ADVANCED PLUG-IN ELECTRIC VEHICLE TRAVEL AND CHARGING BEHAVIOR AKA EVMT STUDY

UC DAVIS PLUG-IN HYBRID AND ELECTRIC VEHICLE RESEARCH CENTER

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EVMT AS A PERFORMANCE METRIC FOR:

- GHG reduction?
- Local criteria pollutant reduction?
- Gasoline replacement?
- Energy security?
- Technology advancement?
MAXIMIZING ZVMT MAY INVOLVE TRADEOFFS

• Which is better for GHG? Blended or zVMT for the first 40 miles?
• Which is better for criteria?
• Cold Starts?

Same electricity and gasoline,
More miles blended?

WHAT ARE THE INTERACTIONS?

• More chargers needed per vehicle
• Too small = no benefit
• Medium size = more chargers
• Large BEV = lower frequency, more access needed
OUR ROLE

• Provide stakeholders and policy makers analysis to help make informed decisions and have informed discussions
• Analyze cause and effect under different policy scenarios

PROJECT OVERVIEW

• Provide most in-depth study of PEV usage and charging dynamics. Inform policy on battery size/vehicle architecture/consumer behavior interaction
• 30,000 person survey to inform data collection
• Monitor all vehicles in PEV households. PEVs: Leaf, Volt, Prius Plug-in, (C-Max?)
• 108 households
• Monitor OBD driving and charging parameters along with location
• Determine PEV household travel dynamics. How is the PEV used compared to other cars? EVMT impacts?
• Determine charging frequency and location. L1, L2, QC location.
PROJECT OBJECTIVES

• Show eVMT as a percentage of household miles across all available vehicles, not only the one being studied. Find out where the “other” gasoline miles go.
• Explain the “why” in the distribution of eVMT between different households who own the same PEV and among different PEVs.
• Provide the building blocks to construct eVMT with multiple formulas with differing consumer interaction
• Measure dependence on public charging infrastructure as a function of vehicle model
• Determine which other metrics are important to explain variation in VMT and eVMT

TWO MAIN DATA COLLECTION EFFORTS: SURVEY AND ON-ROAD DATA COLLECTION

• Survey will be sent to 30,000 PEV households of most makes and models
• 1 Year data collection of 108+ households with Plug-in Prius, Volt, and Leaf vehicles. Collect data from all household vehicles
**MAKING SENSE OF THE DATA**

- **Raw Data**
  - 10,000 EV Miles
  - 5,000 ICE Miles
  - 1,000 Miles
  - 16,000 Miles

- **Tri Data**
  - 1,000 EV Miles
  - 5,000 ICE Miles
  - 15,000 Miles
  - 39,000 Miles

- **Summary Data**
  - Survey Data
  - OEM Trip Data

- **Survey Data**
  - 108
  - 10,000+

**Expanded Summary Analysis**

**SURVEY INFORMS ON-ROAD DATA COLLECTION**

- Household demographics, income
- Household vehicles
- Vehicles per driver
- Commute location
- Travel behavior/needs, Important destinations, HOV usage
- Home and work charging infrastructure
- Electricity prices
- Purchase motivation
- Risk taking
ON-ROAD DATA COLLECTION

- Travel patterns, distribution
  - PEV
  - Other vehicles
- Charging behavior
  - Location
  - Time
  - Frequency
  - Power
  - Level
  - Efficiency
- Gasoline operation
  - MPG
  - Cold Starts
- Electric operation
  - MPKWH
  - eVMT (engine off and blended)
- Comfort/climate control

ON-ROAD DATA INFORMS SURVEY

- Back-casting – how well does the survey data about travel and charging behavior predict actual behavior?
- What factors explain variation in eVMT per household?
  - Behavior
  - Vehicle architecture
  - Battery size
  - Charger availability
  - Others? Gasoline Price
- What is the distribution of these households?
- What are the implications for policy?
CHANGING CONTEXT OVER TIME
GASOLINE PRICE VS. EVMT

• If Gas is $2.80, Break-even cost for:
  • Plug-in Prius is 16¢/kWh
  • C-Max is 19¢/kWh
  • Volt is 22¢/kWh
• Home electricity is 15¢/kWh
• PIP “fill” = 3¢ savings
• C-Max “fill” = 32¢ savings
• Volt “fill” = 92¢ savings

TIMELINE
EXTENDING THE ANALYSIS

• Add more models first
  • C-Max
  • BEVx
  • Tesla
• Add volume
  • Perhaps shorter time periods?
  • Only PEVs?
  • Connect results to OEM Data
• Analysis beyond ARB deliverables
  • Grid impacts
  • Emissions impacts

QUESTIONS?
EV PLANNING TOOLBOX

BACKGROUND

• CEC Pier Funded project. AKA “UC Davis MPO GIS EV Market and Charger Planning Toolbox”
• Associated with CCSC
• Interview MPOs regarding their needs and build tools to help planning for chargers and EVs
• Outcomes
  • Tools for GIS Professionals
    • Market tool
    • Workplace charging tool
    • Fast charging tool
  • Consumer tool “EV Explorer”  [http://gis.its.ucdavis.edu/evexplorer]
MARKET TOOL

- Predict PEV Owner Distribution
- Based on a stochastic sample of households
- Sample is stratified by Independent Variable Effects
- Sample is stratified by scenario planning parameters
  - % New Car Buyers
  - % PEV Buyers
  - % BEV Buyers

MARKET TOOL DATA NEEDS

- Census income
- Housing type
- Commute distance
- Target market size
ARCGIS INTERFACE

TOOL VALIDATION
PRICE EQUALIZATION

RANGE EQUALIZATION
WORKPLACE CHARGING TOOL

- Detailed spatial distribution of workers’ employment and residential location.
- Tool can evaluate work charging demand
  - Free work charging
  - Paid work charging

SAMPLE RESULT – FREE WORK CHARGING
FAST CHARGING TOOL

• Relies on 2009 Caltrans survey of over 42,000 households

• One day of travel, used only non-work trips in a personal vehicle (mostly gasoline vehicles). Work trips and work charging can be included if desired

• Tool can
  • Evaluate current chargers
  • Evaluate proposed locations
  • Choose new sites that are underserved
  • Evaluate different battery sizes
CHARGE WINDOW ILLUSTRATION

- D = 85 mile tour
- Charge window on D is mile 37-64

- A = 4 customers
- B = 3 customers
- C = 6 customers

METHODS – SCALING DEMAND

- Used current distribution of BEV 60, 80 by county. Assumed 80% of Leafs had fast charge capability
- Demand in charge window is scaled by the number of times customers are willing to stop per day. From about 2000 leaf owners

**How Many Quick Charge Events Per Day do You Find Reasonable on An Occasional Basis?**

- 100%
- 51%
- 13%
- 4%
- 2%
- 1%
- 0%
- 0%
MODEL FLOW

1. Create from-to paths from Caltrans 42,000 households
2. Scale the trips to represent current distribution of BEV 60, 80 (Source ARB CVRP). Yolo might have 1000 survey takers and 500 BEVs so each household counts half.
3. Separate out non-work tours (or leave them in)
4. Set them out to complete trips in their BEVs and make charge windows
5. Scale demand by willingness to stop
6. Evaluate demand for stations based on trip distribution/purpose, BEV population, willingness to stop

<table>
<thead>
<tr>
<th>Vehicle Scenario</th>
<th>Charger Scenario</th>
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<tbody>
<tr>
<td>Current distribution of BEV 80s, 60s</td>
<td>Current fast charger network</td>
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<tr>
<td>Current distribution of BEV 80s, 60s</td>
<td>Current and proposed fast charger network</td>
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<tr>
<td>Future distribution of BEV 80s, 150s, 300s</td>
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<td>Current, proposed, and model chosen chargers</td>
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CURRENT BEVS (60, 80) CURRENT

[Map of current BEV distribution with legend]
INTERPRETING THE RESULTS – EXISTING CHARGERS ARE LOWER OR HIGHER...

• Model reflects opportunity not actual demand
• Pricing
• Congestion uncertainty
• Nearby services – Is it pleasant? Can I shop?
• Hours of operation
• Only county level data not specific within county
• Efficiency of other household cars may be a factor
• Survey phrasing “How many times are you willing to stop on occasional long distance tours” does not define occasional. We model occasional to mean non-work tours, but respondents may have a different definition
• Cargo, 4 wheel drive etc may be more valuable on longer trips

EVALUATING FUTURE DEMAND

• Used market module of the Toolbox to forecast demand distribution in the future for BEVs at a level of 500,000 BEVs. Adjusted ranges to fit scenario including BEV 80, 150, 300 (model only assigns BEV 80s and 300s by default).
• Scenario is 50% BEV 80s, 25% BEV 150s, 25% BEV 300s
• These are just scenarios not predictions. Modeler can input what they want. We don’t know battery prices which drive scenarios.
DEMAND FROM CURRENT VEH, CURRENT LOCATIONS
DEMAND FROM FUTURE VEH, FUTURE LOCATIONS

FUTURE SCENARIO CHOOSING THE BEST STATIONS WITH THREE BEV SIZES
INITIAL RESULTS

• For a North-South corridor,
  • Bakersfield-Sacramento: CA 99 seems better in the near term due to local demand along the corridor
  • Sacramento – Redding: Either CA70/99 or I-5 though CA70/99 appears to have more population along it
  • Redding-Oregon: I-5 demand may be better than shown due to Oregon based traffic near border
• Some areas show low demand now, but demand should grow if longer range BEVs are popular and BEVs are less “concentrated”

REGIONAL MODELS MAY MISS SOME DEMAND.
LARGER REGIONS HAVE LESS ERROR.

\[
y = 1758.6x^{1.813}
\]

Percent of Demand From Inside Region vs Battery Size

- Los Angeles
- Bay Area
- San Diego
- Sacramento
- Power (Bay Area)
FUTURE USE

- Designed to be a tool for others to use
- Metropolitan Planning Organization were the primary focus, but others including NREL, Ford, Aerovironment, NRG, PG&E, and Chargepoint have expressed interest
- Fast charging module most applicable for California, based on dataset suitability.
- Market module and workplace charging module is more portable because it is based on census data rather than a Caltrans Dataset