Characterizing Plug-in Electric Vehicle (PEV) Driving and Charging Behavior

UCDAVIS SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS
An Institute of Transportation Studies Program

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Research Question

- PEV Usage Assumptions → surveys, travel diaries, GPS/OBD data from ICEVs
- PEV Usage From Experience → Highly granular GPS tracked data of all vehicles (PEVs and ICEVs) at a household (HH) level

What is the gap between our Assumptions on PEV Usage & PEV Usage From Experience?

Key Usage Metrics: HH level eVMT/Utility Factor(UF) , Energy Consumption, & GHGs

Research Implications

For Policymakers

- What are the factors that **impact PEV usage?**
  - HH size, car ownership, PEV range, access to chargers, pricing, typical driving needs
- Compare **real world zero emission miles vs. All Electric Range(AER)**
- How to **increase eVMT & maximize GHG reduction benefits** from PEVs?

For OEMs

- **PHEV Fuel Economy, BEV energy consumption/mile, AER utilization**
  - Calibrate or improve on-road GHG estimates from powertrain simulation models

Data

- Year-long sec by sec GPS tracked data from all the vehicles in the HH
- As of Nov. 2018, 325 HHs, 121 BEVs,188 PHEVs, and 282 ICEs logged
  - Leaf(57), Bolt(15), Tesla(49); Volt(84), Prius PHEV(22), Prius Prime PHEV (13), Cmax/Fusion Energi PHEV (60), Pacifica(10)
- Scope of work: 121 BEVs, 30,000 vehicle days (driving, charging, or both)

Table 1 BEV Driving and Charging Data Summary (*As of 8/1/2018*)

BEV Type	N Vehicles	N Trips	N Charging Sessions
Leaf-24 kWh (L24)	30	41069	9382
Leaf-30 kWh (L30)	27	35517	6630
Bolt-60 kWh (B60)	15	14254	2948
ModelS_60-80 kWh (T60)	25	21353	5756
ModelS_80-100 kWh (T80)	24	21287	5426
All BEVs	**121**	**133480**	**30142** *68% L2* *12% DCFC*

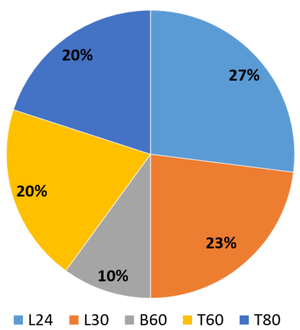

Figure 1 % of Vehicle Days by BEV Type

Methods

- ANOVA and non-parametric tests on three variants of daily driving distance
  - Average , habitual(HDD), and 95th percentile(95th Perc+) or more by type of day (weekday vs. weekend)
- k-Means clustering on daily driving and charging behavior
  - Reduce vehicle-days to 6 representative driving and charging profiles
  - Uncover similarities/dissimilarities between short-range BEVs (Leafs) and long-range BEVs (Bolts and ModelS)

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Preliminary Results- Vehicle Level

Table 2 Pairwise Comparisons: Non-Parametric Test Results

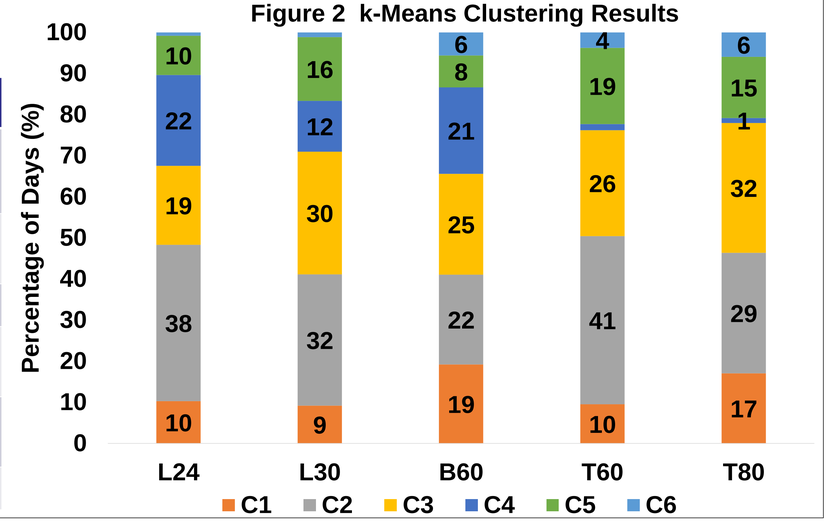
BEV Type	BEV Type	Average	HDD	95th Perc+	Average	HDD	95th Perc+
		p-val(Weekdays)			p-val(Weekends)		
T60	L24	0.024	**0.176**	<.0001	<.0001	0.1261	0.0004
T80	L24	0.024	**0.917**	<.0001	<.0001	0.0359	0.0005
T60	L30	0.028	**0.073**	<.0001	<.0001	0.0226	0.0051
T80	L30	0.043	**0.291**	<.0001	<.0001	0.0114	0.0051
T80	B60	0.394	**1.000**	0.001	**0.1029**	**0.8512**	**0.7399**
T60	B60	**0.418**	**0.410**	0.015	**0.1988**	**0.5574**	**0.4507**
L30	L24	**0.994**	**0.497**	0.077	**0.6836**	**0.3708**	**0.1927**
T80	T60	**0.928**	**0.312**	**0.653**	**0.4777**	**0.6965**	**0.7566**
L30	B60	**0.306**	**0.446**	**0.227**	0.0021	0.0109	0.002
L24	B60	**0.206**	**0.588**	0.007	0.0011	0.047	0.0002

- ✓**ANOVA and Non-Parametric Test Results** : On weekdays, ***no statistically significant differences in the most frequently driven distance*** (habitual driving distance-HDD) **across all BEVs** (p-val 0.0708 at 95 signif. levels) & **between all BEV types**
- ✓**k-means Clustering Results**:
  - L30 ***have highest share of DCFC*** (2 years of free DCFC at EVgo stations)
  - ***Bolts spend comparable % of days*** in C3 and C4 as ***L24*** (more level 1 charging and less than 25 miles driven)
  - ***Not much difference between VMT*** on days with ***L1 only or L2 only charging***
  - **DCFC enables long-distance travel** (100 miles or more) for ModelS (44% of days) the most, followed by Leafs (26% of days) , but only on 8% of days for Bolts

Table 3 Driving & Charging Clustering Means Summary

Cluster	Cluster Characteristics
C1	L1 & L2 charging; 1.3 sessions; 80 miles
C2	L2 dominant; 1.16 sessions; 24 miles
C3	Did not charge; 19 miles
C4	L1 dominant; 1.15 sessions; 25 miles
C5	L2 and DCFC; 1.8 sessions; 103 miles
C6	Did not charge; 75 miles

Figure 2 k-Means Clustering Results



Work In Progress

- Vehicle level analysis of PHEVs
  - Relationship between recharging frequency, VMT, MPGE, and utility factor
- HH level analysis: BEV/PHEV only, (1 or 2) ICE+ 1 BEV/PHEV, BEV+PHEV
- Explore HH level trip and daily travel substitution patterns
- Incorporate effects of activity by time of day (weekday vs. weekend) and season
- Density based spatial clustering to identify the most frequented O-D pair and charging location at a HH level

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