Understanding current and future potential PEV buyers: Implications for policy

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Canadian PEV Study Report now available
http://www.rem.sfu.ca/people/faculty/jaxsen/cpevs/
Following media attention for different alternative fuels (New York Times 1980-2013)

Source: Melton, Axsen & Sperling (2016), Nature Energy
Focusing on the Canadian market...

- Compare PEV “Pioneers” with the potential mainstream market.
- Forecast PEV sales (among potential future buyers) under different policies.
1) Data collection:

The Canadian Plug-in Electric Vehicle Study (CPEVS)
A perspective on the PEV market: Now and future

New vehicle buyers

PEV “Pioneers” (PEVOS, 2014/15 n = 126)

Potential “Early Mainstream” PEV buyers (NVOS, 2013 n = 1754)
Canadian “Mainstream” Survey (n = 1754), representative of new vehicle buying households

Source: Axsen et al. (2015), Electrifying Vehicles
Participants (BEV+PHEV) across BC

PEV owners survey (“Pioneers”) British Columbia, 2014-15, n = 126

Participation by Vehicle Type

- Nissan Leaf: 45%
- Chevrolet Volt: 26%
- Tesla Model S: 10%
- Smart Fortwo
- Mitsubishi i-MiEV
- Ford C-Max Energi
- Fisker Karma
- Ford Focus Electric
- BMW i3
- Conversions
- Toyota Plug in Prius
## CPEVS: Reflexive, multi-method design

### Part 1: Web-Based
- Current vehicle fleet
- Current electricity use
- Vehicle parking conditions
- Lifestyle preferences
- Attitudes
- Technology awareness

### Part 2: Mail & Web-Based
- Home recharge assessment
- 3-Day driving diary
- Buyers guide information booklet: Introduction to vehicle technologies, renewables and vehicle charging

### Part 3: Web-Based
**Vehicle Preferences**
- Options for different vehicle types:
  - Discrete choice experiments
  - Design space exercises (higher and lower price options)
**Green Elec. and Charging Preferences**
- Options for powering home and vehicle:
  - Discrete choice experiments
  - Design space exercises (higher and lower price options)

### Interviews: In-person
- Vehicle ownership history
- Perspectives of PEVs, renewables and utility controlled charging
- Lifestyles and interest

### Potential Outputs
- PEV recharge potential
- PEV recharge profiles
- PEV buyer segmentation analysis
- PEV preferences
- PEV use scenarios
- PEV market forecasts
- Climate policy scenarios
- Linking PEVs & renewables
- PEV charging preferences
PEV interest determined through discrete choice experiment and “design space” exercise

Which version of your HONDA CIVIC would you like to purchase?

1. Use the drop down menus to select the upgrades that you would like.
   - Select an “electric range” first, and then a “refuel or recharge time”.
   - The purchase price will change based on your selected upgrades.
2. Select the vehicle that you are most likely to buy next.

Ensure that all of the dropdowns are filled even if you do not plan on selecting one of the vehicles.

Remember to be realistic: consider budget constraints and consult other household members if you would normally do so.

Click HERE to open the example response that we provided earlier in a new window.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Electric Range</th>
<th>Gasoline Fuel Use</th>
<th>Refuel or Recharge Time</th>
<th>Purchase Price</th>
<th>I CHOOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Gasoline HONDA CIVIC</td>
<td>None</td>
<td>6.16 L/100km</td>
<td>5 mins.</td>
<td>$25,000</td>
<td>Gasoline</td>
</tr>
<tr>
<td>A Hybrid HONDA CIVIC</td>
<td>None</td>
<td>4.12 L/100km</td>
<td>5 mins.</td>
<td>$26,380</td>
<td>Hybrid</td>
</tr>
<tr>
<td>A Plug-in Hybrid HONDA CIVIC</td>
<td>Electric for the first 32 km (+$2,680)</td>
<td>4.12 L/100km</td>
<td>Level 2: 0.9 hrs (+$2500)</td>
<td>$30,180</td>
<td>Plug-in Hybrid</td>
</tr>
<tr>
<td>An Electric Only HONDA CIVIC</td>
<td>Electric only for: 200 km (+$13,820)</td>
<td>4.12 L/100km</td>
<td>Level 1: 32.5 hrs (+$50)</td>
<td>$38,820</td>
<td>Electric</td>
</tr>
</tbody>
</table>

Source: Axsen et al. (2015), Electrifying Vehicles
2) The PEV “Pioneers”
“Images” that PEV owners associate with their PEV

n= 59 (Leaf); 32 (Volt); 12 (Tesla)

Source: Axsen et al. (2015), Electrifying Vehicles
Preferences: PEV Pioneers love their PEV, tend to prefer BEV (over PHEV)

Source: Axsen et al. (2015), Electrifying Vehicles
Motivations: 4 lifestyle segments of Pioneers

Source: Axsen et al. (2015), Electrifying Vehicles
3) Comparing Pioneers to the potential "Mainstream"
PEV “Pioneers” are more highly educated, higher income, “greener” and more “techie”

### Graduate Degree

- **PEV Owners**: 30%
- **Mainstream**: 11%

### Household Income = +$90k

- **PEV Owners**: 67%
- **Mainstream**: 33%

### Technology Orientation (0-25)

- **Pioneers**: 15
- **Mainstream**: 10

### Environmental Orientation (0-25)

- **Pioneers**: 20
- **Mainstream**: 10

**Source**: Axsen et al. (2015), *Electrifying Vehicles*
Mainstream awareness is low

“How is each of the following vehicle fueled?

Mainstream buyers are more attracted to PHEVs, not so much BEVs

Source: Axsen and Goldberg (Under Review), Transportation Research Part D
4: PEV forecasts.... the Respondent-based Preference and Constraint (REPAC) model
Comparing PEV policies

Demand-focused policies

- Purchase incentives
  - Rebates, tax breaks, fee reductions

Supply-focused policies

Adapted from: Lutsey et al. (2015), ICCT White Paper
Responding to critiques of alternative fuel vehicle forecast studies

Al-Alawi and Bradley’s (2013) recommendations for a “useful” model:

1. **Better represent consumer behaviour:**
   - Use consumer data (survey, e.g. choice model)
   - Represent financial and non-financial motivators

2. **Model vehicle supply and actions of automakers**
   - Availability of PEV models (in dealerships)
   - Variety of PEV models
   - Vehicle class

3. **Model national and subnational policy**
   - Demand-focused policies (incentives, charging access)
   - Supply-focused policies (production requirements)

*Source: Al-Alawi and Bradley (2013), Renewable & Sustainable Energy Reviews*
The respondent-based preference and constraint model (REPAC)

- Tech assumptions: battery costs, fuel prices
- Survey data: driving patterns, vehicle class
- Stated choice experiment
  - Survey data: awareness, home charging access
  - Dealership access, model availability
- Vehicle attribute model
- Discrete choice model
- Constraints model

- Latent or unconstrained demand (UD)
- Constrained demand (CD)

Source: Wolinetz & Axsen (Under Review), Technological Forecasting & Social Change

Thanks Amy Miele
The respondent-based preference and constraint model (REPAC)

\[ CD_{i,j} = UD_{i,j} \times HC_i \times PF_{i,j} \times PA_{i,j} \]

- **Constrained Demand**
- **Unconstrained Demand**
- **Home charging**
- **PEV familiarity**
- **PEV availability**
- **Dealership availability**
- **Model variety**

Thanks Amy Miele  
**Source:** Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*
The respondent-based preference and constraint model (REPAC)

\[ CD_{i,j} = UD_{i,j} \times HC_i \times PF_{i,j} \times PA_{i,j} \]

- **Constrained Demand**
- **Unconstrained Demand**
- **Home charging**
- **PEV familiarity**
- **PEV availability**

One feedback: As sales increase, consumer awareness increases.

Thanks Amy Miele  
**Source:** Wolinetz & Axsen (Under Review), *Technological Forecasting & Social Change*
The respondent-based preference and constraint model (REPAC)

\[ CD_{i,j} = UD_{i,j} \times HC_i \times PF_{i,j} \times PA_{i,j} \]

Constrained Demand \hspace{1cm} Unconstrained Demand \hspace{1cm} Home charging \hspace{1cm} PEV familiarity \hspace{1cm} PEV availability

In the future, we’d like to add this feedback:

consumer preference dynamics

Thanks Amy Miele  
Source: Wolinetz & Axsen (Under Review), Technological Forecasting & Social Change
Adding various constraints to understand present and short-term sales

Source: Wolinetz & Axsen (Under Review), Technological Forecasting & Social Change
Demand-focused policies can get PEVs only so far...

"Weaker " demand policy

Source: Wolinetz & Axsen (Under Review), Technological Forecasting & Social Change
Demand-focused policies can get PEVs only so far…

"Stronger" demand-focused policy

"Weaker" demand policy

Source: Wolinetz & Axsen (Under Review), Technological Forecasting & Social Change
Supply-focused policies may be essential for PEV “success” (e.g. with 50+ models available)

PEV new market share (BC)

Source: Wolinetz & Aksen (Under Review), Technological Forecasting & Social Change
Comparing “Norway-like” and “California-like” policies in Canada via REPAC

Source: Wolinetz & Axsen (Under Review), Technological Forecasting & Social Change
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## Summary

### PEV Pioneers

**General**
- Higher income, education
- Green and/or techie lifestyle
- Variety of motives (green, techie)

**PEVs**
- Highly aware and engaged with technology
- Tend to prefer BEV
- Public chargers not essential

### Early Mainstream

- Lower income/education
- Variety of lifestyles
- Even wider variety of motives

- **Low awareness**, higher confusion (e.g. PHEVs, UCC)
- Greatly prefer PHEVs
- Public chargers not essential

### REPAC relative to most PEV forecasting literature:

1. More pessimistic no-policy scenarios (e.g. 1-2% share)
2. More pessimistic about demand-focused policies (e.g. 2-12%)
3. Suggests that supply needs to increase, perhaps through supply-focused policy
Extra
California’s ZEV Mandate

Sales requirement: “the most direct policy change any state can take to ensure increased PEV deployment”

- California: ~15% PEV new market share by 2025
- Credits differ by vehicle (PHEV, EV, Fuel Cell)
- Credits can be traded among automakers (noncompliance = $5k per ZEV credit)
- US Regions: 8 other states have ZEV programs (Section 117 ZEV States)

Policy details from: Lutsey et al. (2015), ICCT White Paper
Critiques of alternative fuel vehicle forecast studies

Al-Alawi and Bradley (2013) summarize several studies that forecast market share of electric drive vehicles. Four modeling approaches:

1. **Time-based diffusion models**: e.g. fitting an s-curve
2. **Constraints models**: e.g. % of population with garage, or with a particular commute distance
3. **Discrete choice models**: quantify consumer preferences, stated or revealed preference (or data-less)
4. **Agent-based models**: flexible, represents decision makers (consumers, even automakers), can be empirically-based or not

Source: Al-Alawi and Bradley (2013), *Renewable & Sustainable Energy Reviews*
Table 2
PEV choice model experimental design (6 choice sets per respondent).

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Next anticipated conventional vehicle</th>
<th>Hybrid vehicle</th>
<th>Plug-in hybrid vehicle</th>
<th>Electric vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase price</td>
<td>Selected by respondent</td>
<td>Conventional price</td>
<td>Conventional price</td>
<td>Conventional price</td>
</tr>
<tr>
<td></td>
<td>10% more</td>
<td>10% more</td>
<td>10% more</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20% more</td>
<td>20% more</td>
<td>20% more</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40% more</td>
<td>40% more</td>
<td>40% more</td>
<td></td>
</tr>
<tr>
<td>Weekly fuel cost</td>
<td>Selected by respondent</td>
<td>40% less</td>
<td>80% less</td>
<td>80% less</td>
</tr>
<tr>
<td></td>
<td>30% less</td>
<td>60% less</td>
<td>60% less</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20% less</td>
<td>40% less</td>
<td>40% less</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10% less</td>
<td>20% less</td>
<td>20% less</td>
<td></td>
</tr>
<tr>
<td>Electric-driving range</td>
<td>n/a</td>
<td>16 km</td>
<td>120 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 km</td>
<td>160 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>64 km</td>
<td>200 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>240 km</td>
<td></td>
</tr>
<tr>
<td>Home recharge access</td>
<td>n/a</td>
<td>n/a</td>
<td>Level 1 (1 kW) Level 2 (6 kW)</td>
<td>Level 1 (1 kW) Level 2 (6 kW)</td>
</tr>
<tr>
<td>Recharge timea</td>
<td>n/a</td>
<td>n/a</td>
<td>Calculated</td>
<td>Calculated</td>
</tr>
</tbody>
</table>

* The discrete choice experiment showed “recharge time” to respondents to help them understand the recharging needs of the PHEV or EV. Recharge time was calculated as the time required for the respondent to fully recharge a depleted battery using their home charger. This time is a function of the vehicle’s electric driving range, the base vehicle type (where larger vehicle bodies are assumed to require more electricity consumption or have a higher kWh/mile), and the speed of the home charger (Level 1 or Level 2).

Source: Axsen et al. (2015), *Energy Economics*
Identifying five consumer segments (or classes) via a latent-class choice model

Table 4
Latent-class results for 5-class solutions (n = 1754).

<table>
<thead>
<tr>
<th>Class label</th>
<th>PEV-enthusiast</th>
<th>PHEV-oriented</th>
<th>HEV-oriented</th>
<th>HEV-leaning</th>
<th>CV-oriented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of membership</td>
<td>0.080</td>
<td>0.254</td>
<td>0.159</td>
<td>0.277</td>
<td>0.230</td>
</tr>
</tbody>
</table>

Discrete choice model

- **HEV constant**
- **PHEV constant**
- **EV constant**
- **Vehicle price (CAD$)**
- **Fuel cost (CADs/week)**
- **PHEV range (km)**
- **EV range (km)**
- **PHEV $ Level 2 charging at home**
- **EV $ Level 2 charging at home**

Implied willingness-to-pay

- Saving $1000/year in fuel
  - **HEV**: $41,245
  - **PHEV**: $125,026
  - **EV**: $137,794
  - **PHEV with Level 2 charging**: $2444
  - **EV with Level 2 charging**: $39,581

Class membership model [relative to base]

- **Constant**
- **Household size (number of people)**
- **$50,000 to $99,999 [Base = “< $50,000”]**
- **$100,000 to $150,999 [Base = “< $50,000”]**
- **$150,000 or more [Base = “< $50,000”]**
- **Bachelor’s degree [Base = “less than Bachelor’s”]**
- **Graduate degree [Base = “less than Bachelor’s”]**
- **Live in Alberta [Base = “rest of Canada”]**
- **Live in British Columbia [Base = “rest of Canada”]**
- **Live in Ontario [Base = “rest of Canada”]**
- **Technology-oriented lifestyle score**
- **Environment-oriented lifestyle score**
- **Environmental concern (NEP score)**
- **Liminality score**

* Significant at 90% confidence level.
** Significant at 95% confidence level.
*** Significant at 99% confidence level.

Source: Axsen et al. (2015), Energy Economics
Modeling PEV policy: The respondent-based preference and constraint model (REPAC)

Model Inputs:
- Survey data describing home charging access and PEV familiarity
- Auto dealership location, brand and stated PEV offerings or certification
- Auto manufacturer PEV announcements and availability by region
- Survey data describing consumer preferences for vehicle attributes
- Survey data describing weekly travel by respondent
  - PEV battery and vehicle component costs
  - Gasoline and electricity prices

Constraints model
What constrains each individual from purchasing a PEV?

Choice model
What vehicle drive train does each individual choose?

Vehicle model
What are the costs and characteristics of vehicles to be chosen?

REPAC model
Output is PEV new market share, i.e. What vehicle do people choose given real-world constraints?

Source: Wolinetz & Axsen (Under Review), Technological Forecasting & Social Change
A ZEV mandate may be essential to achieve 2050 GHG targets

- **Current Policies**
- **“Ambitious” Policies (no ZEV)**
- **+ZEV mandate**

**2050 GHG Target**
80% below 2005 GHGs

**Passenger vehicle GHGs (well-to-wheel)**

- LCFS: 15% less GHG intensive w/ biofuels
- CAFE: 60% less fuel intensive by 2050

**“Ambitious” Policies**
- Carbon Tax: $30/t 2015 to $120/t 2050
- ZEV Subsidies: $5000 in 2015 and 2020

**Source**: Sykes and Axsen (In Progress), Master’s Thesis