In the Slow Lane: ZEV Markets in California, June 2014 to June 2017

STEPS Symposium

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**Brief summary of data sources**

**Pre-2014**
- 1990s: BEV, PHEVs: Ride-n-drive clinics, focus groups, surveys
- Early 2000s: FCEVs, HEVs: Interviews, field tests
- Late 2000s: PHEVs, BEVs: Surveys, field tests, interviews

**2014-15**
- All-CA car-owning households: June; November: Surveys n ~ 1,700 each
- CA and twelve other states new-car buyers: Dec. ‘14 to March ’15: Survey CA n~1,700 (total n ~5,500); Post-survey interviews CA n = 36 (total n ~ 70)

**2017**
- All-CA car-owning households: February, June: Surveys, n ~ 1,700
- Buyers of ICEV/HEV/PEV variants: Winter ’17: Interviews, n = 24
- PEV buyers: Spring ’17: Interviews, n = 24

**?’
Have car-owning households in California considered BEVs?

“Battery electric vehicles (BEVs) run only on electricity; they plug-in to charge their batteries. Have you considered buying a BEV for your household?

- I have not—and would not—consider buying a vehicle that runs on electricity
- I have not considered buying a vehicle that runs on electricity—but maybe some day will
- The idea has occurred, but no real steps have been taken to shop for one
- Started to gather some information, but haven’t really gotten serious yet
- Shopped for an electric vehicle, including a visit to at least one dealership to test drive
- I already have, or have had, a vehicle powered by electricity”

- Starting February 2017 similar questions were added for PHEVs and FCEVs.
- Starting June 2017 the last answer was changed to include the possibility they previously had a PEV or FCEV, but no longer did.
PEV sales in California

• September 2014
  ~ 106,000

Have car-owning and new car buying households in California considered BEVs?

<table>
<thead>
<tr>
<th></th>
<th>June 2014</th>
<th>November 2014</th>
<th>December 2014</th>
<th>February 2017</th>
<th>June 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>All car owning households</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haven't; won't</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Haven't; maybe some day</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Info gathered; not serious</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actively shopped</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consider BEV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea occurred; no steps taken</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Already own, lease</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PEV sales in California

• September 2014
  ~ 106,000

• December 2016
  ~ 246,000

• May 2017
  ~ 300,000 “ZEVs and PHEVs”
  http://www.energy.ca.gov/renewables/tracking_progress/documents/electric_vehicle.pdf
Have car-owning and new car buying households in California considered BEVs?

- June
  - All car owning households (2014)
  - Consider BEV:
    - Haven't; won't
    - Haven't; maybe some day
    - Info gathered; not serious
    - Actively shopped
    - Idea occurred; no steps taken
    - Already own, lease

- November
  - All car owning households
  - Consider BEV:

- December
  - New Car Buyers
  - Consider BEV:

- February
  - All car owning households (2017)
  - Consider BEV:

- June
  - All car owning households
  - Consider BEV:
Number of PEV makes and models (that have been) for sale in consumer retail markets in California since 2010

2010 through 2014: 23

- **10 PHEVs**: Volt, Prius Plug-in, C-Max Energi, Fusion Energi, Panamera S E-hybrid, ELR, i8; *Karma, 918 Spyder, Accord PHEV*

- **13 BEVs**: Leaf, fortwo, iMEV, Focus Electric, Model S, Spark EV, 500e, i3, B-class; *Roadster, RAV4 EV (2nd Gen.), Fit EV, iQ EV*

https://www.driveclean.ca.gov/pev/Plug-in_Electric_Vehicles/Makes_and_Models.php
“Can you name a BEV that is being sold in the US?”

<table>
<thead>
<tr>
<th>Year</th>
<th>All-car owning households</th>
<th>New Car Buyers</th>
<th>All-car owning households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun-14</td>
<td>All</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Nov-14</td>
<td>All</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Dec-14</td>
<td>All</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Feb-17</td>
<td>All</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Jun-17</td>
<td>All</td>
<td></td>
<td>All</td>
</tr>
</tbody>
</table>

- Yes: Right (Other)
- Yes: Right (Tesla, any)
- Yes: Right (Nissan Leaf)
- Yes: Maybe
- Yes: Wrong
- No
Number of PEV makes and models (that have been) for sale in consumer retail markets in California since 2010

2010 through 2014: 23

• 10 PHEVs: Volt, Prius Plug-in, C-Max Energi, Fusion Energi, Panamera S E-hybrid, ELR, i8; Karma, 918 Spyder, Accord PHEV

• 13 BEVs: Leaf, fortwo, iMEV, Focus Electric, Model S, Spark EV, 500e, i3, B-class; Roadster, RAV4 EV (2nd Gen.), Fit EV, iQ EV

+ 2015 through 2017: 40

+ 12 PHEVs: Cayenne S E-hybrid, S500e, GLE 550e, XC90 T8, X5 xDrive40e, Sonata PHEV, Audi A3 e-tron, 330e iPerformance, 740e xDrive, Pacifica Hybrid, Optima, CT6,

+ 5 BEVs: Soul EV, e-Golf, Model X, Bolt, Ioniq

https://www.driveclean.ca.gov/pev/Plug-in_Electric_Vehicles/Makes_and_Models.php
“Can you name a BEV that is being sold in the US?”

- Jun-14: All-car owning households
- Nov-14: New Car Buyers
- Dec-14: All-car owning households
- Feb-17: All-car owning households
- Jun-17: All-car owning households

Graph showing the percentage of households who can name a BEV.
PEV Charging Infrastructure

• August 2014: 5,700 nonresidential charging stations
  http://www.energy.ca.gov/transportation/zev/pev/

• August 2017: “More than 10,000 Level 2 and 1,500 direct current fast charger (DCFC) connectors”
  http://www.energy.ca.gov/renewables/tracking_progress/documents/electric_vehicle.pdf

• December 2017: 13,846 chargers; 3,967 locations
  • 567 Level 1; 11,730 Level 2; 1,549 DC Fast
  https://www.afdc.energy.gov
“Have you seen any electric vehicle charging spots in the parking garages and lots you use?”

New Car Buyers

- Dec-14:
  - Yes, several places: 40%
  - Yes, a few places: 30%
  - Yes, one place: 20%
  - I'm not sure: 10%
  - No, I haven't: 0%

- Feb-17:
  - Yes, several places: 40%
  - Yes, a few places: 30%
  - Yes, one place: 20%
  - I'm not sure: 10%
  - No, I haven't: 0%

- Jun-17:
  - Yes, several places: 40%
  - Yes, a few places: 30%
  - Yes, one place: 20%
  - I'm not sure: 10%
  - No, I haven't: 0%

All Car Owners

- Dec-14:
  - Yes, several places: 30%
  - Yes, a few places: 30%
  - Yes, one place: 20%
  - I'm not sure: 10%
  - No, I haven't: 10%

- Feb-17:
  - Yes, several places: 30%
  - Yes, a few places: 30%
  - Yes, one place: 20%
  - I'm not sure: 10%
  - No, I haven't: 10%

- Jun-17:
  - Yes, several places: 30%
  - Yes, a few places: 30%
  - Yes, one place: 20%
  - I'm not sure: 10%
  - No, I haven't: 10%
“There are enough places to charge battery electric vehicles.”

Scale: -3 = strongly disagree; 3 = strongly agree

June 2014 (top)
June 2017 (bottom)

No difference in means: slight disagreement there are enough
“From what you understand, which of these vehicles are fueled with gasoline and which are plugged in to charge with electricity?” Percent correct.
“As far as you are aware, is each of the following offering incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel?”

- 0.0%
- 10.0%
- 20.0%
- 30.0%
- 40.0%
- 50.0%

Bar chart showing:
- 12/2014 (New Car Buyers)
- 2/2017
- 06/2017

Legend:
- Federal
- California
“Battery electric vehicle technology is ready for mass automotive markets.” Scale: -3 = no, 3 = yes.
We’re hardwiring gender differences in markets for ZEVs

California Clean Vehicle Rebate Applicants, 9/1/12 to 5/31/2015

New-car buyers, CA; 12/2014; “ZEV designers”

What distinguishes consideration to date of PEVs?
All car owners, Feb. 2017

<table>
<thead>
<tr>
<th>Variable group</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
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</thead>
<tbody>
<tr>
<td>Socio-economic, demographics</td>
<td>Age, sex, income</td>
<td>Age, sex</td>
<td>Age, sex</td>
<td></td>
</tr>
<tr>
<td>Context: Residence, Vehicles, Daily Travel</td>
<td>—</td>
<td>Home parking loc. and electricity, new vehicles</td>
<td>Home parking location and electricity</td>
<td>Home parking electricity</td>
</tr>
<tr>
<td>General attitudes: environment, orientation to time, new technology</td>
<td>—</td>
<td>—</td>
<td>Air Quality; CFCS-I, CFCS-F; EBB, EIS</td>
<td>Air Quality</td>
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<tr>
<td>PEV-Specific Awareness, Knowledge, Experience, Assessment</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Know PEV owner, Interest in ZEV tech., range, charge duration, seen charging</td>
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</tbody>
</table>

Key

<table>
<thead>
<tr>
<th>Not included in model</th>
<th>No statistically significant variables</th>
<th>Multiple statistically significant variables, at least some &lt;0.01</th>
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<tbody>
<tr>
<td>—</td>
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</table>
New Car Buyers’ Prospective Interest in ZEVs, Dec. 2014. Base Model.

### Whole Model Test

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>-LogLikelihood</th>
<th>Chi-Square</th>
<th>Prob. &gt; ChiSq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference</td>
<td>112</td>
<td>751.3276</td>
<td>&lt;0.0001</td>
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</tr>
<tr>
<td>Full</td>
<td>2047.6542</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Reduced</td>
<td>2423.318</td>
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</table>

### Lack of Fit

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>-LogLikelihood</th>
<th>Chi-Square</th>
<th>Prob. &gt; ChiSq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of Fit</td>
<td>6524</td>
<td>2047.6542</td>
<td>4095.308</td>
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<tr>
<td>Saturated</td>
<td>6636</td>
<td>0</td>
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<tr>
<td>Fitted</td>
<td>112</td>
<td>2047.6542</td>
<td>1.000</td>
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</table>

### Effect Likelihood Ratio Tests

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Likelihood Ratio Chi-Square</th>
<th>Prob. &gt; ChiSq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement: Electricity</td>
<td>4</td>
<td>31.4484106</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Replacement: Hydrogen</td>
<td>4</td>
<td>10.2745216</td>
<td>0.0360</td>
</tr>
<tr>
<td>Highest Home PEV Charging Access</td>
<td>12</td>
<td>32.6172477</td>
<td>0.0011</td>
</tr>
<tr>
<td>Home natural gas</td>
<td>4</td>
<td>10.3376525</td>
<td>0.0351</td>
</tr>
<tr>
<td>Familiarity Factor 1: HEVs, PEVs,</td>
<td>4</td>
<td>12.9592756</td>
<td>0.0115</td>
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<tr>
<td>FCEVs</td>
<td></td>
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</tr>
<tr>
<td>Familiarity Factor 2: ICEVs</td>
<td>4</td>
<td>15.7699371</td>
<td>0.0033</td>
</tr>
<tr>
<td>Driving Experience Factor 1: ZEVs</td>
<td>4</td>
<td>15.0889216</td>
<td>0.0045</td>
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<tr>
<td>Driving Experience Factor 2: HEVs</td>
<td>4</td>
<td>18.3296375</td>
<td>0.0011</td>
</tr>
<tr>
<td>Prior BEV Evaluation Factor 1:</td>
<td>4</td>
<td>11.5805438</td>
<td>0.0208</td>
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<tr>
<td>safety, reliability</td>
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<tr>
<td>Prior BEV Evaluation Factor 2:</td>
<td>4</td>
<td>13.4185287</td>
<td>0.0094</td>
</tr>
<tr>
<td>driving range, charging time</td>
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<tr>
<td>Prior FCEV Evaluation Factor 2:</td>
<td>4</td>
<td>12.2441157</td>
<td>0.0156</td>
</tr>
<tr>
<td>driving range, fueling time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior Consideration of PEV</td>
<td>12</td>
<td>52.076929</td>
<td>&lt;0.0001</td>
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<tr>
<td>Prior Consideration of FCEV</td>
<td>12</td>
<td>26.7270647</td>
<td>0.0085</td>
</tr>
<tr>
<td>Government offer incentives</td>
<td>16</td>
<td>30.9529399</td>
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<tr>
<td>Seen Public EVSEs</td>
<td>4</td>
<td>9.44515586</td>
<td>0.0509</td>
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<tr>
<td>Personal interest in ZEV tech</td>
<td>4</td>
<td>40.0566242</td>
<td>&lt;0.0001</td>
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<tr>
<td>Environmental Factor: air pollution</td>
<td>4</td>
<td>22.5081516</td>
<td>0.0002</td>
</tr>
<tr>
<td>regional threat, personal worry</td>
<td></td>
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</tr>
</tbody>
</table>

- Highest Home PEV Charging Access; Home natural gas
- Replacement for Gasoline and Diesel: Electricity; Hydrogen
- Environmental Factor: air pollution regional threat, personal worry
- Familiarity Factors: (HEVs, PEVs, FCEVs); ICEVs
- Driving Experience Factors: ZEVs; HEVs
- Prior BEV Evaluation Factors: (safety, reliability); (driving range, charging time)
- Prior FCEV Evaluation Factor: (driving range, fueling time)
- Prior Consideration: PEV; FCEV
- Should government offer incentives
- Seen Public EVSEs
- Personal interest in ZEV tech
## Base Model plus Respondent Sex? No.

<table>
<thead>
<tr>
<th>Model Description</th>
<th>AICc</th>
<th>BIC</th>
<th>DF</th>
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<tbody>
<tr>
<td>Base model</td>
<td>4356.18</td>
<td>4967.33</td>
<td>112</td>
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<tr>
<td>Base + Respondent sex</td>
<td>4337.96</td>
<td>4968.76</td>
<td>116</td>
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<tr>
<td>Base + Respondent sex + Respondent sex crossed by the following, one at a time:</td>
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<tr>
<td>Prior Consideration of a PEV</td>
<td>4353.18</td>
<td>5044.82</td>
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<tr>
<td>Replacement: electricity</td>
<td>4340.76</td>
<td>4991.88</td>
<td>120</td>
</tr>
<tr>
<td>Personal interest in ZEV tech</td>
<td>4347.39</td>
<td>5039.02</td>
<td>128</td>
</tr>
<tr>
<td>Environmental factor: air pollution regional threat, personal worry</td>
<td>4346.38</td>
<td>4997.5</td>
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<tr>
<td>Driving experience factor 2: HEVs</td>
<td>4346.48</td>
<td>4997.6</td>
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<tr>
<td>Prior BEV Evaluation Factor 1: safety, reliability</td>
<td>4340.35</td>
<td>4991.47</td>
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<td>Prior BEV Evaluation Factor 2: driving range, charging time</td>
<td>4343.61</td>
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<tr>
<td>Highest Home PEV Charging Access</td>
<td>4353.67</td>
<td>5045.30</td>
<td>128</td>
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<tr>
<td>Familiarity Factor 1: HEVs, PEVs, FCEVs</td>
<td>4344.02</td>
<td>4995.14</td>
<td>120</td>
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<tr>
<td>Familiarity Factor 2: ICEVs</td>
<td>4337.71</td>
<td>4988.83</td>
<td>120</td>
</tr>
</tbody>
</table>
Majority of consumers are unaware of and unengaged with ZEVs

• PEV and ICEV/HEV buyers are answering different questions
  – PEV buyers: “How do I get a PEV?”
  – ICEV/HEV buyers: “Why would I buy a PEV?”
    • They likely have not asked themselves this question until we ask them

• ICEV/HEV buyers:
  1. **Unaware and unengaged**: Don’t know PEVs are a possibility: “What PEVs?”
  2. **Aware but unengaged**: Have no impetus to solve even their first (imagined) problem with PEVs; no impetus to ask if there are other problems.
Take-away messages

• First barrier to growing ZEV markets continues to be the vast majority of households—even in CA—knows nothing about ZEVs, including:
  – Sales of PEVs started over six years ago;
  – An increasing variety of ZEV makes and models for sale;
  – Falling PEV prices;
  – Increasing BEV driving range;
  – Growing extent of PEV charging infrastructure, and nascent H₂ fueling; and,
  – Incentives.

• Financial incentives and declining PEV prices may be necessary, but are not sufficient conditions
  – In the absence of engagement they result only in ZEVs remaining an expensive unknown.

• While we’re contemplating how to grow ZEV markets, solve the riddle of why we are leaving women out
With thanks to participants and funders...

~ 8,500 CA Survey Respondents and 82 Interviewees

• California Energy Commission: Sustainable Transportation Energy Pathways; National Center for Sustainable Energy
  – 2014 and 2017 Surveys of California Car-owning households

• California Air Resources Board
  – 2014-15 Survey and interviews of California New-car buying households
  – 2017 Interviews with PEV owners

• Sustainable Transportation Energy Pathways
  – 2017: Interviews of buyers of ICEV/HEV/PEV variants

• National Center for Sustainable Transportation
  – Gender research: re-analysis of survey and interview data