electrical energy consumption (see Eq. (5)), E_{Elec} the electrical energy consumed (see Eq. (6)), E_{Kin} the kinetic energy at first engine on (see Eq. (7)), and Eff_{Motor} the electric motor efficiency. The EER is necessary because efficiencies of the electric motor and engine are dramatically different.

$$\boldsymbol{EER = \frac{MPGe_{EPA}}{MPG_{EPA}}} \quad (5)$$

In Eq. (5), $MPGe_{EPA}$ is the EPA electric only fuel economy and MPG_{EPA} is the EPA combined highway and city fuel economy for the vehicle using petroleum only.

$$\boldsymbol{E_{Elec} = E_{BattCon} - Eff_{Batt} \cdot E_{BattProd}} \quad (6)$$

Eq. (6) is calculated using the energy consumed and produced measured at the battery $E_{BattCon}$ and $E_{BattProd}$ respectively. Eff_{Batt} is the battery efficiency is used to accommodate for the fact that energy is lost when it is either put into or taken out of the battery.

$$\boldsymbol{E_{Kin} = \frac{1}{2}mv_{AEO}^2} \quad (7)$$

In Eq. (7) m is the mass of the vehicle (assumed to be curb weight plus 200lbs), and v_{AEO} is the velocity of the vehicle at engine on. It is necessary to account for the kinetic energy of the vehicle as the starting point of hybrid mode may not be at rest. Depending upon the vehicle the kinetic energy of the vehicle at highway speeds may be a significant portion of the traction battery capacity.

Results

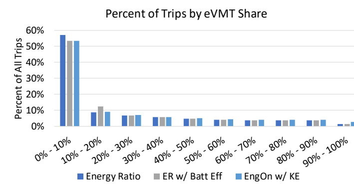

Figure 1. Percent of Hybrid Trips by eVMT Share

Figure 1 shows the percent of hybrid trips, binned by eVMT share of total VMT.
On average of all trips our methodology results in 4% greater eVMT with a median of 2.8% greater eVMT.

Figure 2 shows the distribution of eVMT delta, the percent of a trips eVMT to VMT using our method vs. the Energy Ratio only method.
On average our methodology shows more eVMT than using the Energy Ratio only method.

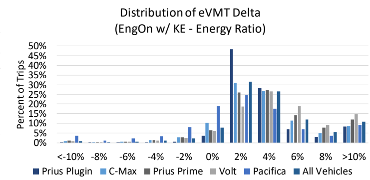

Figure 2. Distribution of eVMT Delta for Vehicle Types

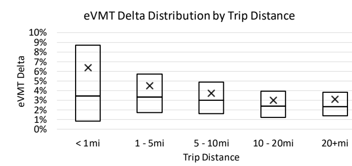

Figure 3. Distribution of eVMT Delta for Trip Length

Figure 3 shows that the mean eVMT delta is highest for short trips and has the largest variability. As trips get longer the variability decreases, but so does the median difference in eVMT. For 20+mi trips the energy ratio only methodology estimates 2.3% less eVMT.

Conclusion & Future Directions

Our methodology can capture every All-Electric trip the same as the past methodology and is able to accommodate for both Blended and CS trips with a single approach. Our methodology estimates on average 4% greater eVMT share for hybrid PHEV trips than that of an energy ratio only approach, having the largest difference for shorter trips (those under 1mi in total distance). This methodology is important when considering future policies such as geofencing that may delay the use of the PHEV battery or when analyzing the regional impact of PHEVs.

The use of tracking potential energy may be useful if analysis is done on a tour basis and should be further investigated in the future. This especially be done if the accuracy of the GPS elevation data or map-based location data can be greatly improved possibly by maintain previous location, and by using map information like Google Map's Snap to Roads API. The subdivision of trips into shorter stopped engine off to stopped engine off sections could yield higher eVMT and we plan to investigate it further in the future.

UC DAVIS

PLUG-IN HYBRID & ELECTRIC VEHICLE RESEARCH CENTER

of the Institute of Transportation Studies

Contact information:
Christopher Nitta – cjnitta@ucdavis.edu
Vaishnavi Chaitanya Karanam - vckaranam@ucdavis.edu
Matthew Favetti – mpfavetti@ucdavis.edu
Gil Tal – gtal@ucdavis.edu