Characterizing California Electric Vehicle Consumer Segments

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Thanks also to Georgina Arreola, Colin Santulli, and others at CSE

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Building Performance

Clean Transportation

Distributed Generation

Energy Efficiency

Energy Storage

Renewable Energy

CSE's Plug-In & Fuel-Cell Electric Vehicle (EV) Activities

CLEAN VEHICLE REBATE PROJECT™

MOR-EV
Massachusetts Offers Rebates for Electric Vehicles

CHEAPR
Connecticut Hydrogen and Electric Automobile Purchase Rebate

Incentives Design & Administration

Consumer & Dealer Outreach

DOER Massachusetts Department of Energy Resources

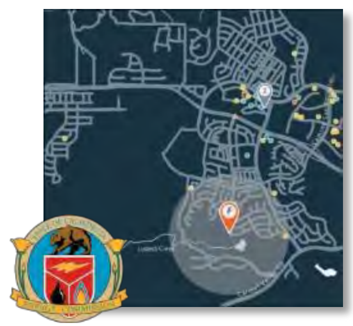
California Environmental Protection Agency
Air Resources Board

SANDAG

CALIFORNIA PLUG-IN ELECTRIC VEHICLE COLLABORATIVE

Stakeholder Engagement

Fleet Assistance & Clean Cities



PEV, Alt.-Fuel, & ZEV Planning & Implementation

2nd Life Battery Research & Vehicle-Grid Integration

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Statewide Monetary Incentives: CA's CVRP

		CVRP	Federal Tax Credit
	**Hydrogen Fuel-Cell Electric Vehicles**	*$5,000*	*$8,000*
	**Battery Electric Vehicles (& i3 REx)**	*$2,500*	*$7,500*
	**Plug-in Hybrid Electric Vehicles**	*$1,500*	*$2,500–$7,500*
	Neighborhood Electric Vehicles		
	**Zero-Emission Motorcycles**	*$900*	

Plug-in electric vehicles = all-battery + plug-in hybrid
i.e., PEVs = BEVs + PHEVs

Outline: Characterizing Consumer Segments

- Background & Approach
- Results
  - Highly-influenced “Rebate Essentials”
  - Low-Initial-Interest “Converts”
  - Commonalities
- Summary “Profiles”

Background & Approach

How can consumer research help us grow markets for electric vehicles?

1. "**Adding fuel to the fire**": understand existing, generally enthusiastic adopters to target similar consumers
   - Segment: all-battery vs. plug-in hybrid EVs
   - Characteristics, motivations, and trends
   - Who is "pre-adapted" to adopt? (e.g., Williams and Kurani 2006)
2. "**Tough nuts to crack**": understand and break down barriers faced by consumers targeted based on policy priorities
   - Multi-unit dwellers
   - Disadvantaged Communities
   - Low-to-moderate income consumers
3. "**Expand market frontiers**": understand the margins of the market to target consumers who can be induced to join
   - Adopters with low initial interest in EVs -- "converts"
   - Adopters most influenced by incentives -- "rebate essentials"

Methodology Overview

	1. Rebate Essentials	
Research Objective	Identify characteristics associated with:	
	increased rebate influence	
Strategic Purpose	Informs targeting resources at:	
	consumers who otherwise would not adopt	
Model	Binary logistic regression	
Outcome variable:	"Would you have purchased or leased your PEV without the CVRP rebate?" [yes, no]	
Predictor variables:	Consumer, household, vehicle, and transactional data Reduced based on lack of theoretical relevance, "actionability," and to a lesser extent, correlations	
Data	1a. plug-in hybrid (PHEV) (n=7,711)	1b. All-battery (BEV) (n=11,478)

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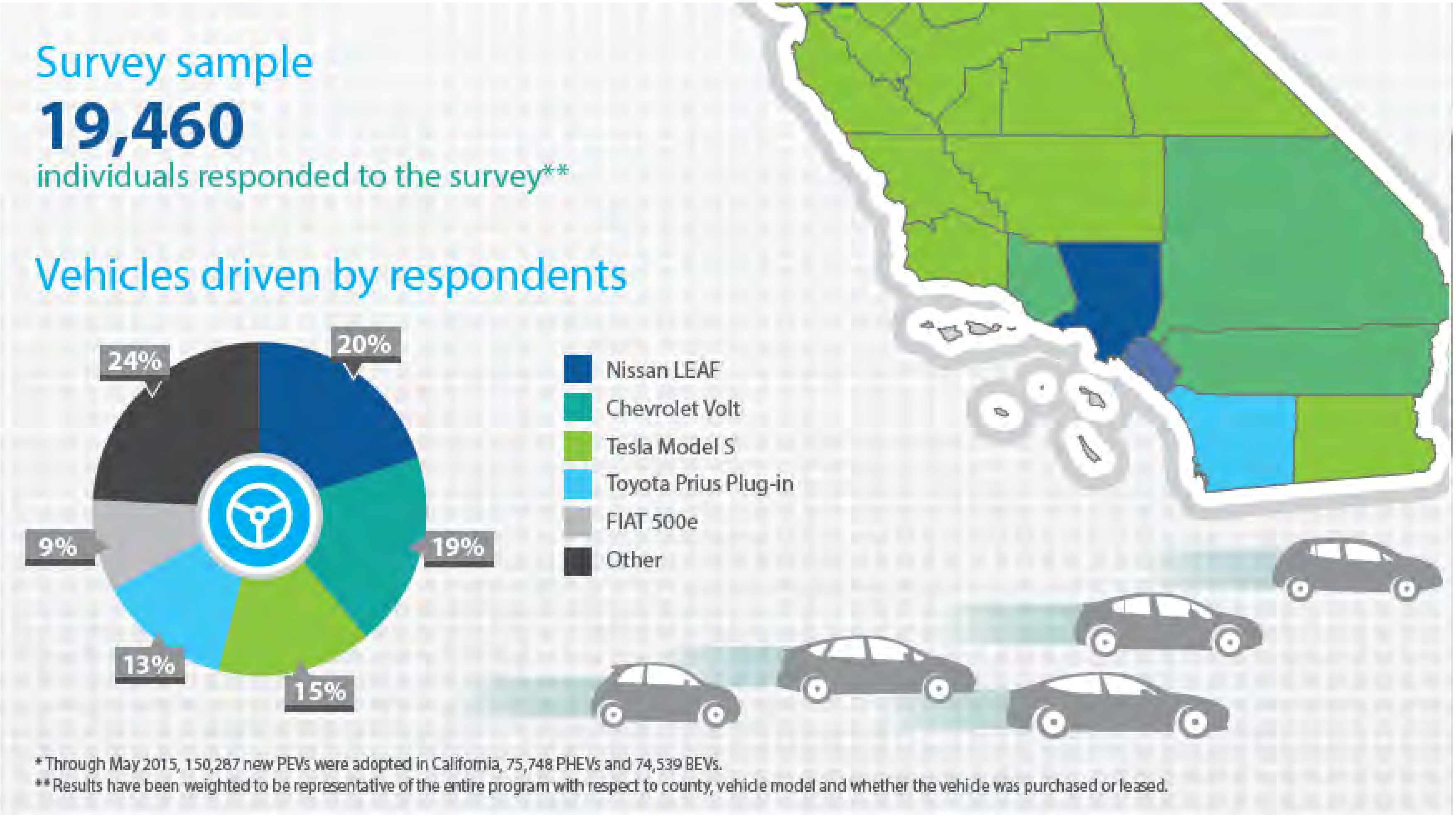
Methodology Overview

	1. Rebate Essentials		2. Converts	
Research Objective	Identify characteristics associated with:			
	increased rebate influence		initial interest in adopting	
Strategic Purpose	Informs targeting resources at:			
	consumers who otherwise would not adopt		non-enthusiast, more mainstream consumers	
Model	Binary logistic		Ordered logistic	
Outcome variable:	"Would you have purchased or leased your PEV without the CVRP rebate?" [yes, no]		"Which of the following statements best describes your interest in a PEV when you started your search for a new vehicle?" [scale]	
Predictor variables:	Consumer, household, vehicle, and transactional data Reduced based on lack of theoretical relevance, "actionability," and to a lesser extent, correlations			
Data	1a. PHEV (n=7,711)	1b. BEV (n=11,478)	2a. PHEV (n=7,711)	2b. BEV (n=11,478)

Weighted EV Consumer Survey

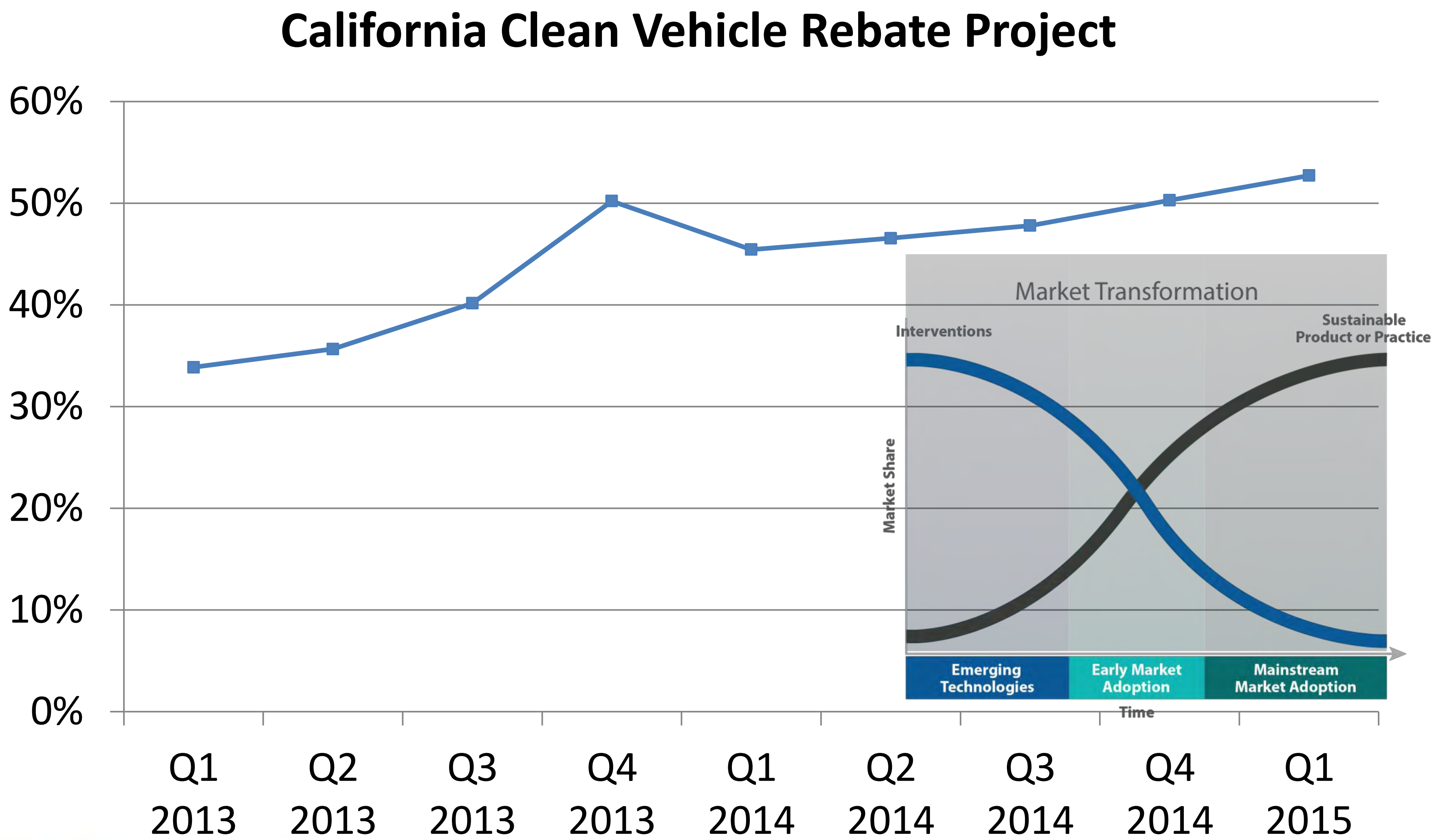
(CVRP vehicles acquired Sep 2012 thru May 2015)



Center for Sustainable Energy (2016). CVRP Infographic: What Drives California's Plug-in Electric Vehicle Owners? Retrieved 9/20/2016 from https://cleanvehiclerebate.org/eng/content/infographic-what-drives-california-plug-electric-vehicle-owners

Characterizing Highly Influenced “Rebate Essential” Consumers

Percent that state they would not have purchased/leased without the rebate



Source: EV Consumer Survey
Respondents: 19,460
Purchase dates 9/1/12-5/31/15
Sampling weights applied

Rebate Essential: Common Odds-Increasing Factors

Variable	PHEV Odds Ratio	BEV Odds Ratio
Consumer demographics		
Male	1.38	1.18
Non-white ethnicity	1.25	1.23
Graduate degree (vs. 2^{nd}-highest: bachelor's)	1.08	1.11
Lower household income ($50k)	1.05	1.04
Reasons and interest		
More motivated by saving money on fuel	1.24	1.33
More motivated by carpool lane access	1.04	1.12
Less motivated by reducing environmental impacts	1.08	1.08
Lower initial interest in EVs	1.41	1.29
Information gathering		
Found it more difficult to find information on EVs	1.22	1.18
Spent more time researching EVs online	1.19	1.15
Did not hear about the rebate from the dealer	1.18	1.17
Transactional factors		
Vehicle price is lower ($)	1.000019	1.000016

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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Rebate Essential: Different Odds-Increasers

Variable	PHEV Odds Ratio	BEV Odds Ratio
Consumer demographics		
Younger (years)	1.007	
More people in household (#)		1.07
Housing & region		
Multi-unit dwelling (vs. non-MUD)		1.19
No solar (vs. 2nd-highest: planning solar)		1.003
No workplace charging (vs. 2nd-highest: WPC)		1.18
Central CA (vs 2nd-highest: Far South CA)		1.51
Reasons and interest		
More motivated by energy independence	1.09	
Transactional factors		
Buy (vs. lease)	1.27	
Chevy PHEV (vs. 2nd-highest: Toyota)	1.14	
Nissan BEV (vs. 2nd highest: FIAT)		1.04
Acquisition date (days)		1.001

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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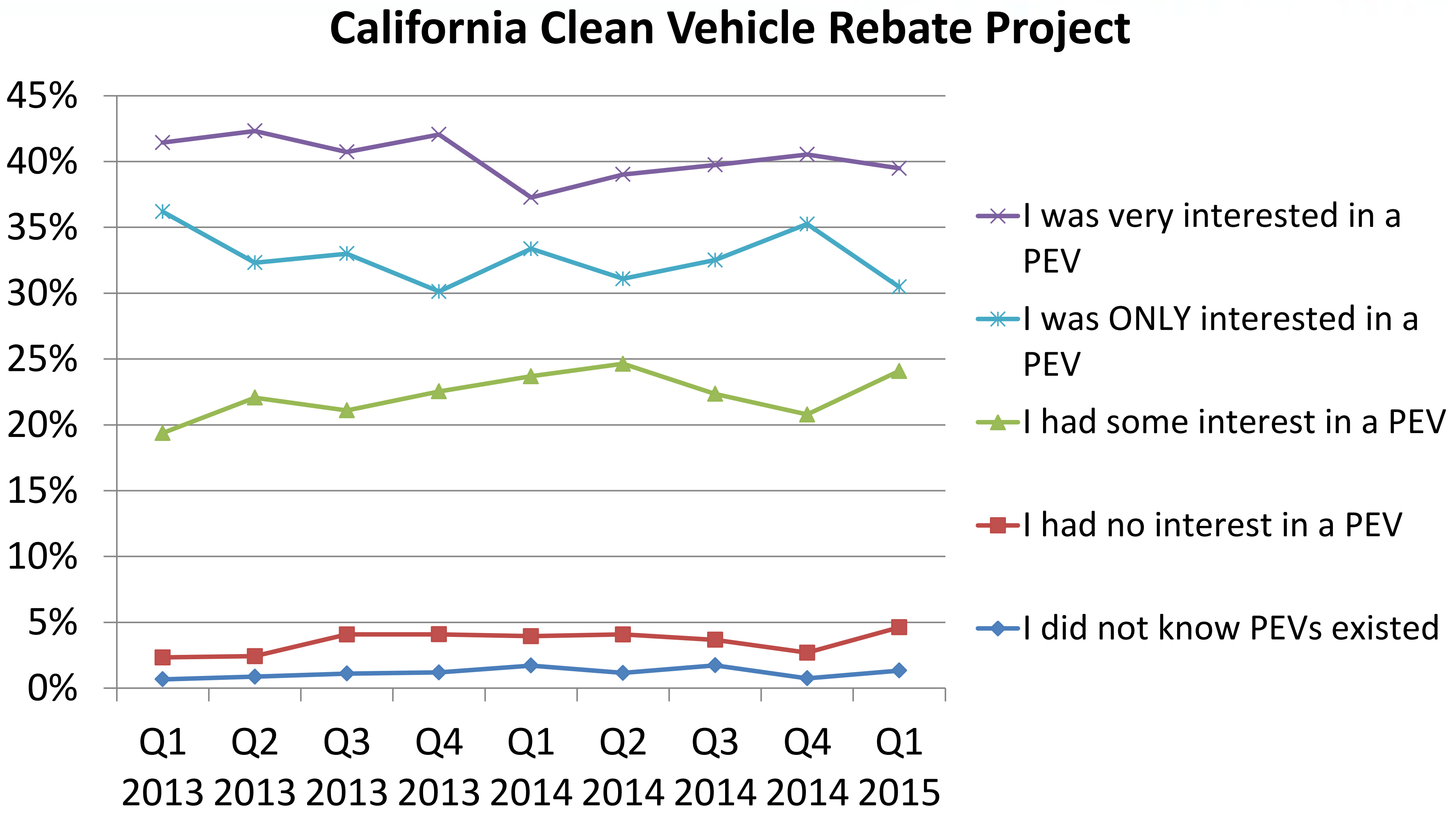
Characterizing Low-Initial-Interest “Converts”

Which of the following statements best describes your interest in a PEV when you started your search for a new vehicle?"



Source: EV Consumer Survey
Respondents: 19,460
Purchase dates 9/1/12-5/31/15
Sampling weights applied

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Low-Interest Converts: Common Odds-Increasing Factors

Variable	PHEV Odds Ratio	BEV Odds Ratio
Consumer demographics		
Ethnicity is other than white	1.35	1.43
Housing and region		
No solar (vs. 2nd-highest: planning solar)	1.25	1.20
Reasons and enablers		
More motivated by saving money on fuel	1.10	1.06
Less motivated by reducing environmental impacts	1.21	1.31
Less motivated by carpool lane access	1.09	1.04
Less motivated by energy independence	1.09	1.08
Rebate essential	1.73	1.54
Information gathering		
Found it more difficult to find information on EVs	1.21	1.24
Spent *less* time researching EVs online	1.35	1.36
Transactional factors		
Lease (vs. buy)	1.25	1.21
First EV	3.96	4.34

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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Low-Interest Converts: Different Odds Increasers

Variable	PHEV Odds Ratio	BEV Odds Ratio
Consumer demographics		
Bachelor's degree (vs. 2nd: Some college or less)		1.08
More people in household (#)		1.09
Housing & region		
No workplace charging (vs. access to WPC)		1.16
Central CA (vs 2nd-highest: South CA)		1.24
Reasons and interest		
More motivated by vehicle performance		1.11
Information gathering		
Heard about the rebate at the dealership	1.23	
Transactional factors		
Vehicle price is higher ($)		1.0000059
Ford (vs. 2nd-highest: Other)	1.10	
FIAT (vs. 2nd highest: Nissan)		1.08
Replacing a vehicle		1.10

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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Common Characteristics Across All Segments

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
Consumer demographics				
Ethnicity is other than white	1.25	1.35	1.23	1.43
Reasons, interest, and enablers				
More motivated by saving money on fuel	1.24	1.10	1.33	1.06
Less motivated by reducing enviro impacts	1.08	1.21	1.08	1.31
More rebate essential	Y	1.73	Y	1.54
Lower initial interest in EVs	1.41	Y	1.23	Y
Information gathering				
Found it more difficult to find info on EVs	1.22	1.21	1.18	1.24

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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Common Characteristics Across All Segments

Variable	PHEV-RE[a]	PHEV-C[b]	BEV-RE[c]	BEV-C[d]
Consumer demographics				
Ethnicity is other than white	1.25	1.35	1.23	1.43
Reasons, interest, and enablers				
More motivated by saving money on fuel	1.24	1.10	1.33	1.06
Less motivated by reducing enviro impacts	1.08	1.21	1.08	1.31
More rebate essential	Y	1.73	Y	1.54
Lower initial interest in EVs	1.41	Y	1.23	Y
Information gathering				
Found it more difficult to find info on EVs	1.22	1.21	1.18	1.24

a. Other predictors included: vehicle price, buy vs. lease, vehicle make, age, gender, education, income, importance of HOV lane access, importance of energy independence, time spent researching PEVs, heard about CVRP at dealership

b. Other predictors included: buy vs. lease, vehicle make, first EV, solar at home, importance of HOV lane access, importance of energy independence, time spent researching PEVs, heard about CVRP at dealership

c. Other predictors included: purchase date, vehicle price, vehicle make, multi-unit dwelling residence, region of residence, solar at home, gender, education, income, importance of HOV lane access, time spent researching PEVs, heard about CVRP at dealership, access to workplace charging

d. Other predictors included: vehicle price, buy vs. lease, vehicle make, first EV, added vs. replaced, region of residence, solar at home, education, number in household, importance of HOV lane access, importance of energy independence, importance of vehicle performance, time spent researching PEVs, access to workplace charging

PHEV n = 7,711; BEV n=11,478

All factors significant with $p < 0.05$

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Summary “Profiles”

The rebate is more essential to consumers:

- focused on **"financial and practical"** aspects of adoption
  - saving money on vehicle price and fuel costs, being fully exposed to a purchase rather than a lease, being constrained by lower household income, carpool lane access
- who face **"greater contextual constraints"** or are otherwise less easily able to adopt
  - lower household income, perhaps younger and less established, perhaps more risk adverse and thus looking to an established hybrid brand, perhaps with less cultural exposure to EVs
- whose adoption is **driven less by "green enthusiasm"** than other values
  - less motivated by reducing environmental impact and more motivated by increased energy independence and saving money on fuel costs; and
- with **"challenging informational environments"**
  - low initial interest in EVs, greater difficulty finding information on EVs, who did more research online, but who perhaps benefitted from higher education to navigate these complex informational environments and have found out about the rebate before showing up at the dealership for their acquisition

The convert is more likely:

- **less demographically specific/constrained**
  - May or may not be constrained by income, have postgraduate degrees, or be male
- **driven less by "energy and the environment"** than traditional vehicle-operation reasons
  - less motivated by reducing environmental impact and energy independence, and carpool lane access, and more by saving money and perhaps vehicle performance
  - No solar, perhaps no workplace charging
- with **"challenging informational environments"**
  - low initial interest in EVs, perhaps with less cultural exposure to EVs, greater difficulty finding information on EVs, who did *less* research online, and may learn about the rebate from the dealer
- "**switching from old to new**"
  - Leasing their first EV as a replacement vehicle

Data Sources

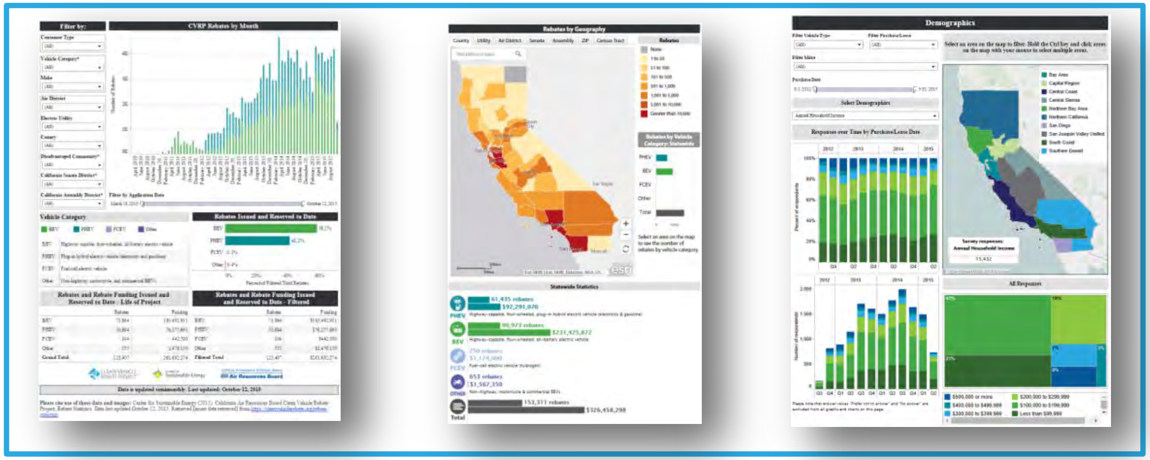
Program:

- CVRP EV Consumer Survey (n=19,460)
  - EV purchase/lease dates 9/2012–5/2015
  - Weights applied to make responses represent 91,085 program participants along the dimensions of vehicle model, county, and buy vs. lease
- CVRP Rebate Applications (n=164,934)
  - EV purchase/lease dates 3/2010–9/2016

Where can I get the data?: CSE Transparency Tools

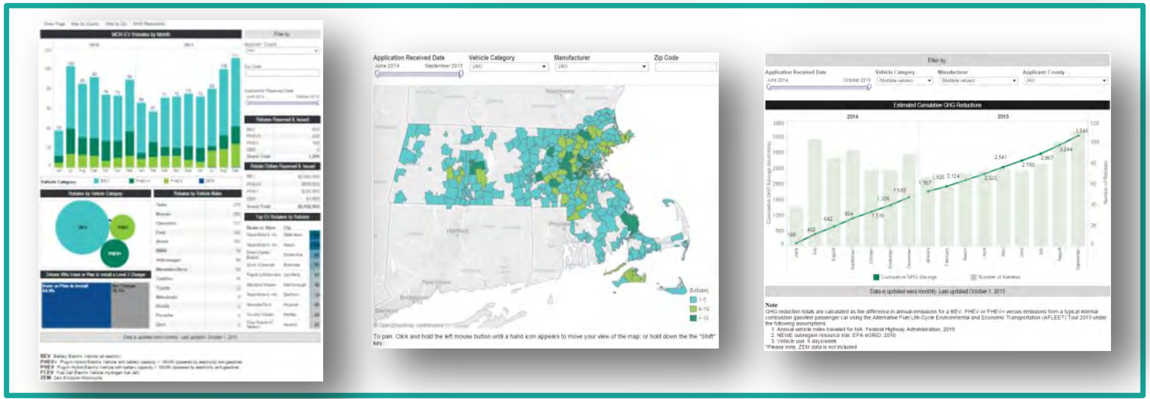
- Public, online, interactive dashboards facilitate informed action
  - Data characterizing >163,000 EVs and consumers
  - ~$350M in rebates processed
  - >19,000 survey responses statistically represent >90,000 consumers

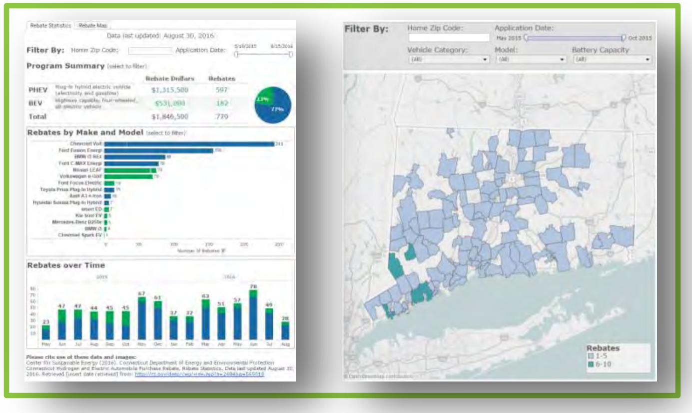
Also: zevfacts.com



cleanvehiclerebate.org

ct.gov/deep





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Consumer research and analysis

- **Target Consumer Segments**: Converts, Rebate Essentials (forthcoming Oct 2016 pres and Jan 2017 paper)
- Progress in **Disadvantaged Communities** (forthcoming pres, Oct 2016)
- **Information Channels** (EV Roadmap pres, 2016)
  - Exposure & importance of various channels, consumer time spent researching various topics
- **Infographics**
  - Overall (CVRP infographic , 2016)
  - Disadvantaged Communities (forthcoming, Oct 2016)
- Characterization of **Participating Vehicles and Consumers** (CVRP research workshop pres, 2015)
- **Program Participation** by Vehicle Type and County (CVRP brief 2015)
- **Dealer services**: Importance and Prevalence (EF pres 2015)

Also:

- Evaluation of the CT Dealer Incentive (forthcoming pres, Oct 2016)

Thank You for Your Attention

What would you like to know more about?

What decisions are you facing?

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We work nationally in the clean energy industry and are always open to exploring partnership opportunities.

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Additional details follow…

Data Details

- CVRP EV Consumer Survey data (N=19,460)
- Unweighted to minimize standard errors and produce unbiased and consistent estimates (Solon, Haider, & Wooldridge, 2013)
- Plug-in electric vehicles (PEV) = PHEVs + BEVs
- PHEV (n=7,711) and BEV (n=11,478) analyses run separately
  - BEVx removed (BMW i3 REx, a special type of PHEV)
- Outcome variables:

1. Would you have purchased or leased your PEV without the CVRP rebate?
   - yes
   - no
2. Which of the following statements best describes your interest in a PEV when you started your search for a new vehicle?
   - I did not know PEVs existed
   - I had no interest in a PEV
   - I had some interest in a PEV
   - I was very interested in a PEV
   - I was ONLY interested in a PEV

Missing Data Analysis Steps and Decisions

1. Vehicle price replaced with mean by vehicle model
2. Cases missing outcome variable dropped
3. Listwise deletion applied for variables missing for <1% of cases each (and cumulatively, <5% of total)
4. Variables missing for >2% of data and having lower theoretical importance dropped from analysis
5. Remaining missing data addressed using multiple imputation with chained equations (MICE) with 20 iterations (Little's test resulted in rejection of MCAR assumption)
   - All regression variables used to predict missing values

Modeling Assumptions

- Alternatives: probit, discriminant analysis
  - Negligible differences expected between probit and logit
  - Discriminant analysis relies on distributional assumptions (difficult to meet given the number and type of our predictors)
- Logistic regression makes few assumptions, relatively robust to violations
  - Independence of observations
  - Linear relationships between independent variables and log odds
  - Independent variables measured without error
- Primary assumption of *ordered* logistic regression is the proportional odds assumption (the relationship between each pair of outcome groups is the same)
  - Brant test: proportionality of odds assumption not met
  - But, BIC test showed ordered logistic regression preferable to generalized logistic regression

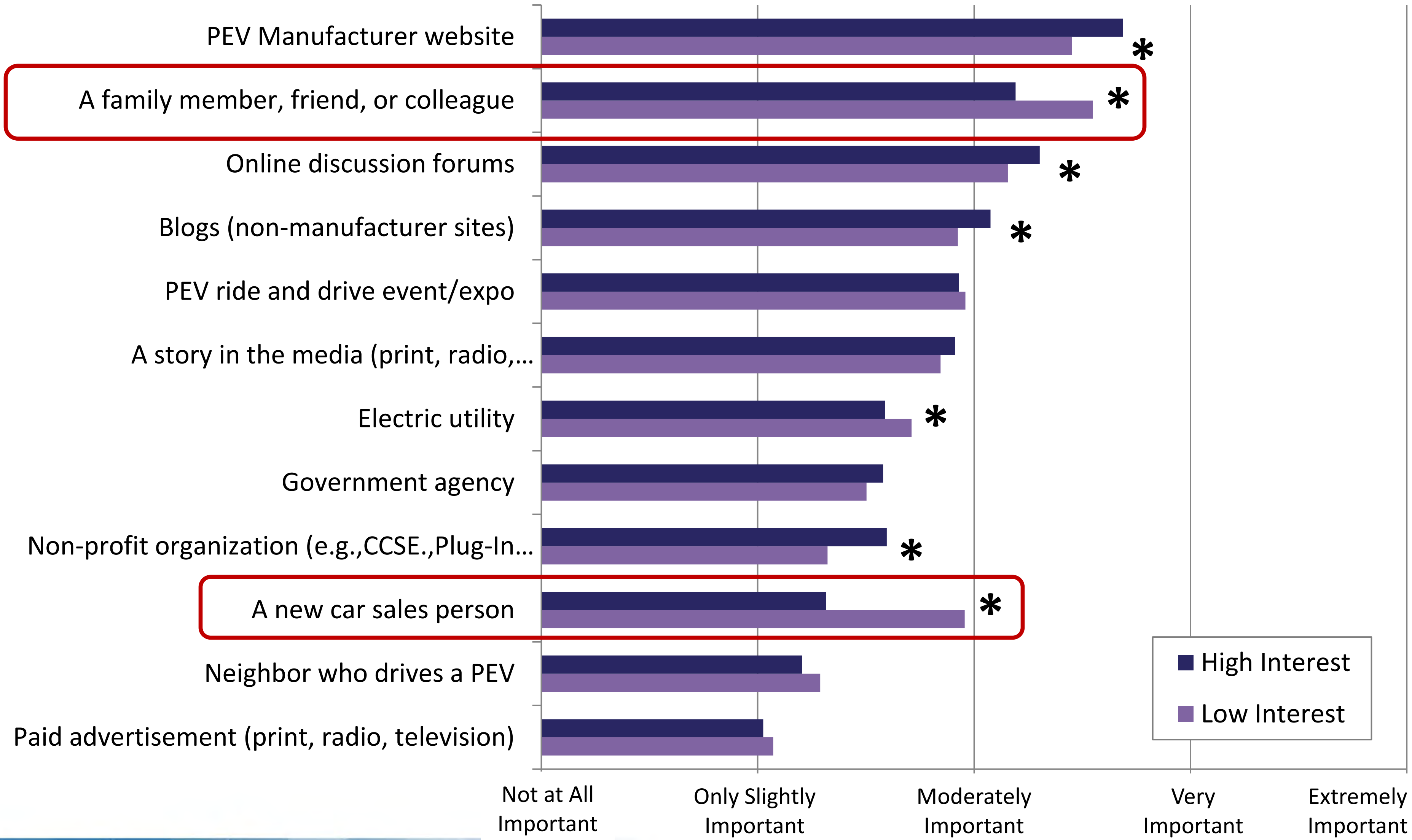
Regression Analysis Steps and Decisions

1. All predictors entered (using dummy variables for categorical variables)
2. Joint significance of dummy variables tested
3. Joint significance of non-significant predictors tested → jointly non-significant
4. Model rerun with non-significant predictors removed to achieve a more parsimonious model
5. Steps 1–4 repeated until all predictors significant

Model Diagnostic Results

	1. Rebate Essentials		2. Converts	
MICE Convergence	20 burn-in iterations were needed			
Proportionality of odds	n.a.		Brandt: not met BIC: ordered preferable	
Model Significance	All significant across 20 (x2) imputed datasets (log-likelihood chi-sq compared to the null)			
Pseudo R^2	1a. PHEV 0.0524–0.0542	1b. BEV 0.1385–0.1398	2a. PHEV 0.0565–0.0574	2b. BEV 0.0735–0.0745

How important was information from the following sources in your decision to acquire (purchase/lease) a PEV?



Source: EV Consumer Survey
Respondents: 18,434
Purchase dates 9/1/12-5/31/15
Sampling weights applied

*statistically significant difference

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Target Consumers: “Rebate Essential” Segment

Consumers most influenced by the rebate:

- **Demographics**: male, non-white, higher education, lower HH income, perhaps younger and larger HHs
  - **BEVs:** MUDs, no solar or workplace charging, Central CA
- **Motivations and interest**: less motivated by environmental impacts, more motivated by saving money on fuel, carpool lane access, and perhaps energy independence; lower initial interest in EVs
- **Information gathering**: found it more difficult to find info on EVs, spent more time researching online, learned about the rebate before going to the dealer
- **Vehicle characteristics**: lower price, bought (vs. lease)

Target Consumers: Low-Interest "Converts"

Consumers most influenced by the rebate:

- **Demographics**: non-white, perhaps larger HHs
  - No solar, perhaps no workplace charging, Central CA
- **Motivations and interest**: less motivated by environmental impacts, more motivated by saving money on fuel and perhaps vehicle performance, less by carpool lane access and less by energy independence; more rebate essential
- **Information gathering**: found it more difficult to find info on EVs, spent less time researching online, learned about the rebate at the dealer
- **Vehicle characteristics**: perhaps lower price; leasing (vs. buy), first EV, replacing a vehicle

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Comparing Rebate Essentials to Low-Initial-Interest Converts

Common Characteristics Across All Segments

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
Consumer demographics				
Ethnicity is other than white	1.25	1.35	1.23	1.43
Reasons, interest, and enablers				
More motivated by saving money on fuel	1.24	1.10	1.33	1.06
Less motivated by reducing enviro impacts	1.08	1.21	1.08	1.31
More rebate essential	Y	1.73	Y	1.54
Lower initial interest in EVs	1.41	Y	1.23	Y
Information gathering				
Found it more difficult to find info on EVs	1.22	1.21	1.18	1.24

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

Demographics that Increase Odds of Segment Membership

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
<u>Consumer demographics</u>				
Male	1.38		1.18	
Non-white	1.25	1.35	1.23	1.43
Younger (years)	1.007			
Graduate degree (vs. 2nd: bachelor's)	1.08		1.11	
Bachelor's degree (vs. 2nd: Some college or less)				1.08
Lower household income ($)	1.05		1.04	
More people in household (#)			1.07	1.09

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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Housing and Regional Characteristics that Increase Odds of Segment Membership

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
<u>Housing and region</u>				
Multi-unit dwelling			1.19	
No solar (vs. 2nd-highest: planning solar)		1.25	1.003	1.20
No workplace charging (vs. WPC access)			1.18	1.16
Central CA (vs. 2nd-highest that varies)			1.51	1.24

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

Housing and Regional Characteristics that Increase Odds of Segment Membership

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
<u>Housing and region</u>				
Multi-unit dwelling			1.19	
No solar (vs. 2nd-highest: planning solar)		1.25	1.003	1.20
No workplace charging (vs. 2nd-highest: WPC)			1.18	
No workplace charging (vs 2nd: non-commuters)				1.14
Central CA (vs. 2nd-highest that varies)			1.51	1.24

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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Motivations, Interest, and Enablers that Increase Odds of Segment Membership

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
Reasons, interest, and enablers				
More motivated by saving money on fuel	1.24	1.10	1.33	1.06
Less motivated by reducing enviro impacts	1.08	1.21	1.08	1.31
More motivated by carpool lane access	1.04	0.92	1.12	0.96
More motivated by energy independence	1.09	0.92		0.93
More motivated by vehicle performance				1.11
More rebate essential	Y	1.73	Y	1.54
Lower initial interest in EVs	1.41	Y	1.29	Y

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

Info Gathering Factors that Increase Odds of Segment Membership

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
Information gathering				
Found it more difficult to find info on EVs	1.22	1.21	1.18	1.24
Spent more time researching EVs online	1.19	0.74	1.15	0.74
Did not hear about the rebate from the dealer	1.18	0.81	1.17	

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

Transactional Factors that Increase Odds of Segment Membership

Variable	PHEV-RE	PHEV-C	BEV-RE	BEV-C
Transactional factors				
Replacing a vehicle				1.10
First EV		3.96		4.34
Vehicle price is lower ($)	1.000019		1.000016	0.999994
Buy (vs. lease)	1.27	0.80		0.83
Chevy PHEV (vs. 2^{nd}-highest: Toyota)	1.14			
Ford PHEV (vs. 2^{nd}-highest: Other)		1.10		
Nissan BEV (vs. 2^{nd}: FIAT)			1.04	
FIAT (vs. 2^{nd}-highest: Nissan)				1.08
Acquisition date (days)			1.001	

PHEV n = 7,711; BEV n=11,478
All factors significant with $p < 0.05$

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