Advanced Plug-in Electric Vehicle Travel and Charging Behavior

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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, Ford Energi, 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

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
eVMT Percentages Three Ways: By PEV, Household, Avg Driver VMT
Accounting for All HH Vehicle GHG Emissions per Mile, Prius HH Most Efficient
HH Miles Relatively Constant

Mean Monthly HH VMT

Household VMT

0 500 1000 1500 2000 2500


- Prius HH VMT
- Energi HH VMT
- Volt HH VMT
- Leaf HH VMT
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

![Graph showing the percentage of trips for different vehicles with high and low SOC during IC starts over soak times.

- C-Max IC Starts
  - High SOC: 30%
  - Low SOC: 25%

- Fusion IC Starts
  - High SOC: 35%
  - Low SOC: 15%

- Prius IC Starts
  - High SOC: 28%
  - Low SOC: 40%

- Volt IC Starts
  - High SOC: 10%
  - Low SOC: 5%


% of All Trips (for IC Starts): Preliminary

% of All Trips: 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, 0%

eTrips
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

<table>
<thead>
<tr>
<th>Range</th>
<th>10 miles</th>
<th>20 miles</th>
<th>40 miles</th>
</tr>
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<tbody>
<tr>
<td>PHEV 10</td>
<td>$</td>
<td>$</td>
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<tr>
<td>PHEV 20</td>
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<td>PHEV 40</td>
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<tr>
<td>PHEV 40</td>
<td>$</td>
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</tbody>
</table>

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

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.
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
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

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Linear Regression Model

TABLE 3 Linear Regression Model

| 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* |

\[ R^2 = 0.165702 \]
\[ R^2 (adj) = 0.158691 \]