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PLUG-IN HYBRID & ELECTRIC VEHICLE RESEARCH CENTER

Advanced Plug-in Electric Vehicle Travel and Charging Behavior

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Advanced Clean Cars Symposium

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California Environmental Protection Agency

Air Resources Board

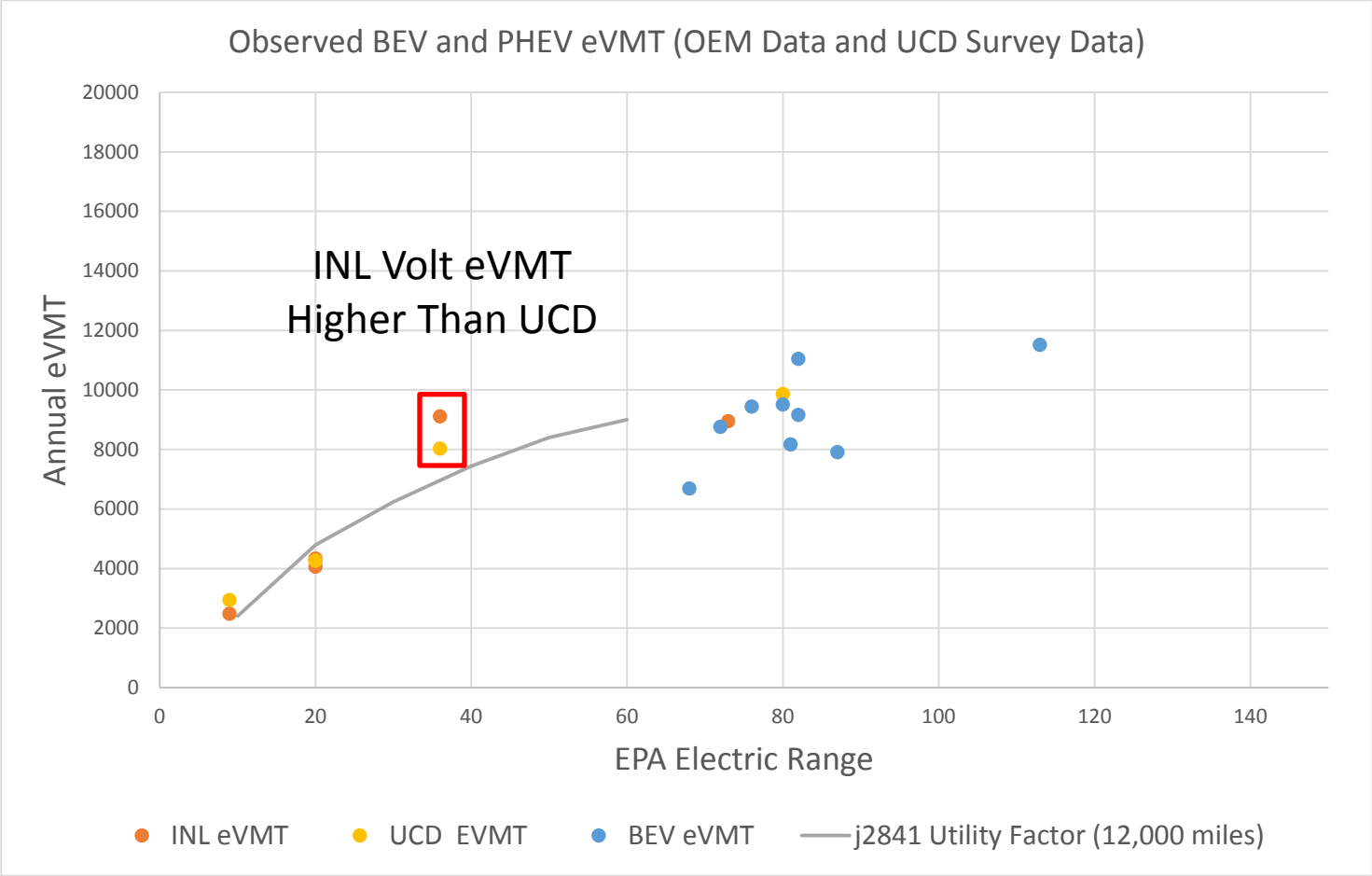
Overview

- Project Background
- Baseline statistics on participating households
- Household travel changes over time
- Engine starts of plug-in hybrids
- Overall motivation to plug in
  - Charging behavior of participating households

Project Background

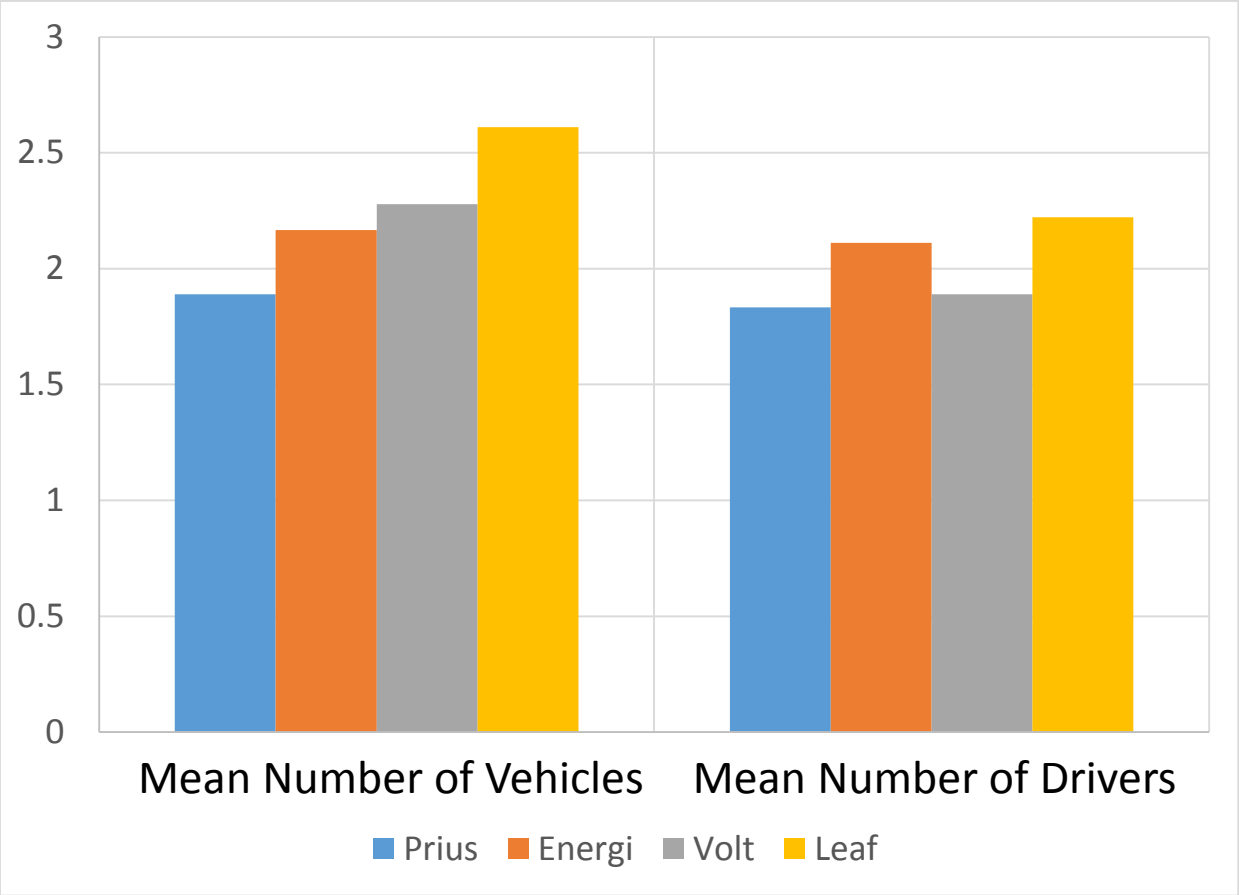
- Project consists of 3 components:
  1. Intro survey to recruit households statewide
     - Over 6000 completed surveys from throughout California
  2. High resolution on-board data collection of PEV and ICE vehicles in selected households for 12 months
     - PEV models: Leaf, Volt, Prius Plug-in, C-Max, i3 REx, Tesla
     - PEV parameters: battery SOC, speed, RPM, GPS, charging level and kWh, etc.
     - ICE parameters: speed, RPM, GPS, fuel economy variables, refueling
     - 264 Households: 72 Completed, 60 in progress, 132 forthcoming beginning Fall 2016
  3. Exit survey of selected households
- Project rolled out in different phases
  - First wave began summer 2015

eVMT Overview:
UCD Data Consistent with OEM Data

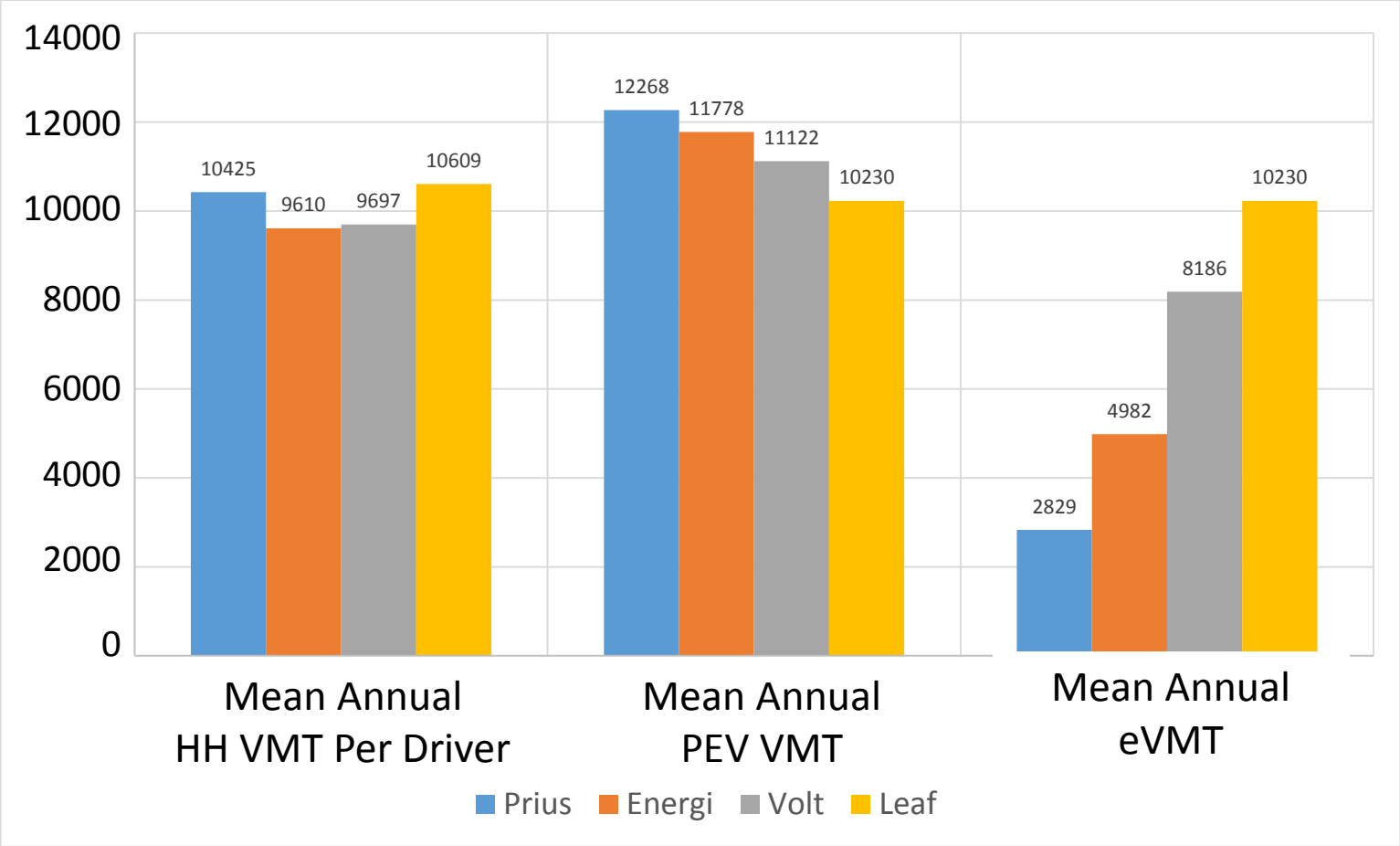


Source: Nicholas, Michael and Tal Gil. 2016, January 10-14. EVMT in the Household Fleet: Integrating Battery Electric Vehicles into Household Travel. In Transportation Research Board. Washington DC.

Our Leaf Households Have More Cars and Drivers than Prius Households



PEV Households Similar in Travel Needs (per Driver) But Shift Miles to Higher MPG Vehicles



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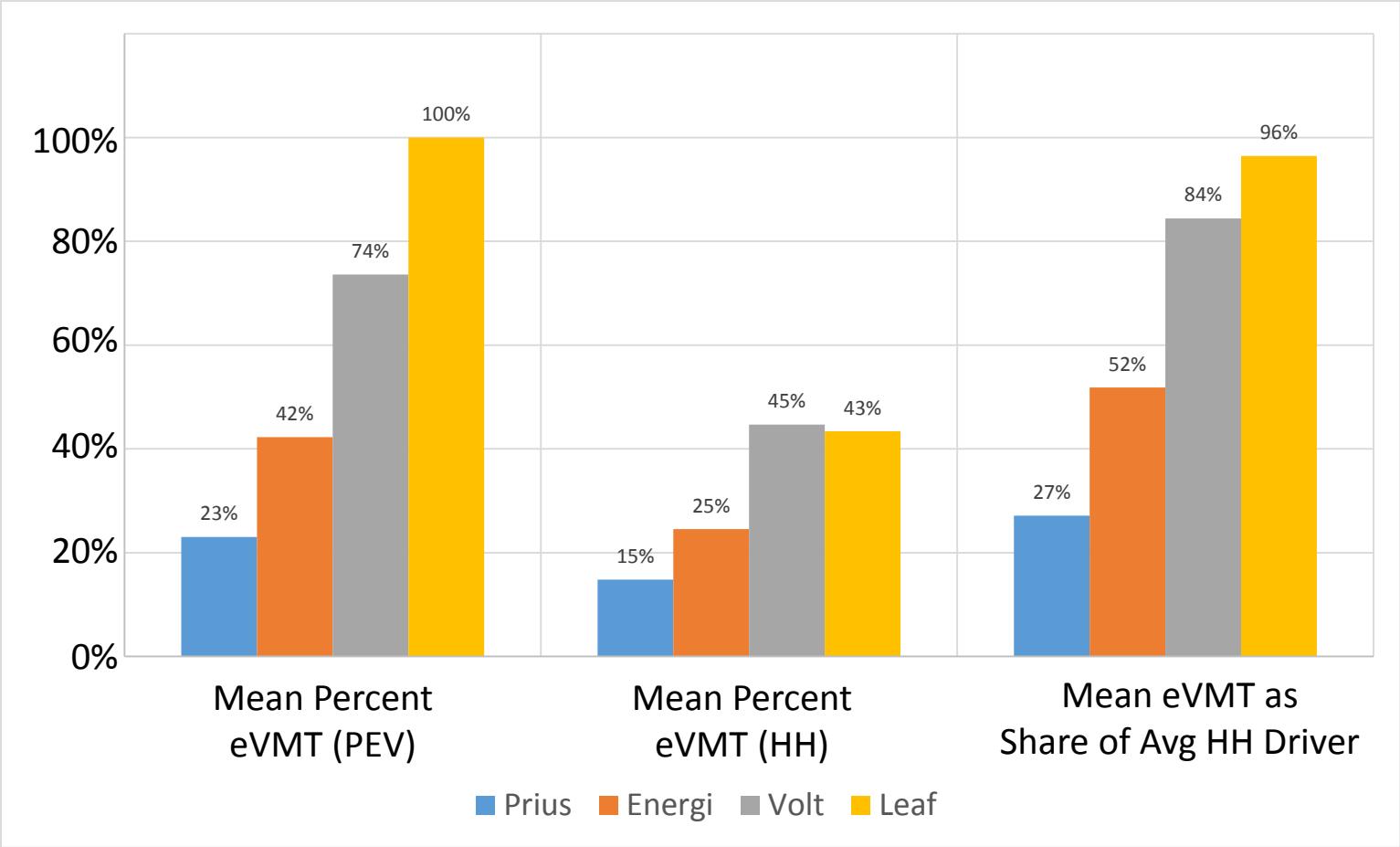
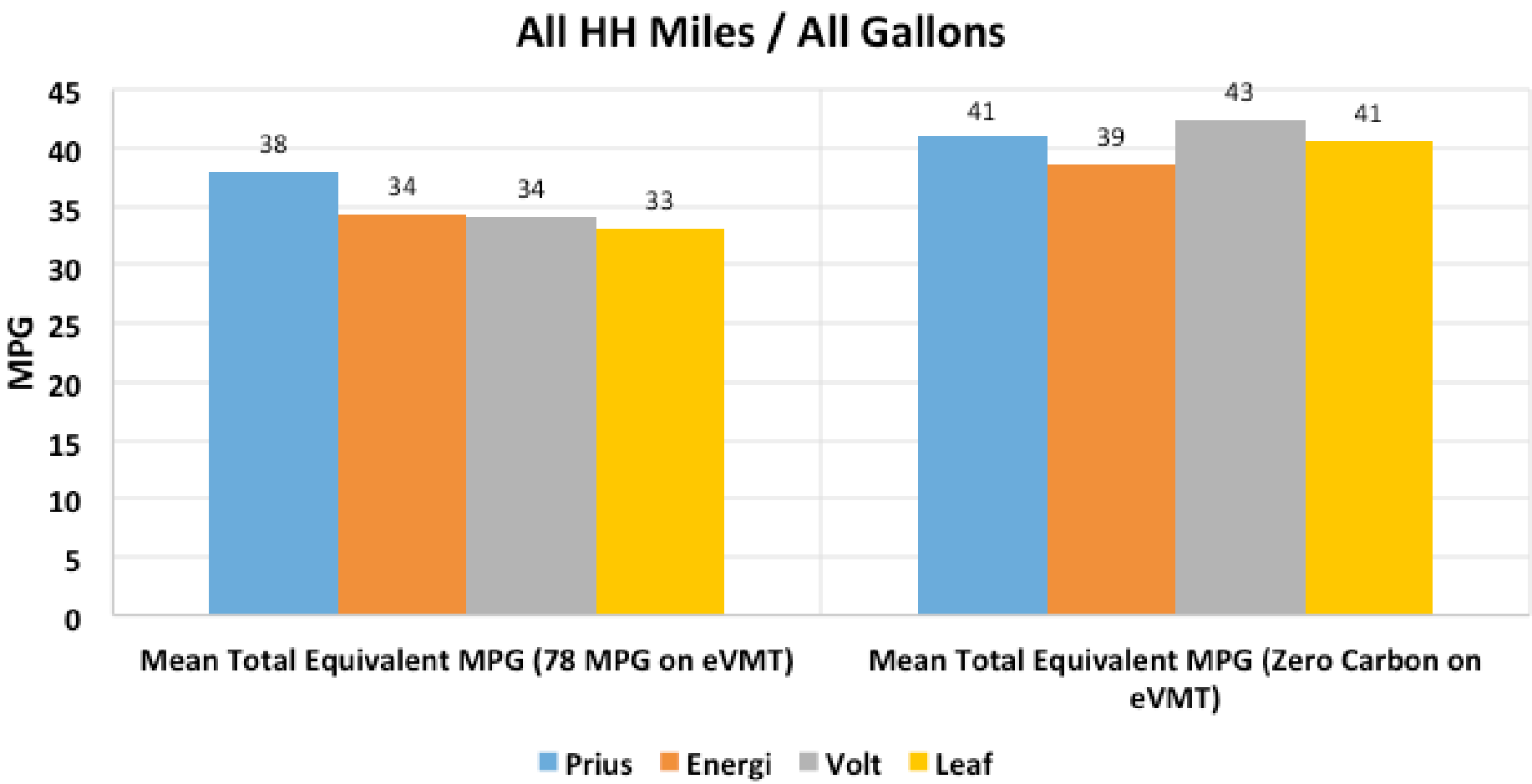
eVMT Percentages Three Ways: By PEV, Household, Avg Driver VMT



Accounting for All HH Vehicle GHG Emissions per Mile, Prius HH Most Efficient



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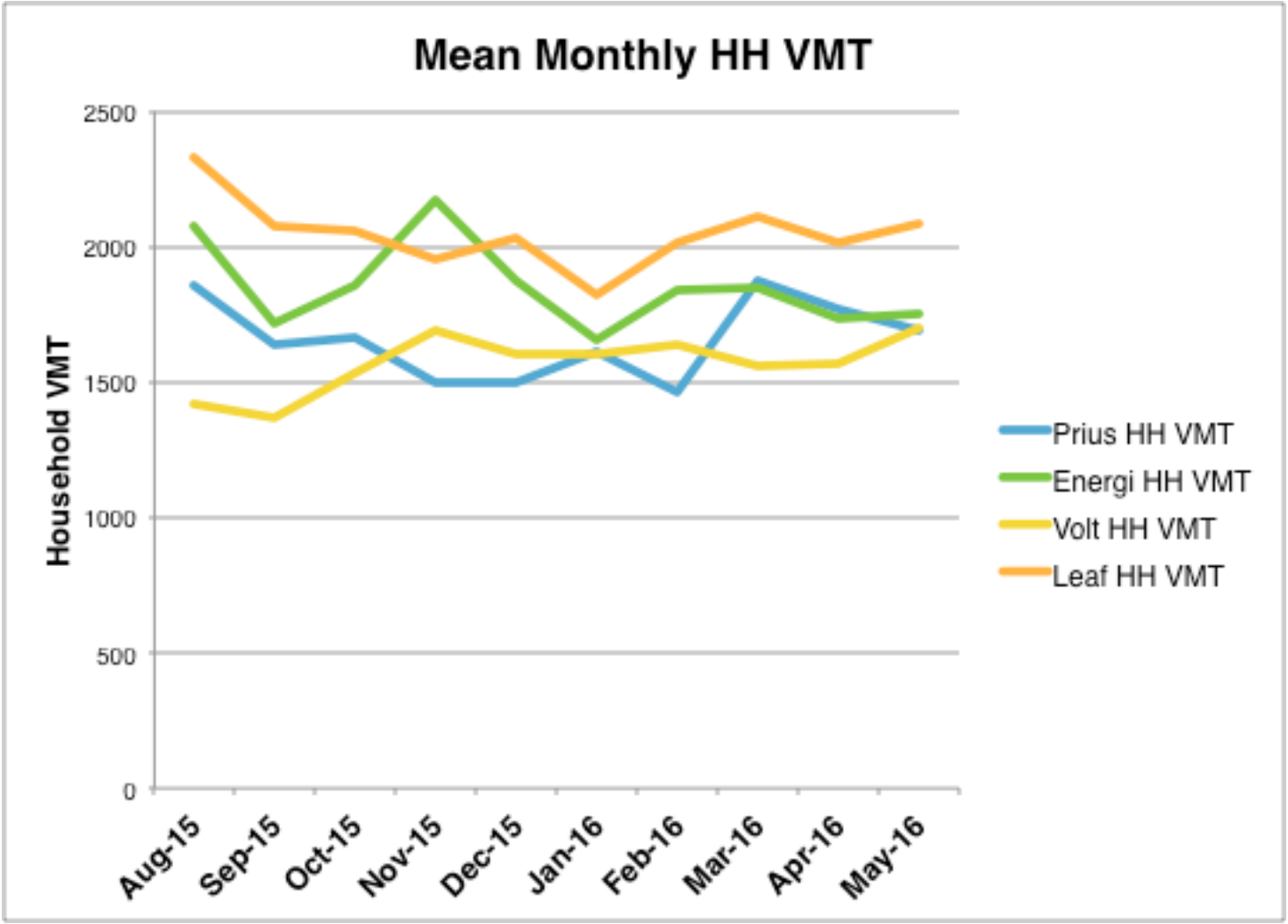
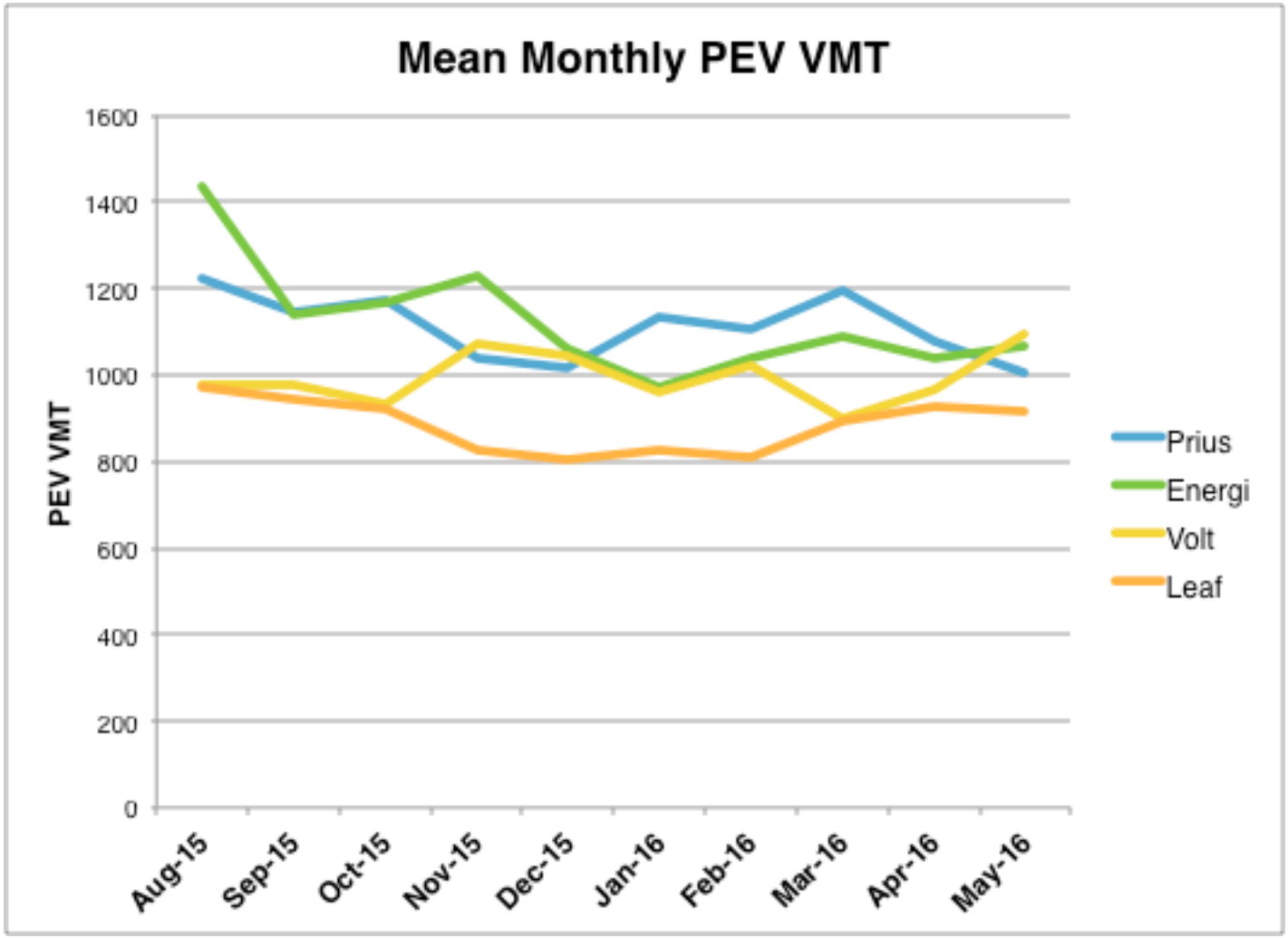
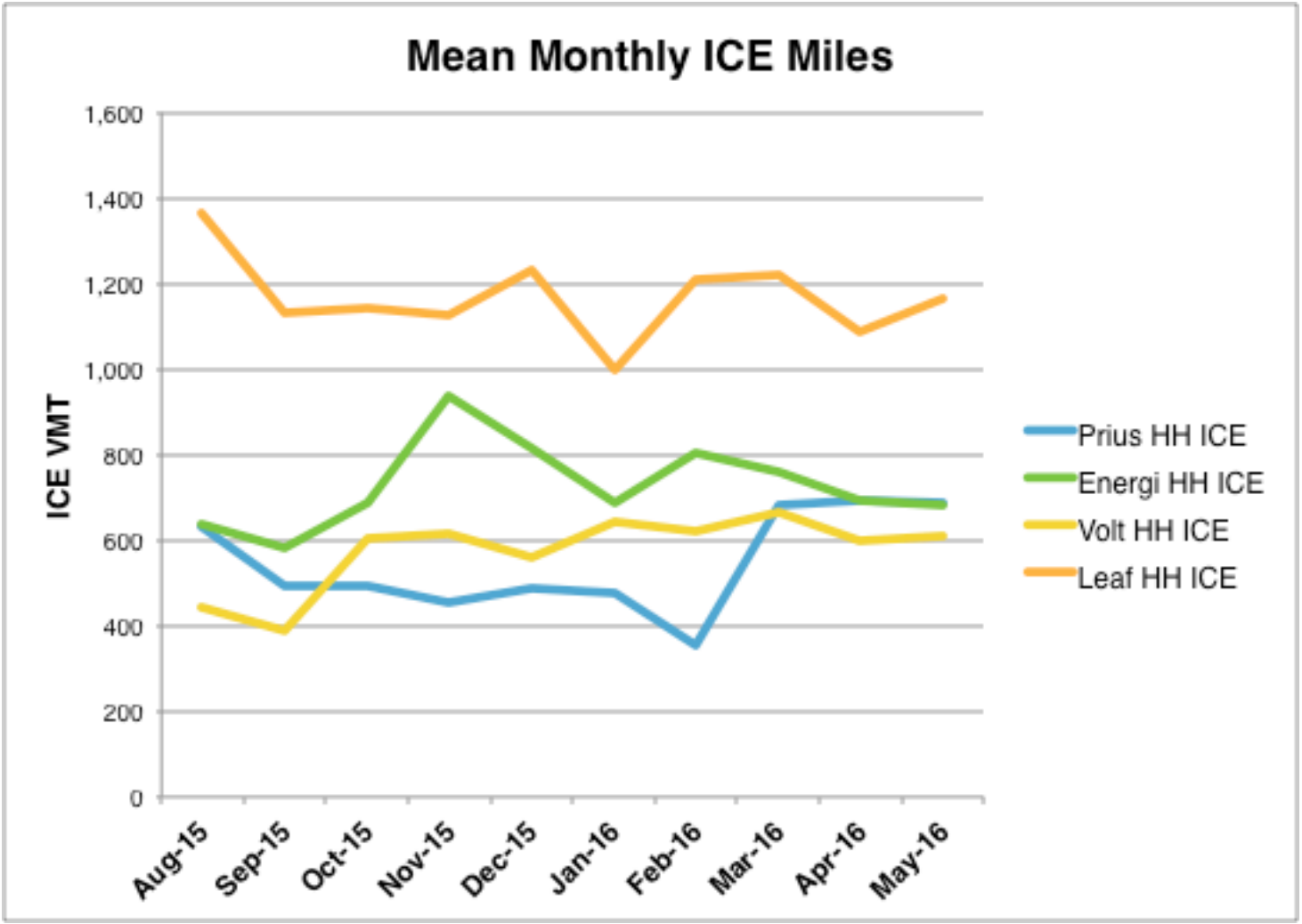
HH Miles Relatively Constant



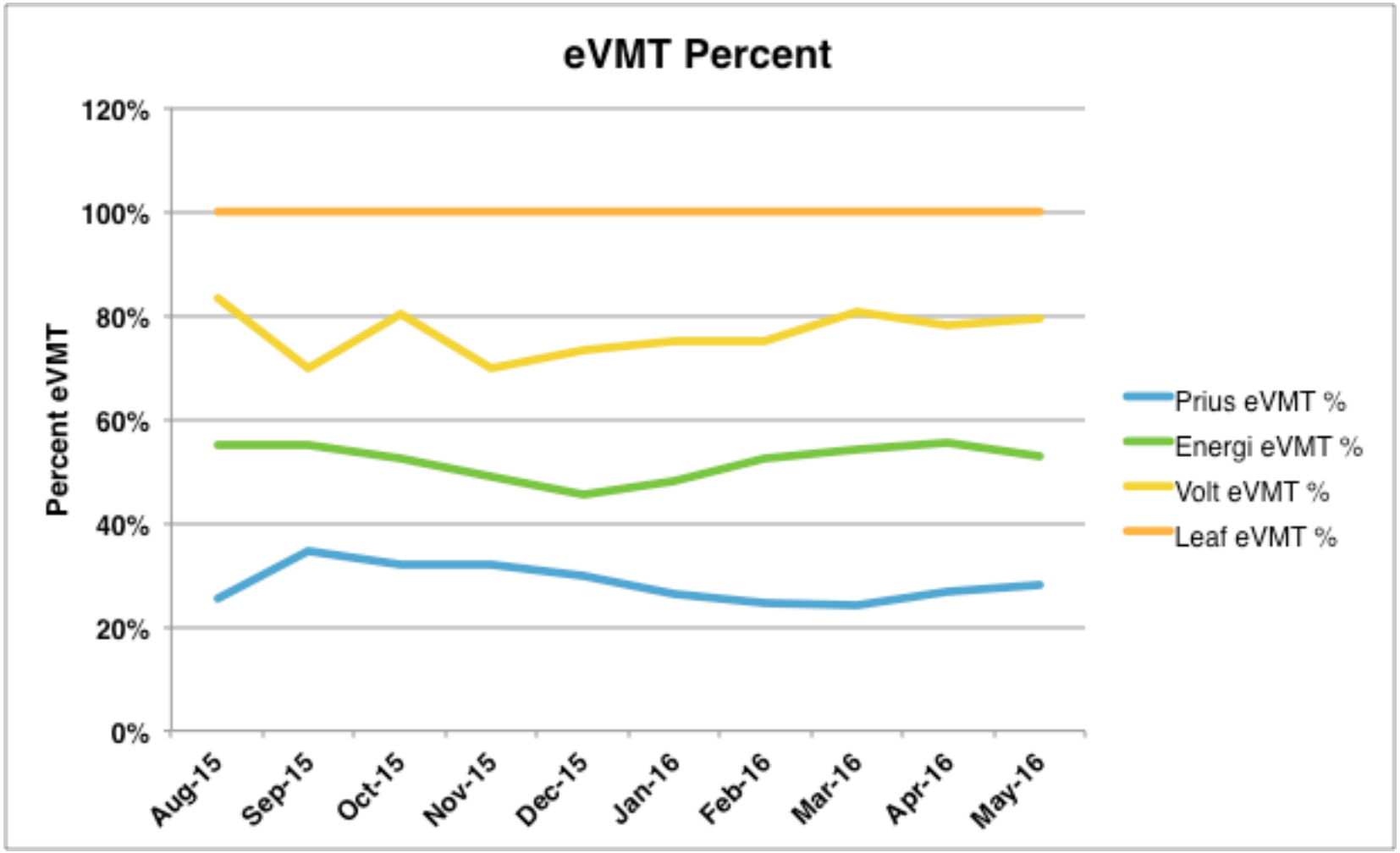
VMT Down for Fusion and Prius



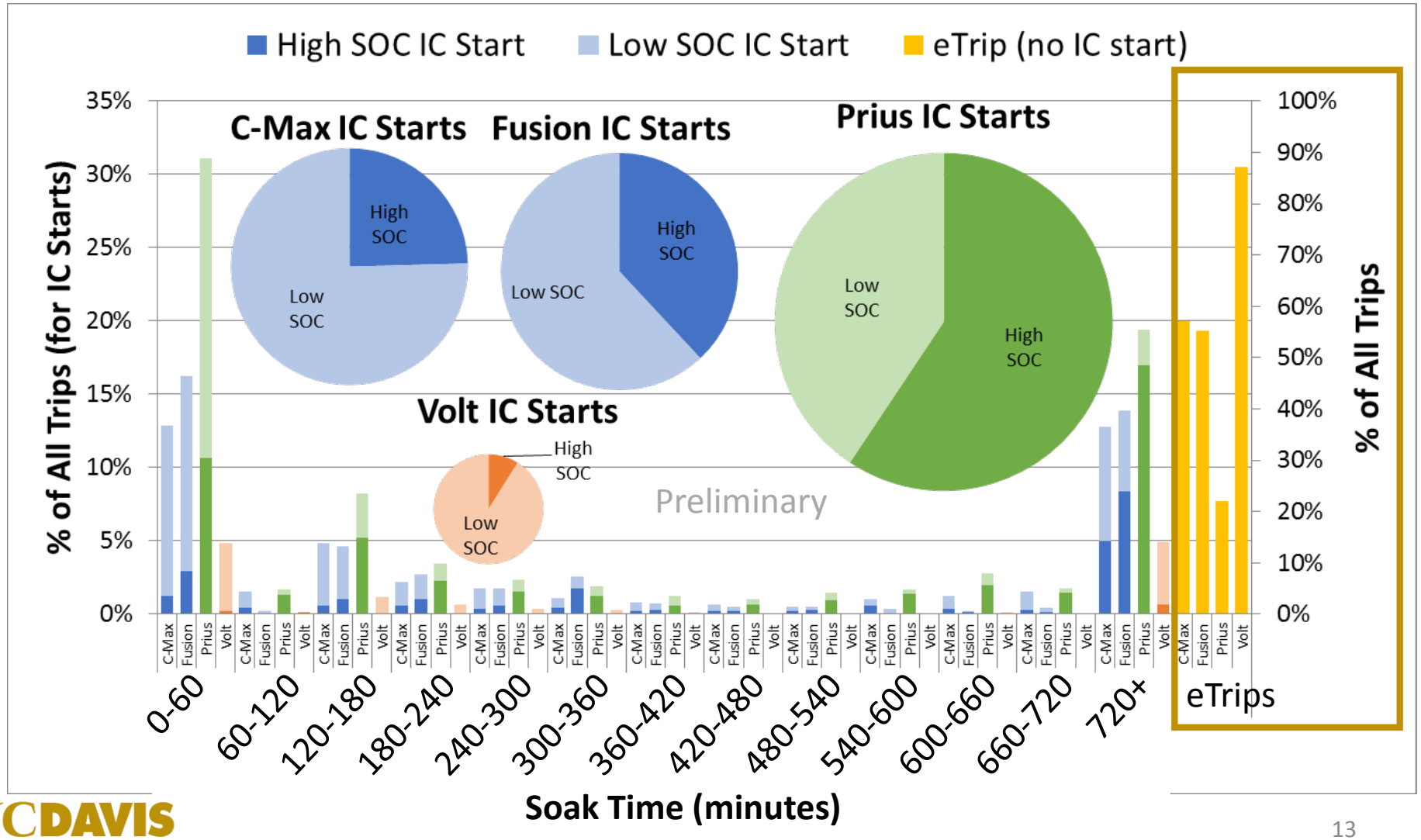
“Other Vehicle” ICE Miles Increasing Slightly for PHEVs



Seasonal Effects?
% eVMT Down in Winter



Blended PHEVs Long Soak IC Starts Often High Power



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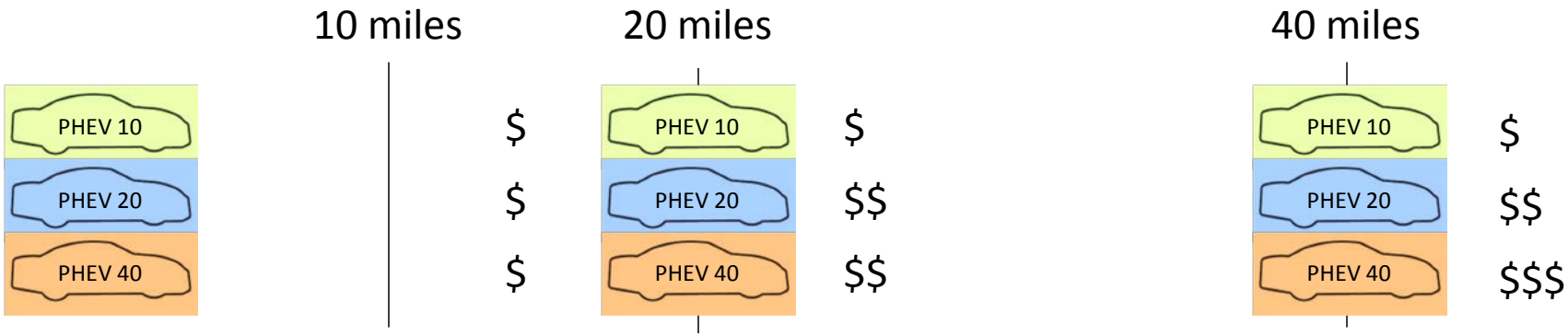
Overall Motivation to Plug In

- You must plug in to get eVMT
  - Is it worth it to the driver? What is the cost/benefit?
- Analysis of survey respondents shows PHEVs more likely to be plugged in when more range can be recovered
  - Longer range PHEVs less likely to never be plugged in because they provide greater potential for more miles to be recovered per charging event
  - Every mile recovered from a charge event increases the likelihood of plugging in by 1.4%

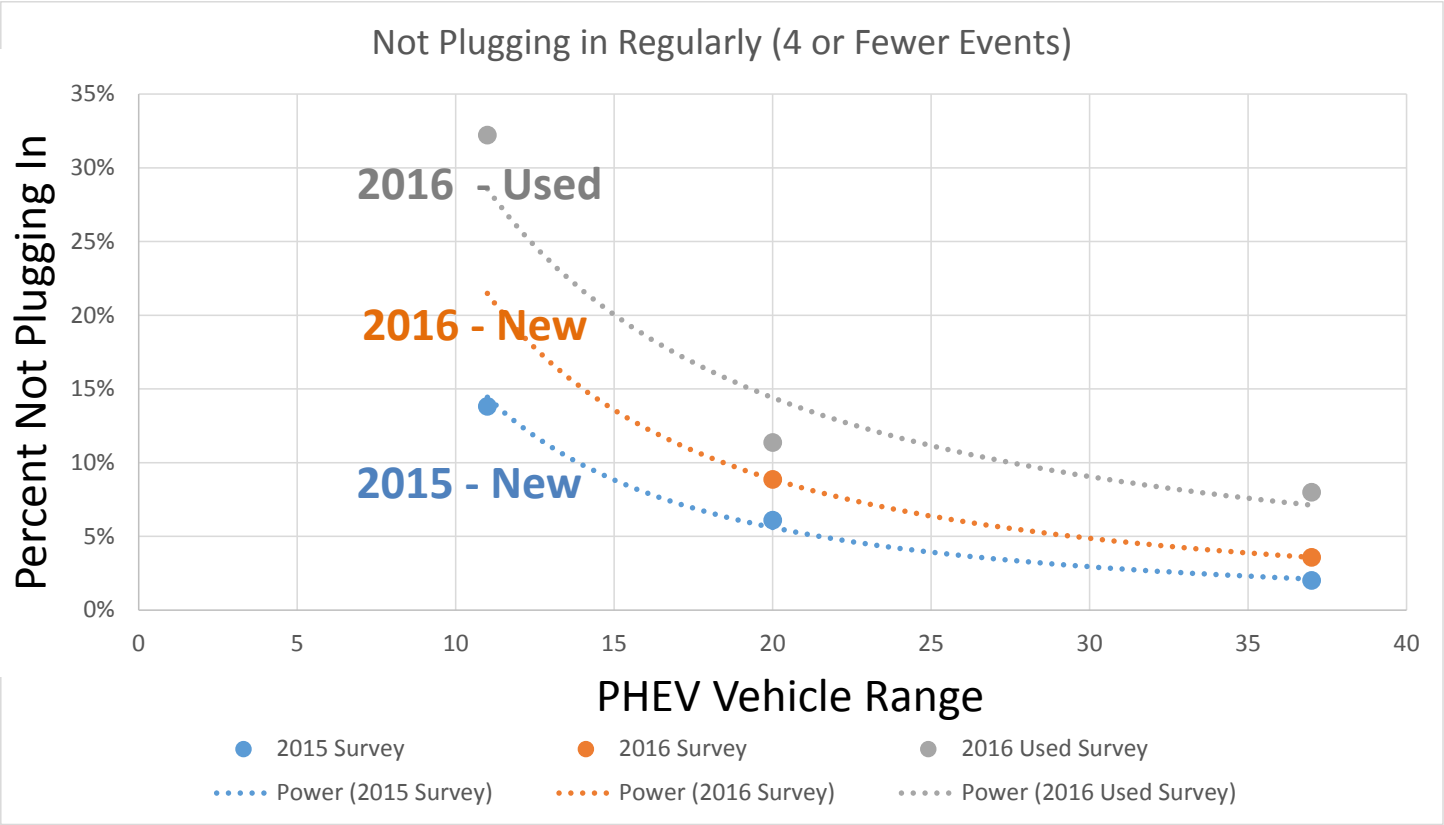
PHEVs With Longer Range Are Unlikely to Never be Plugged in. Cost-Benefit is Always Higher.

- 481 PHEV owners (Plug-in Prius, Energi, Volt) have free charging at work. Do they plug in?
- If one-way distance is 10 miles: All act statistically similar
- Likelihood of plugging in is a function of range recovered
- Longer range PHEVs eventually plug in



Source: Nicholas, Michael and Tal Gil. 2017 (Forthcoming), January 8-12. You Can't Take It With You: Examining The Role Of PHEV Range In The Decision To Plug In. In Transportation Research Board. Washington DC.

Because Low-Range PHEVs Provide Little Cost-Benefit, They are More Likely to Never Be Plugged in



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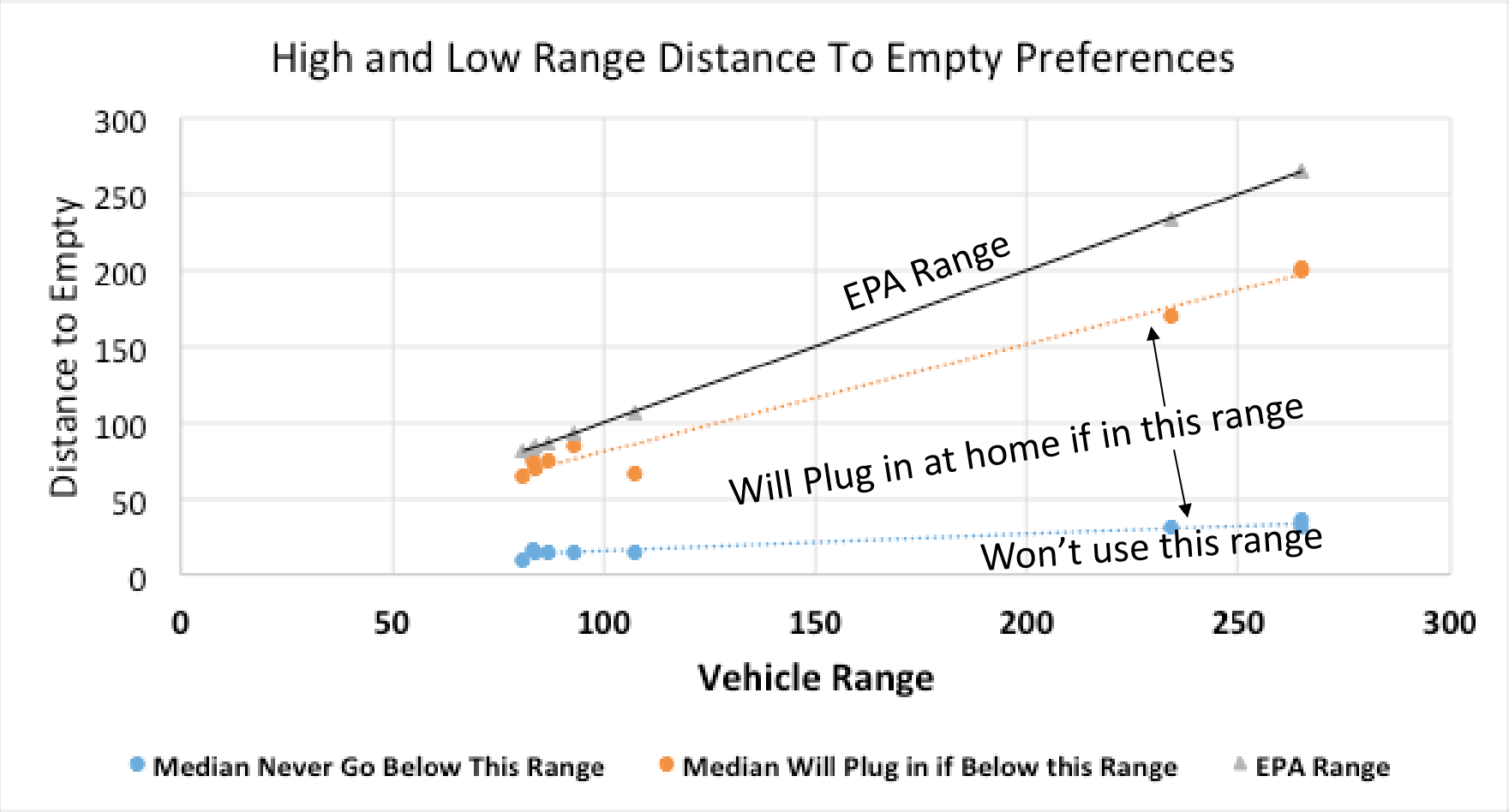
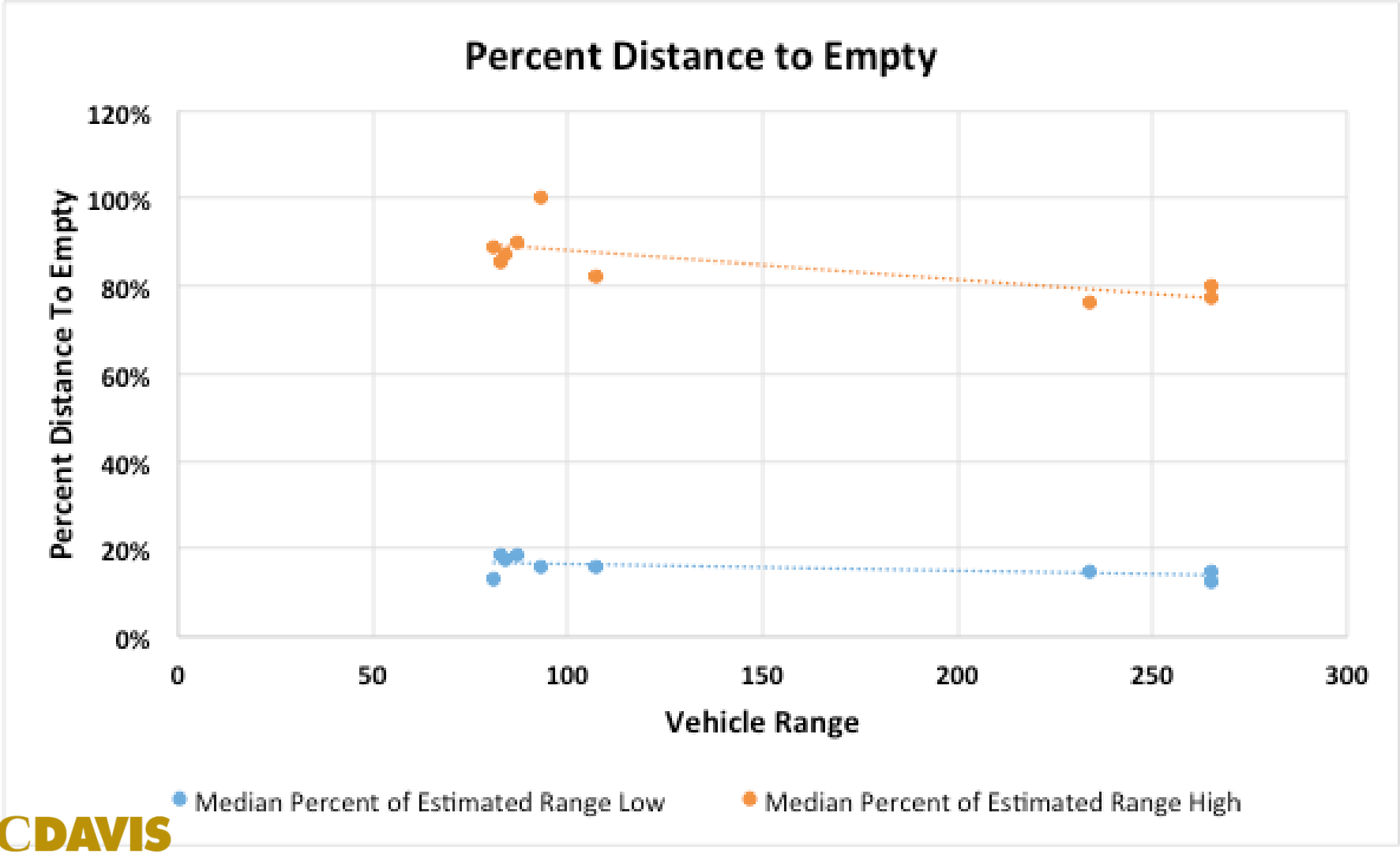
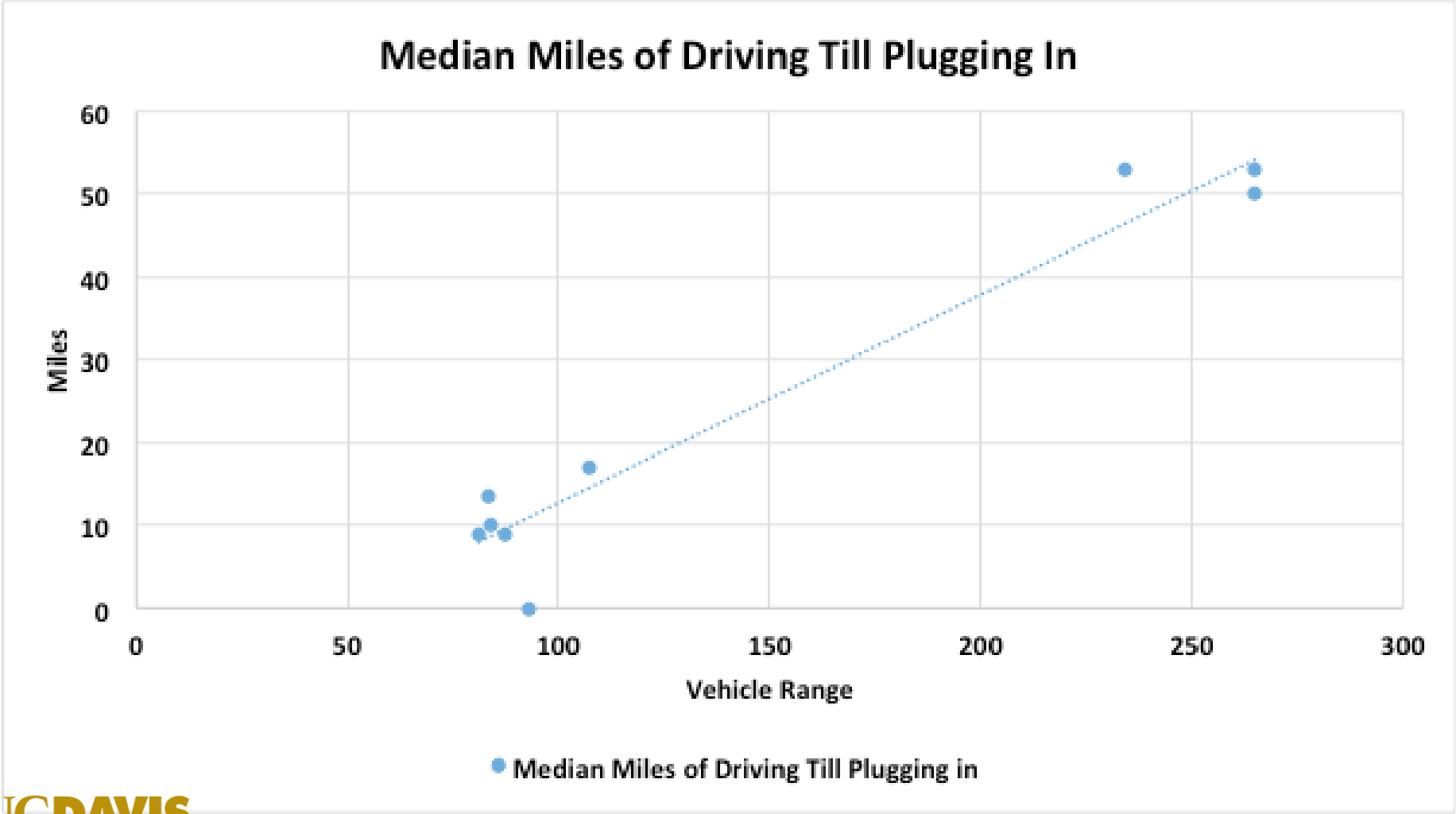
Even BEVs Value Not Plugging in at Home (Survey Preferences)



Many Will Plug in at Home if Battery SOC is > 18% and <80%.



Longer Range BEVs Wait 50 Miles Before Plugging in



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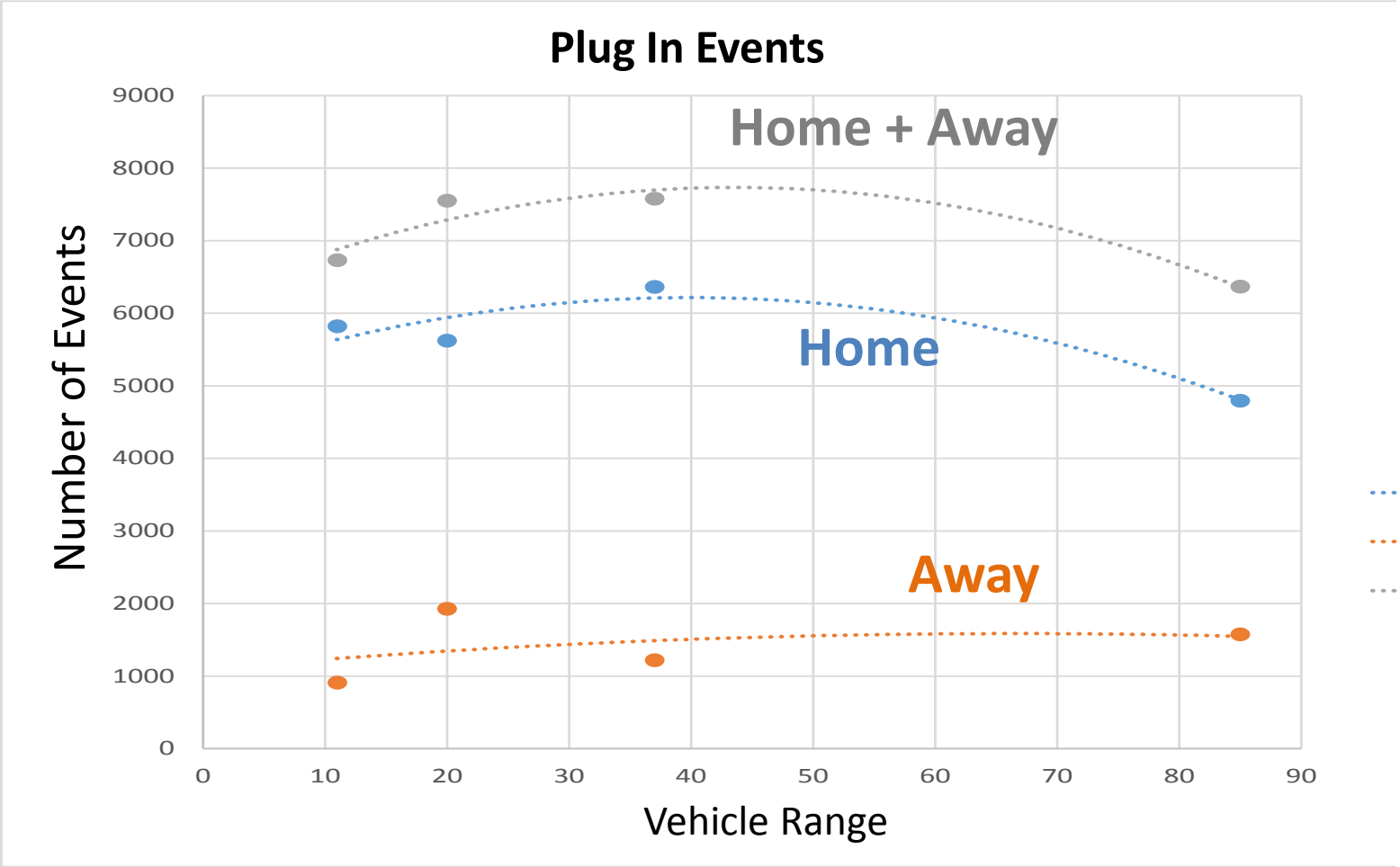
Volt Drivers Plug in the Most. Not Normalized for Charger Access



Conclusions

- Many…but for this project:
- The lower the electric range the fewer eVMT (duh!)
  - Technical potential is lower
  - Customers are not as willing to plug in
- Volts are similar in behavior and potential to Leafs for our sample, but slightly lower eVMT

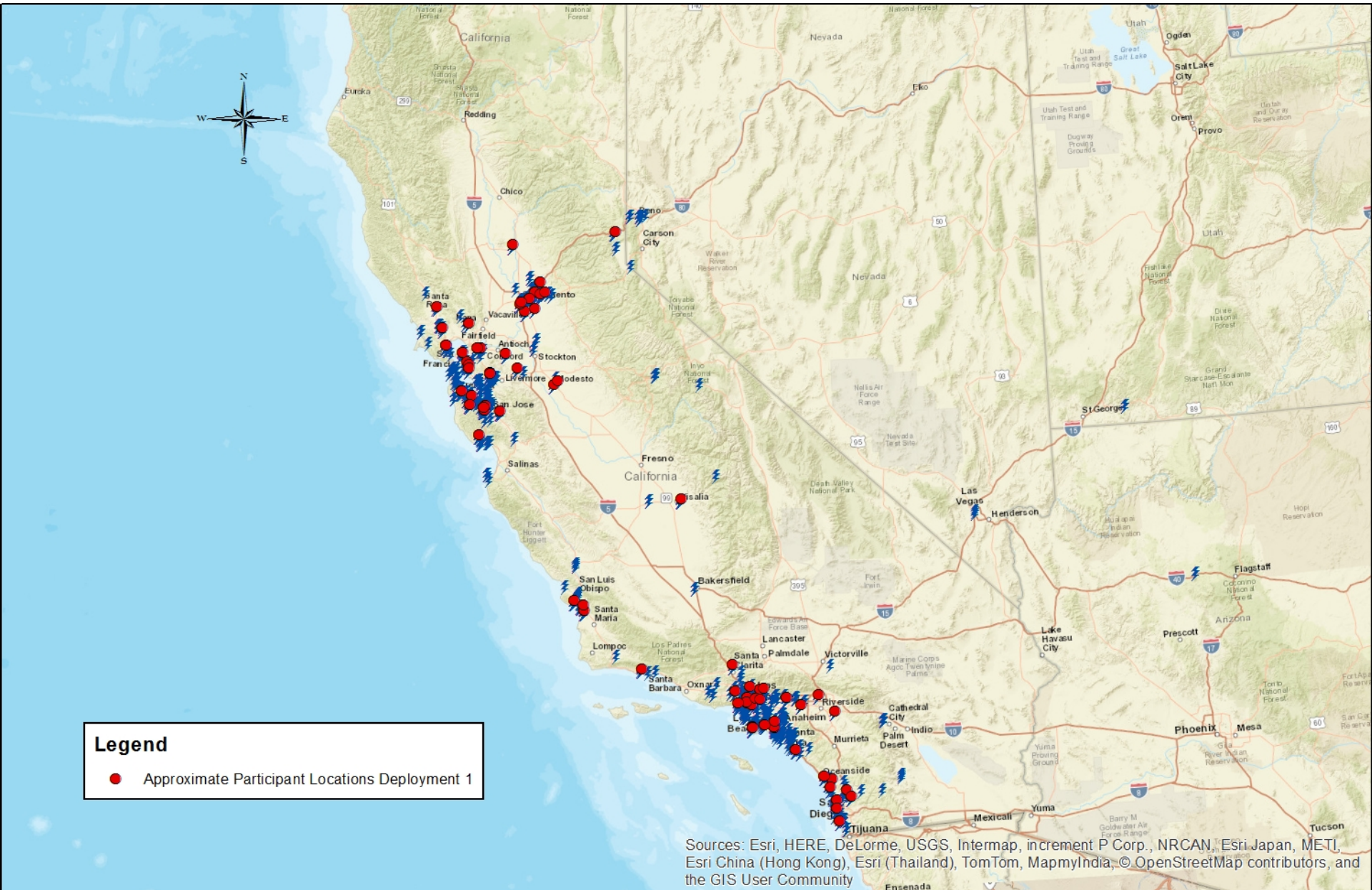
More Conclusions

- Household data show declining use of PEV
  - Older vehicles are naturally used less
  - Gas prices decrease
- High power cold starts more likely on smaller battery PHEVs
- GHG per household mile shows inefficient household miles (especially in BEV HH) need to be replaced with efficient miles.
  - Vehicle replacement is key
  - Substitute gasoline miles in an efficient PHEV
  - Zero carbon electricity is necessary

Thank You

- Michael Nicholas mianicholas@ucdavis.edu
- Gil Tal gtal@ucdavis.edu
- Thomas Turrentine tturrentine@ucdavis.edu

Participant Locations



Linear Regression Model

TABLE 3 Linear Regression Model

Dependent variable: percent of commute days plugging in					
Term		**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept		0.4105088	0.052351	7.84	<.0001*
Weekly congestion frequency (days)		-0.047059	0.010829	-4.35	<.0001*
Time restrictions dummy		-0.0801766	0.019353	-4.14	<.0001*
Income fraction from 500000		-0.172085	0.082624	-2.08	0.0378*
Recoverable One Way Miles		0.0144503	0.002104	6.87	<.0001*
R^2 = 0.165702 R^2 (adj) = 0.158691					