Consumer Behavior and the Plug-In Electric Vehicle Purchase Decision: A Research Synthesis

Presentation at ECEEE Summer Study 2017
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Lawrence Berkeley National Laboratory

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Today's Agenda

- Introduction
- Relevant consumer behavior research themes
- Insights from transportation literature and data
- Concluding thoughts

Introduction

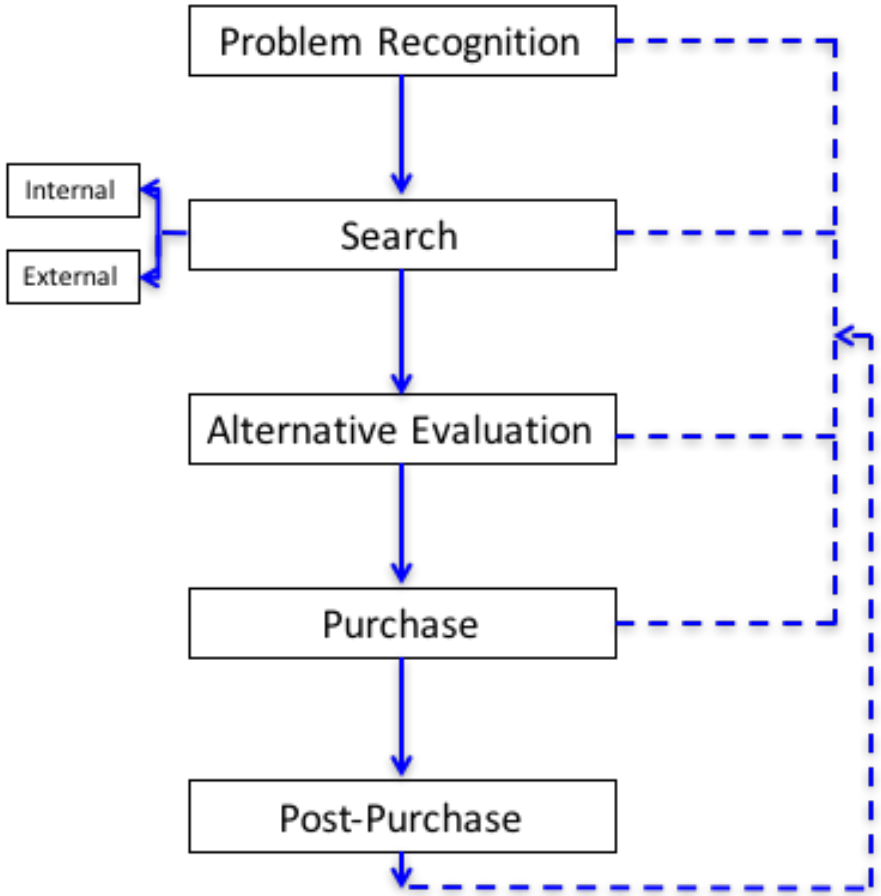
Project Overview

- Major tasks
  - Conduct a broad, thorough (not exhaustive) review:
    - General consumer behavior literatures (especially marketing)
    - Studies and data about light-duty vehicle purchase, in general
    - Studies and data specific to PEVs
  - Structure and communicate findings so they can inform DOE programs
- Deliverables:
  - Report
  - Web-based reference database tied to the report

Relevant Consumer Behavior Research Themes

The Consumer Purchase Decision Process

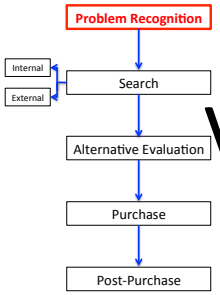
Decision Process Steps



Influences

- Internal factors
  - Long-term
    - Demographic, psychological, and behavioral attributes
    - Consumer experience with product/brand
    - Switching costs
    - Brand attitude, loyalty
  - Short-term
    - Affect throughout the process
    - Impulse triggers
- External factors
  - Perception of risk
    - Negative consequences of a poor purchase decision
    - Probability of negative consequences
      - Prospect theory
      - Search, experience, credence goods
  - Risk management/consumer involvement in purchase
    - Constraints regarding purchase context
      - Too little time
      - Rapidly changing products
  - Role of third parties

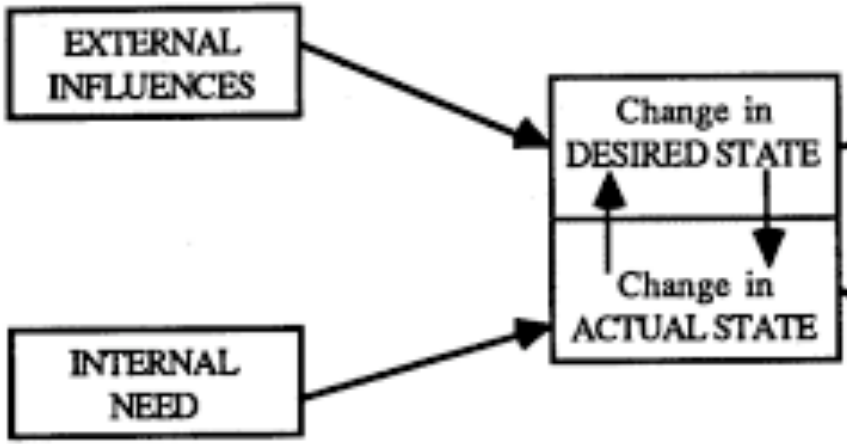
Insights from Vehicle Purchase Literature and Data



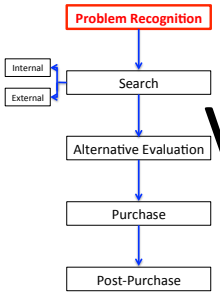
Vehicle Insights – Problem Recognition

State of existing vehicle(s)

Life events



Source: Punj & Srinivasan (1992)



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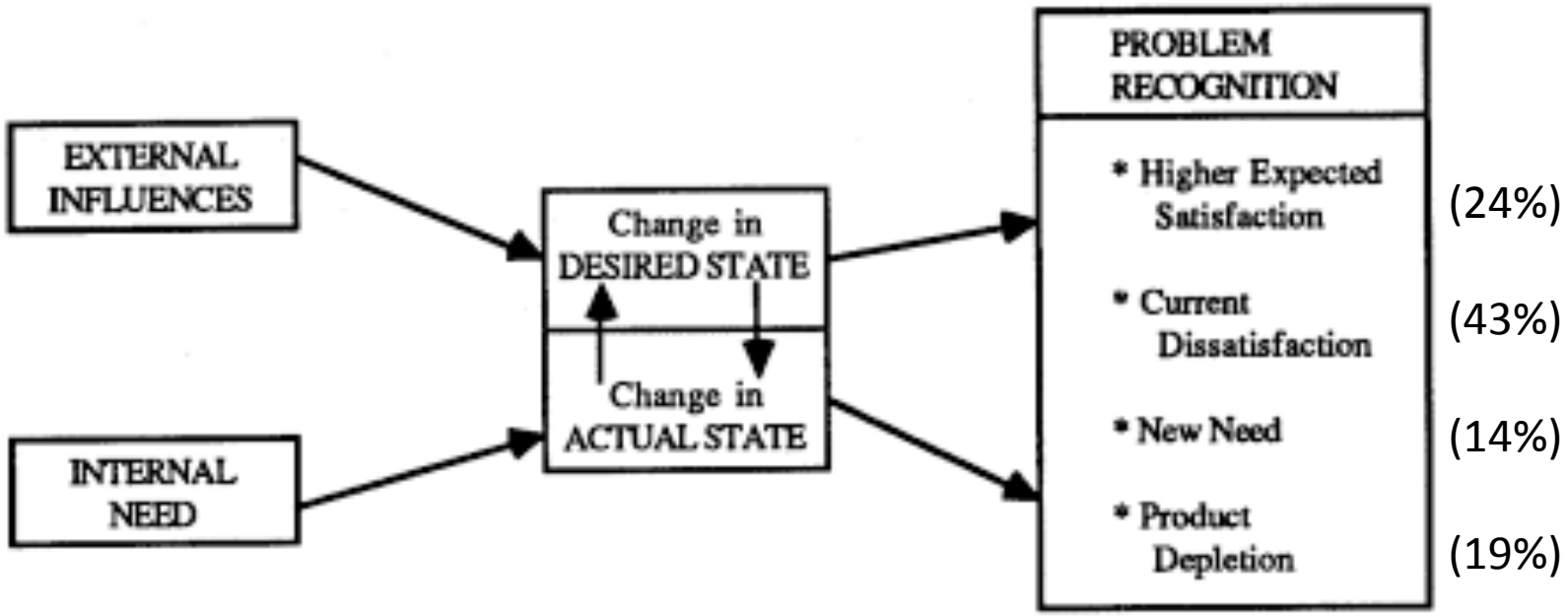


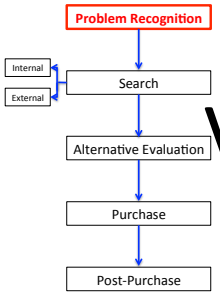
Source: Punj & Srinivasan (1992)

Group I: *HIGHER EXPECTED SATISFACTION*
* Had a car but wanted one more.
* Old car ran fairly well, but the *new models had better styling.*
* Old car ran fairly well, but could get *better gas mileage* with a new car.

Group II: *CURRENT DISSATISFACTION*
* *Old car needed repairs too often* and was not reliable.
* Old car ran fairly well, but *if it broke down, it would not be worth fixing.*

Group III: *PRODUCT DEPLETION*
* *Old car stopped running* and had to be replaced.
* Old car ran fairly well, but *it is best to trade every two or three years.*

Group IV: *NEW NEED*
* Old car ran fairly well, but *wanted a car for a different purpose* -- recreation, hauling things, carrying more people (or fewer people).
* *Did not have a car* and wanted to get one.



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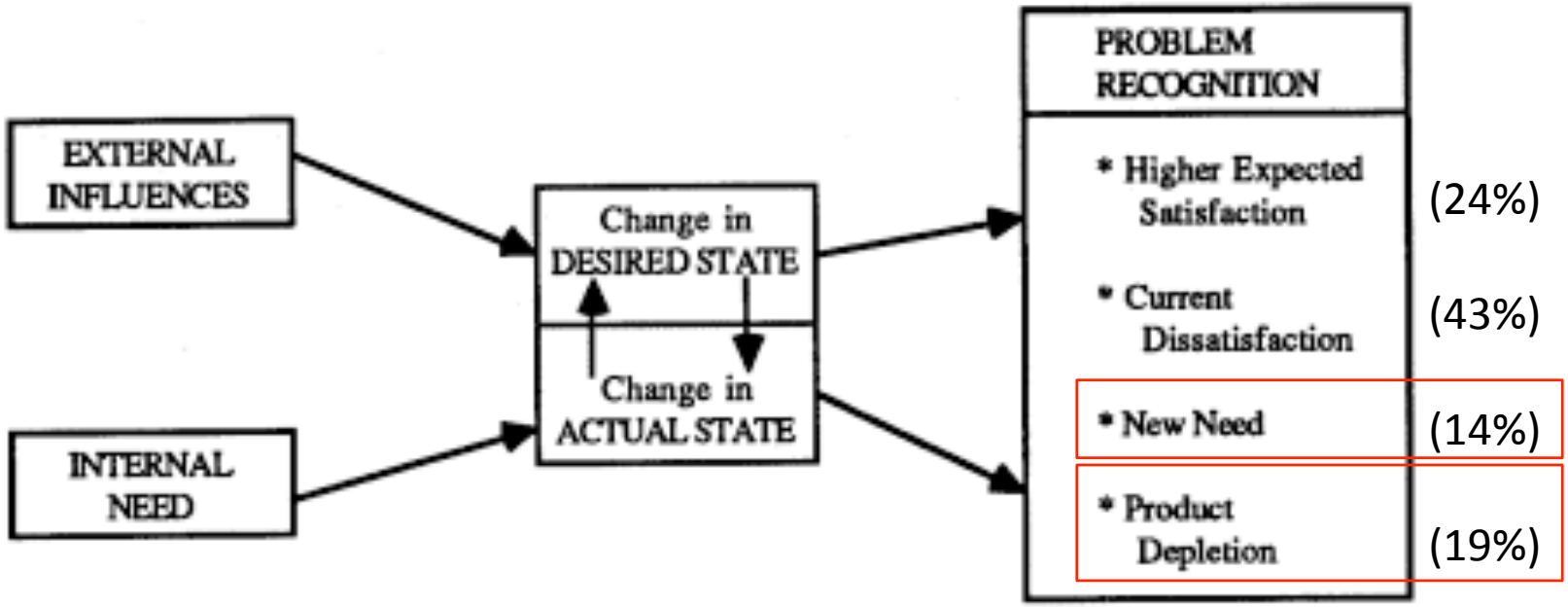
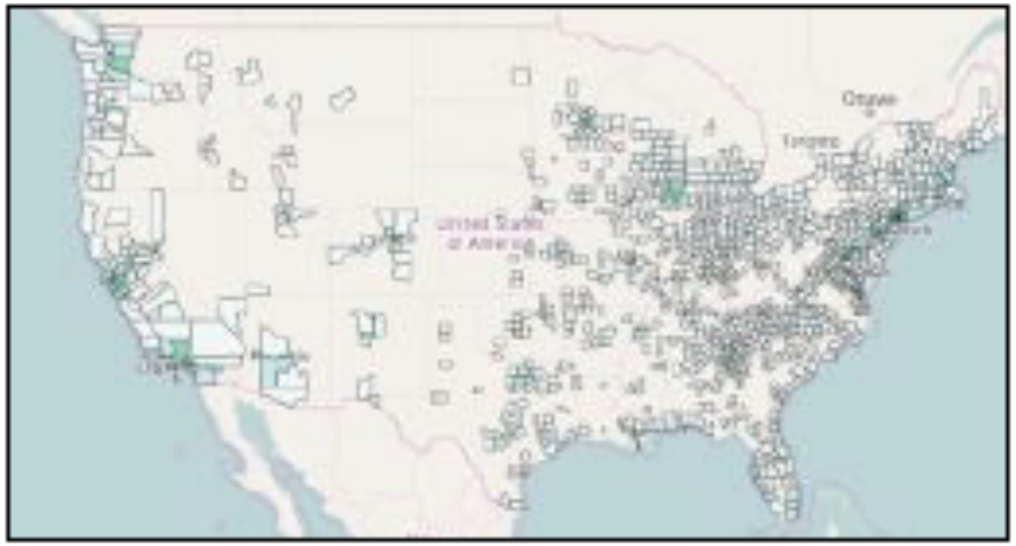


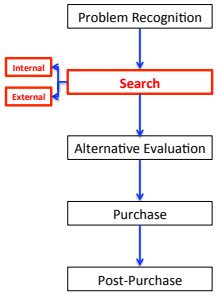
Source: Punj & Srinivasan (1992)

- **Product depletion** segment (30% today?):
  - Considered the smallest number of makes before visiting a dealership;
  - Made the smallest number of pre-decisions;
  - Shopped for the smallest number of aggregate models across dealership visits
- **New need** segment (18% today?):
  - Shopped for the highest number of aggregate models across dealer visits

Vehicle Insights - Internal Search

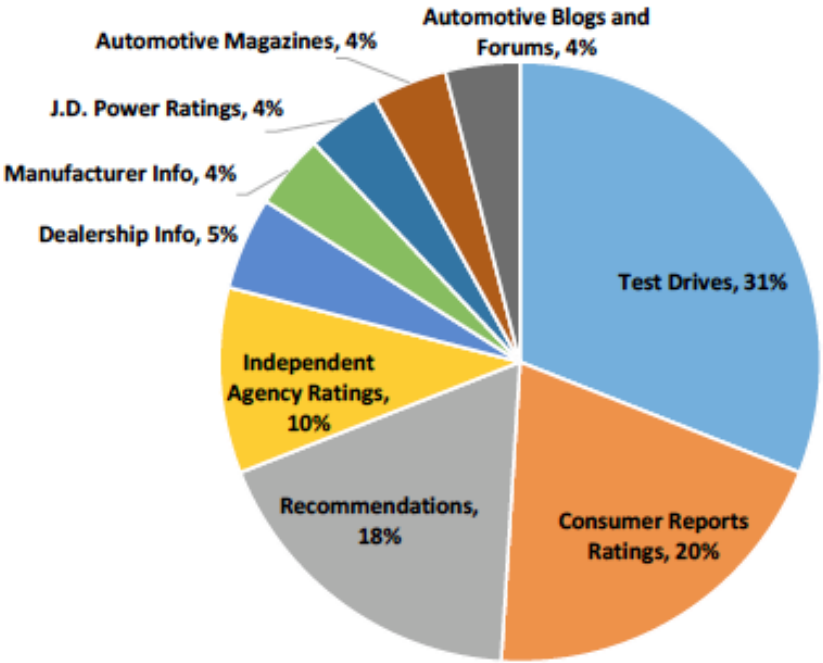
HEV Density

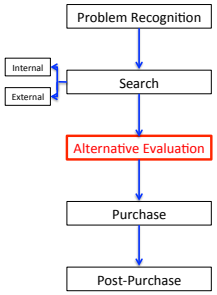




Vehicle Insights – External Search

- Test drives
- *Consumer Reports* ratings
- Personal recommendations
- Online sources of PEV information





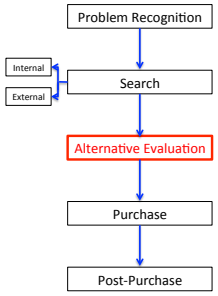
Vehicle Insights – Alternative Evaluation

Evaluating General LDVs

Top Reasons for LDV Purchase
(New Vehicle Buyers, 300,000 respondents)

1. Reliability;
2. Durability;
3. Quality of workmanship;
4. Value for the money;
5. Manufacturer's reputation

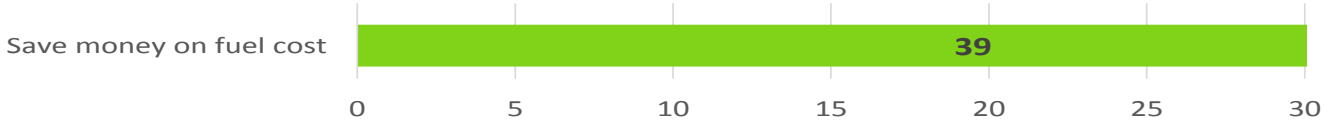
Strategic Vision (2013)



Vehicle Insights –Alternative Evaluation

Evaluating PEVs

Adopters (CA)
Santulli (2015)



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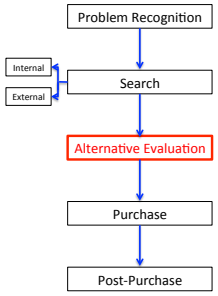

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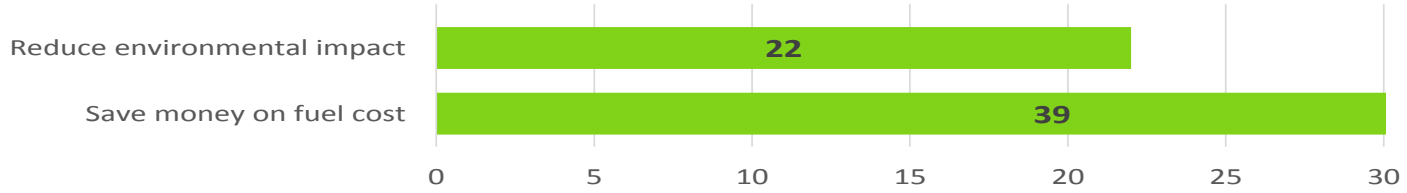

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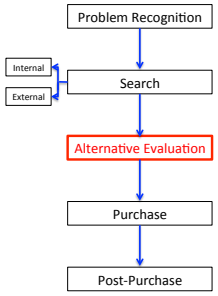

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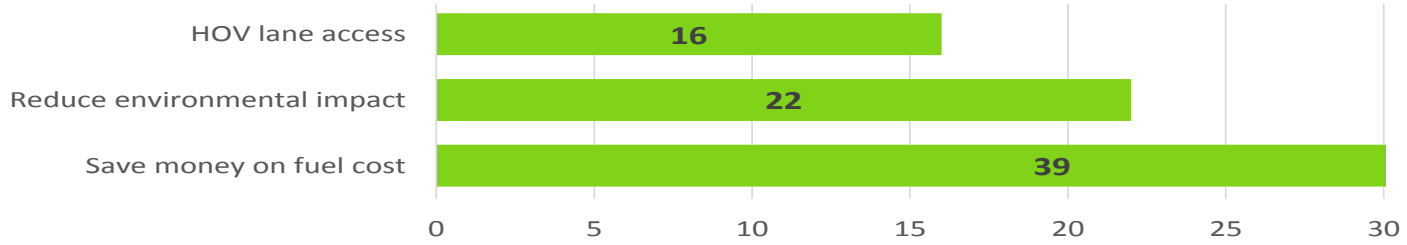

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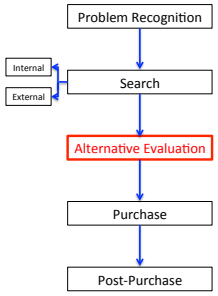

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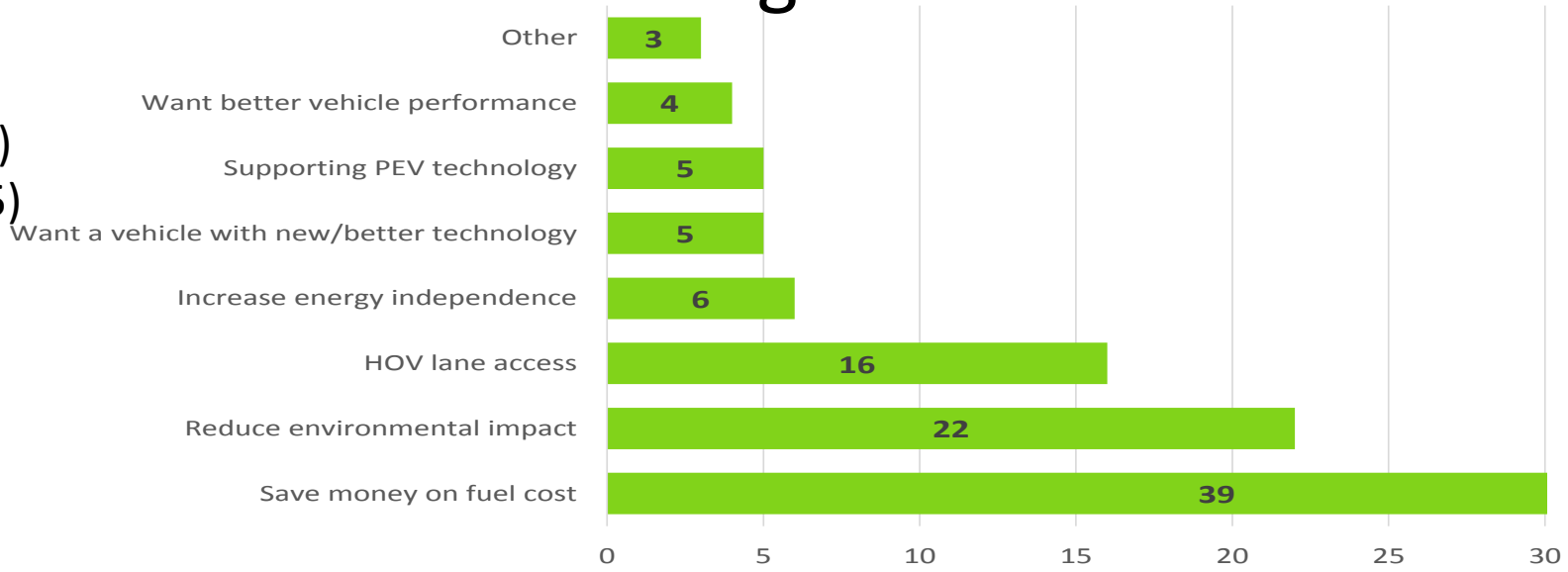

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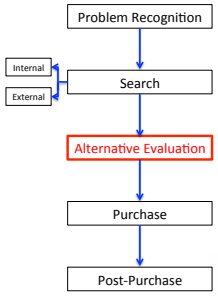
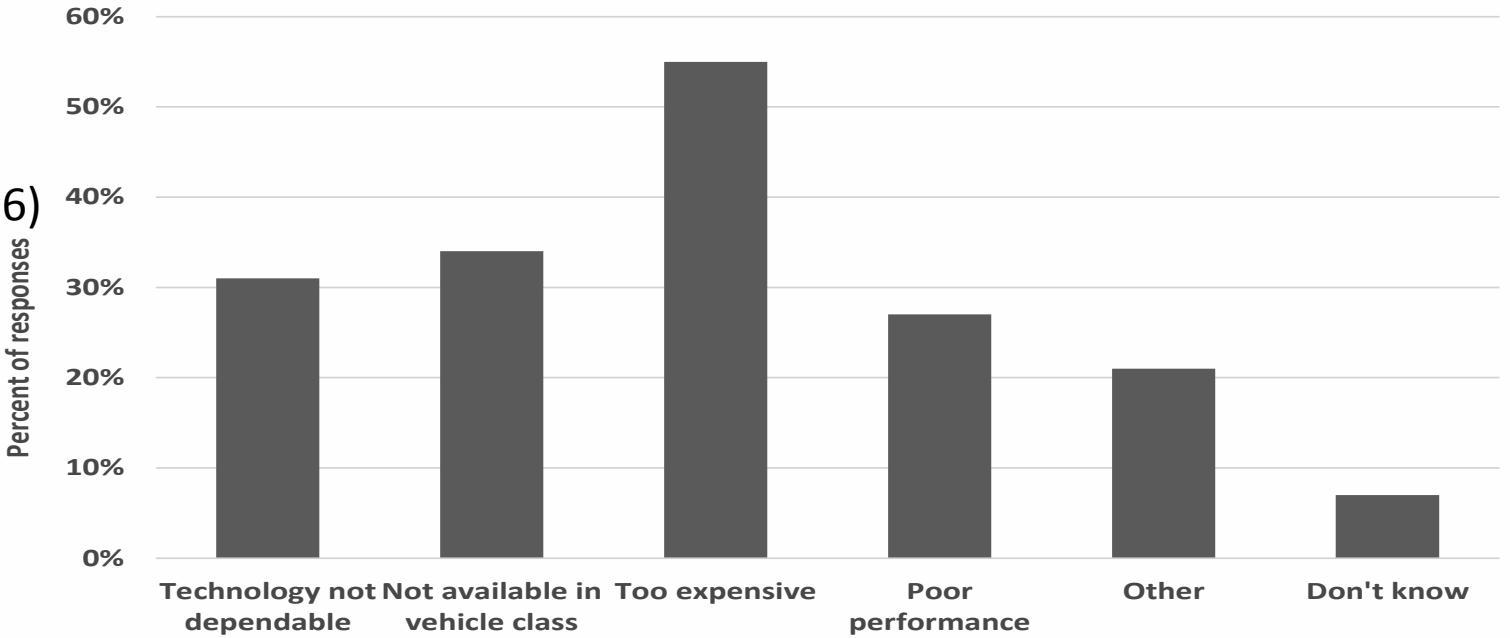


Vehicle Insights –Alternative Evaluation

Evaluating PEVs

Rejecters
Singer (2016)



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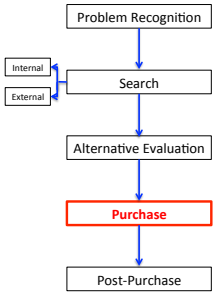


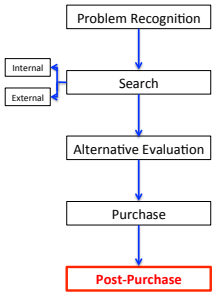
Vehicle Insights – Purchase

- Internal factors

Characteristics	BEV Buyer	PHEV Buyer	ICE-Vehicle Buyer
Gender	77% Male	70% Male	60% Male
Marital Status	81% Married	78% Married	66% Married
Average Age	48 years	52 Years	52 Years
Education	86% College Graduate	77% College Graduate	59% College Graduate
Occupation	42% Professional	37% Professional	25% Professional
Median Household Income	$148,158	$127,696	$83,166
Number of Respondents	3,556	1,000	186,662

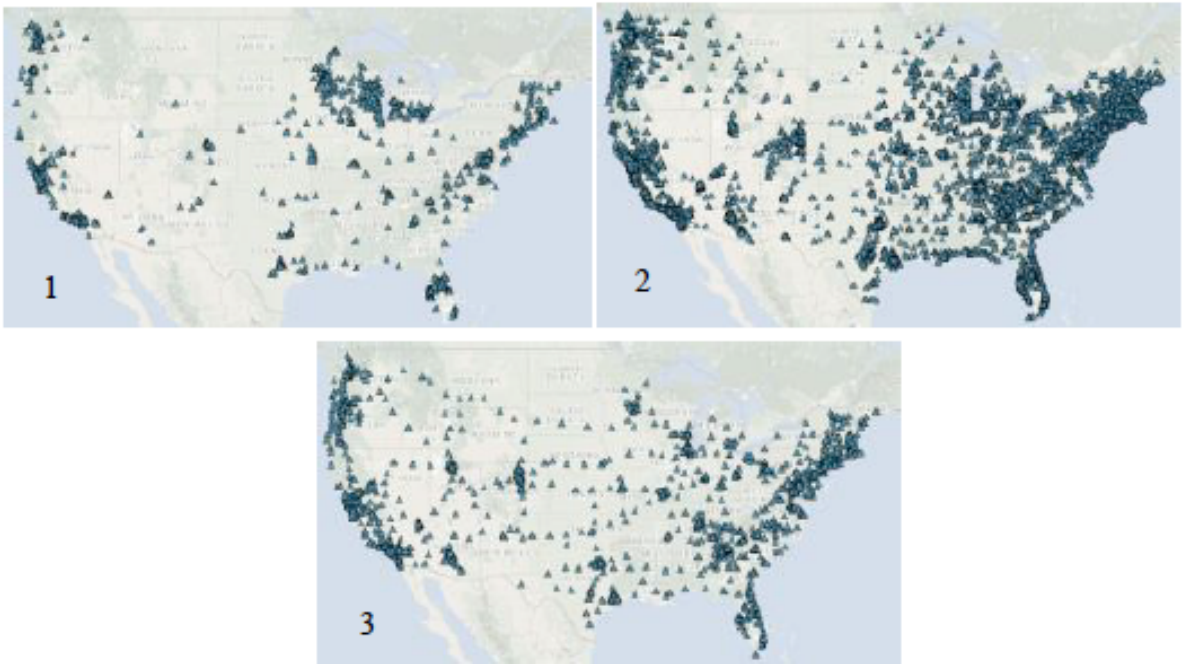
- External factors
  - Shrinking number of dealerships
  - Distribution of product across dealerships
  - Purchase complexity
    - Heterogeneous state incentives
    - Lease terms
    - Technical information

Year	Number of Franchised New LDV Dealerships
1970	30,800
1975	29,600
1980	27,900
1985	24,725
1990	24,825
1995	22,800
2000	22,250
2005	21,640
2010	18,460
2015	16,545



Vehicle Insights – Post-Purchase Behavior

- Charging behavior



Panel 1: Level 1 chargers; Panel 2: Level 2 chargers; Panel 3: DC fast chargers
Source: Alternative Fuels Data Center, April 2017

- Consumer mobility practices

Concluding Thoughts

A Good Purchase for Many

- Increasing PEV value proposition for growing number of consumers
  - Economics
  - Performance
  - Convenience
  - Psycho-social (for many)
  - Societal benefits
- Awareness low, with spatial heterogeneity

Challenges in Purchase Decision Process

- Multiple opportunities for negative consumer emotions to arise throughout the decision process,
  - Important potential consequences for future purchase decisions
- Potentially different negative consequences of purchase for PEV buyers than for buyers of traditionally-fueled vehicles;
  - High financial and psycho-social risk
- Consumers generally make high investments of time and effort in the purchase decision-making process
  - Post-purchase behavior change – anticipated vs. actual

Complications re: Purchase Context

- Time constraints (often part of LDV purchase)
- Competition between PEVs and traditionally-fueled vehicles
  - Traditionally-fueled vehicles have inherent advantages
    - Familiarity/experience
    - Known quality/dependability/reliability attributes
    - Prominent OEM marketing efforts
- Rapid technological change in alternatives
  - True of both PEVs and traditionally-fueled vehicles
  - Contributes to decision avoidance, delayed purchase

Marketing Suggestions

- Emotional appeals are important
- Previous PEV buyers tend to be loyal and could help shape emotional appeals

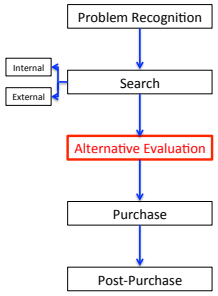
Research Suggestions - 1

Problem Recognition	• Replicate Punj and Srinivasan (1992) to better understand consumer segments today and if/how they behave differently in the vehicle decision-making process • Improve understanding of the connections between PR and PEV purchase decisions
Search	• How much do consumers perceive of PEVs as either a substitute for a traditionally-fueled vehicle or as a new LDV product category. Relevance to the role of past experience in influencing internal search and alternative evaluation • Use randomized control trials and other rigorous social science methods to better evaluate various experiments with experiential learning about PEVs (e.g., ride-and-drives, embedding PEVs in fleets, etc.) • Investigate potential framing effects associated with the presentation of PEV information in general car-buying information sources (e.g., *Consumer Reports*, *Kelley Blue Book*, *Wards Automotive*, etc.). • What are the most effective approaches to seeding new clusters of PEVs in areas of the country with low PEV density? How to empirically determine this? • How do existing "virtual communities of consumption" for PEVs compare to similar communities related to different products? How can these communities best help advance the PEV market? • Follow-up on suggestions of NAS (2015) re: data on how much car shoppers rely on valuable government-funded online resources (e.g., the Alternative Fuels Data Center). The committee recommended both A-B testing of elements of these websites as well as increased consideration of their prominence in search results

Research Suggestions 2

Alternative Evaluation	• Deepen the understanding of the connection between gas prices and the consumer salience of vehicle fuel economy over time • Assess existing PEV adoption/rejection survey efforts re: social science quality, benchmarking them against LDV purchase surveys, etc. Conduct meta-analysis of findings, identify duplication/gaps (especially spatially) • Estimate the economic value to consumers of the convenience of at-home charging and how this value may vary spatially and across demographic groups • Use prospect theory to understand how consumers perceive PEV attributes
Purchase	• Rigorously determine differences between today's and tomorrow's PEV buyers • Estimate the effects of dealership variables (e.g., declining # of dealerships, differing PEV availability, etc.) and purchase complexity on PEV market growth
Post-Purchase Behavior	• Study how consumers' expectations about PEV purchases compare to feelings about outcomes. How will this affect future purchases (buying heuristics, likelihood of evangelism)? • Test the degree to which potential PEV buyers recognize chargers. Is there a role for design thinking in increasing recognition? • Test with more rigor the strength of the effect of the presence of public charging infrastructure on the likelihood of PEV purchase. Is there an over-capacity issue?

Backup slides



Vehicle Insights –Alternative Evaluation

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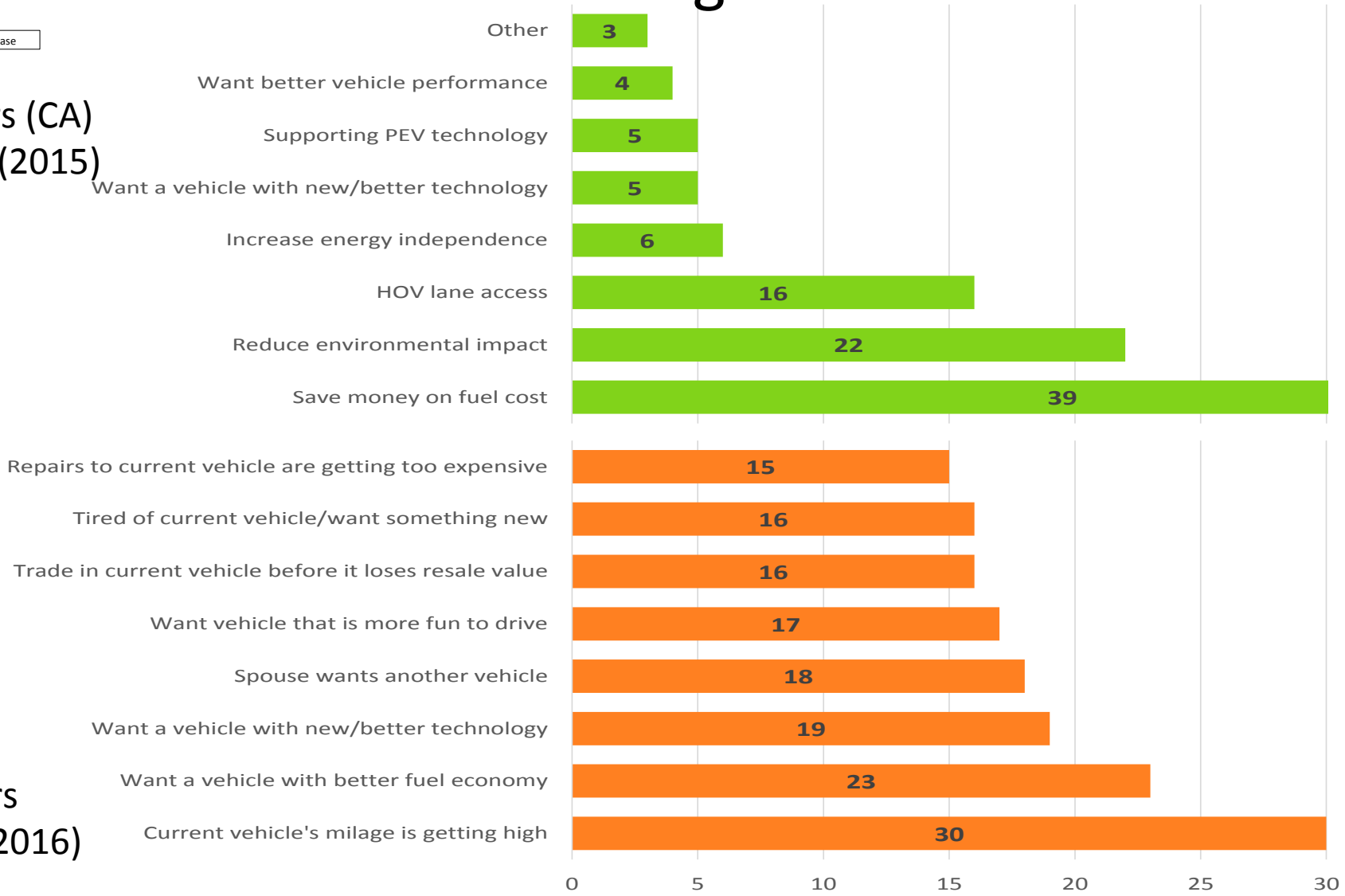
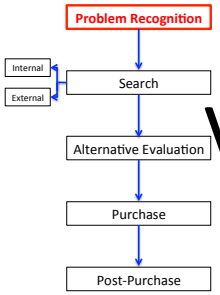


Relevant Recent LDV Studies

- Studies that focus on the relationship between life events and changes to household vehicle ownership:
  - E.g., Prillwitz, Harms et al. 2006; Dargay and Hanly 2007; Yamamoto 2008; Rashidi, Mohammadian et al. 2011; Clark 2012; Oakil, Ettema et al. 2014
- Studies that consider the different types of car ownership level changes (i.e., zero to one, one to two, two to one, one to zero, etc.):
  - Dargay and Hanly (2007), which found that second car ownership is more volatile than first car ownership);
  - Roorda et al. (2009), which found that carless households gaining a first car experienced the highest utility gain, but losing a car had a greater reduction in utility than the increase in utility from gaining a car;
  - Clark et al. (2016), which focuses on types of car ownership level change and a broad range of life events
    - Large-n (40,000 household) panel dataset in the United Kingdom in which adult household members are interviewed annually
    - Changes in household composition and driver's license availability were the strongest predictors of changes in car ownership;
    - Households were more likely to give up a car when their income shrank than they were to acquire a car when their income grew
    - Having children increases the probability of a carless household acquiring a car but also increases the probability that a two-car household will give up a car;
    - Poorer access to public transit predicts a higher probability that a carless household will acquire a car and a lower probability that a single-car owning household will give up a car

Purpose and Motivation

- **Project purpose**: Synthesize consumer behavior research re: the PEV purchase decision process
- **Motivation**: Help the PEV market become less policy-reliant and more representative of the U.S., both spatially and demographically
  - Help OEMs better recoup R&D investments;
  - Help American consumers access the benefits of PEVs;
  - Help with U.S. energy independence and local, regional air quality, while reducing GHGs



Vehicle Insights – Problem Recognition

State of existing vehicle(s)

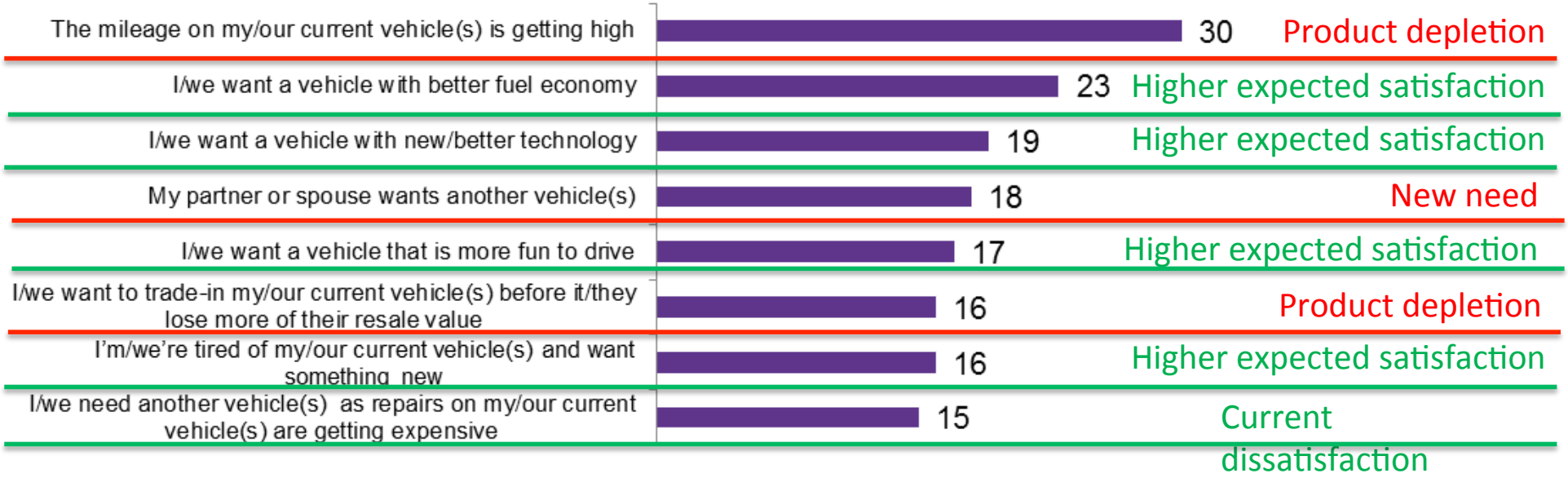
EXTERNAL INFLUENCES

Life events

INTERNAL NEED

Source: Punj & Srinivasan (1992)

PR Backup 1: Reasons for LDV purchase



Note: Americans buy new vehicles every 6-8 years on average (Le-Beau 2012)

- Questions and results from Mintel Group (2015)
- Coded by authors for Punj & Srinivasan (1992) consumer segments

PR Backup 2: Age of vehicles owned by multi-vehicle households in the U.S.

	Number of Cars owned by Household						
	0	1	2	3	4	5	6
	Average Age of Cars Owned in 2009 (years)						
Car 1		9	7.6	7.9	8.5	8.5	10.2
Car 2			9	9.1	8.8	9.4	9.8
Car 3				11.8	11.4	12.3	12.2
Car 4					13.2	12.7	12.5
Car 5						16.8	14.5
Car 6							17.9
% of U.S. Households with this number of vehicles in 2010							
	9.1%	33.8%	37.6%	19.5%			

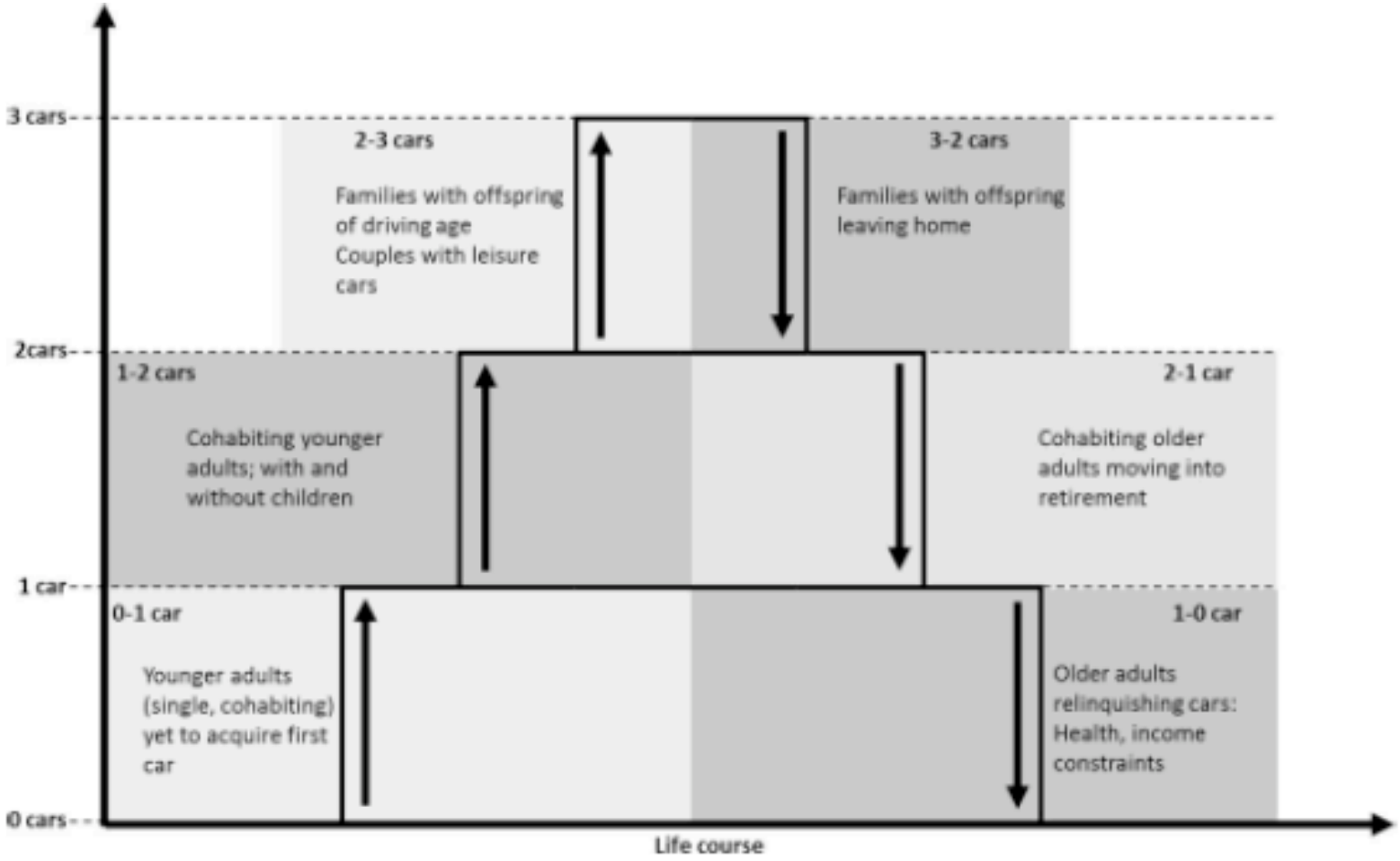
Transportation Energy Data Book (2016) Tables 8.5 and 8.15

PR Backup 3: Household vehicle ownership statistics

	Household Veh. Ownership				Urban Status		Household Composition		
	Number of Vehicles				Average Number of Vehicles per Household				
	0	1	2	3+	Urban	Rural	With Children	Without Children	All Households
1990	11.5%	33.7%	37.4%	17.3%	1.9	2.1	2.2	1.8	1.8
2000	9.4%	33.8%	38.6%	18.3%					
2001					1.8	2.3	2.2	1.7	1.9
2009					1.7	2.4	2.2	1.7	1.9
2010	9.1%	33.8%	37.6%	19.5%	1.9	2.1	2.2	1.8	1.8

Transportation Energy Data Book (2016) Tables 8.5 and 8.8

PR Backup 4: Car ownership level changes and household life cycle



Clark (2012)

Search Backup 1: Consumer knowledge regarding PEV availability and performance

PEV Knowledge or Opinion	% of Respondents
Able to name a specific PEV make & model	48
Reported seeing PEVs in parking lots	49
Believed they had never been in or near a PEV	43
Aware of charging stations on routes they regularly drive	18
Stated PHEVs "just as good or better than" traditional ICEs	52
Consider/expect to purchase PHEVs for next purchase/lease	24
Stated BEVs "just as good or better than" traditional ICEs	45
Consider/expect to purchase BEVs for next purchase/lease	20

Singer (2015)

Alt Eval Backup 1: Most important vehicle attributes and gasoline prices in select years

Year	Price	Fuel Economy	Safety	Dependability	Quality	Gasoline Price ($2015 per gallon)
	More Objective ←			*→ Less Objective*		*Objective*
1980	14% (3)	42% (1)	9% (4)	31% (2)	4% (5)	3.51
1981	21% (3)	20% (2)	12% (4)	40% (1)	7% (5)	3.53
1983	30% (2)	13% (3)	9% (5)	38% (1)	11% (4)	2.92
1985	29% (2)	8% (5)	10% (4)	41% (1)	12% (3)	2.64
1987	31% (2)	4% (5)	14% (3)	44% (1)	8% (4)	2.00
1996	11% (4)	7% (5)	29% (2)	34% (1)	19% (3)	1.95
1998	5% (4)	4% (5)	34% (2)	36% (1)	20% (3)	1.62
2000	11% (4 tie)	11% (4 tie)	24% (2)	33% (1)	22% (3)	2.15
2001	8% (5)	11% (4)	30% (1 tie)	30% (1 tie)	22% (3)	2.05
2004	10% (5)	22% (3)	23% (2)	26% (1)	19% (4)	2.41
2005	7% (5)	12% (4)	28% (2)	33% (1)	21% (3)	2.84
2006	7% (5)	20% (3 tie)	26% (2)	28% (1)	20% (3 tie)	3.10
2007	7% (5)	21% (3)	24% (2)	30% (1)	17% (4)	3.26
2008	8% (5)	27% (1 tie)	23% (3)	27% (1 tie)	15% (4)	3.65
2009	10% (5)	24% (2)	18% (4)	29% (1)	19% (3)	2.65
2011	8% (5)	30% (1)	22% (2 tie)	22% (2 tie)	18% (4)	3.77
2012	14% (5)	29% (1)	15% (4)	25% (2)	16% (3)	3.81
2014	11% (5)	20% (2 tie)	20% (2 tie)	30% (1)	19% (4)	3.43
2015	14% (4)	13% (5)	21% (2)	31% (1)	18% (3)	2.51

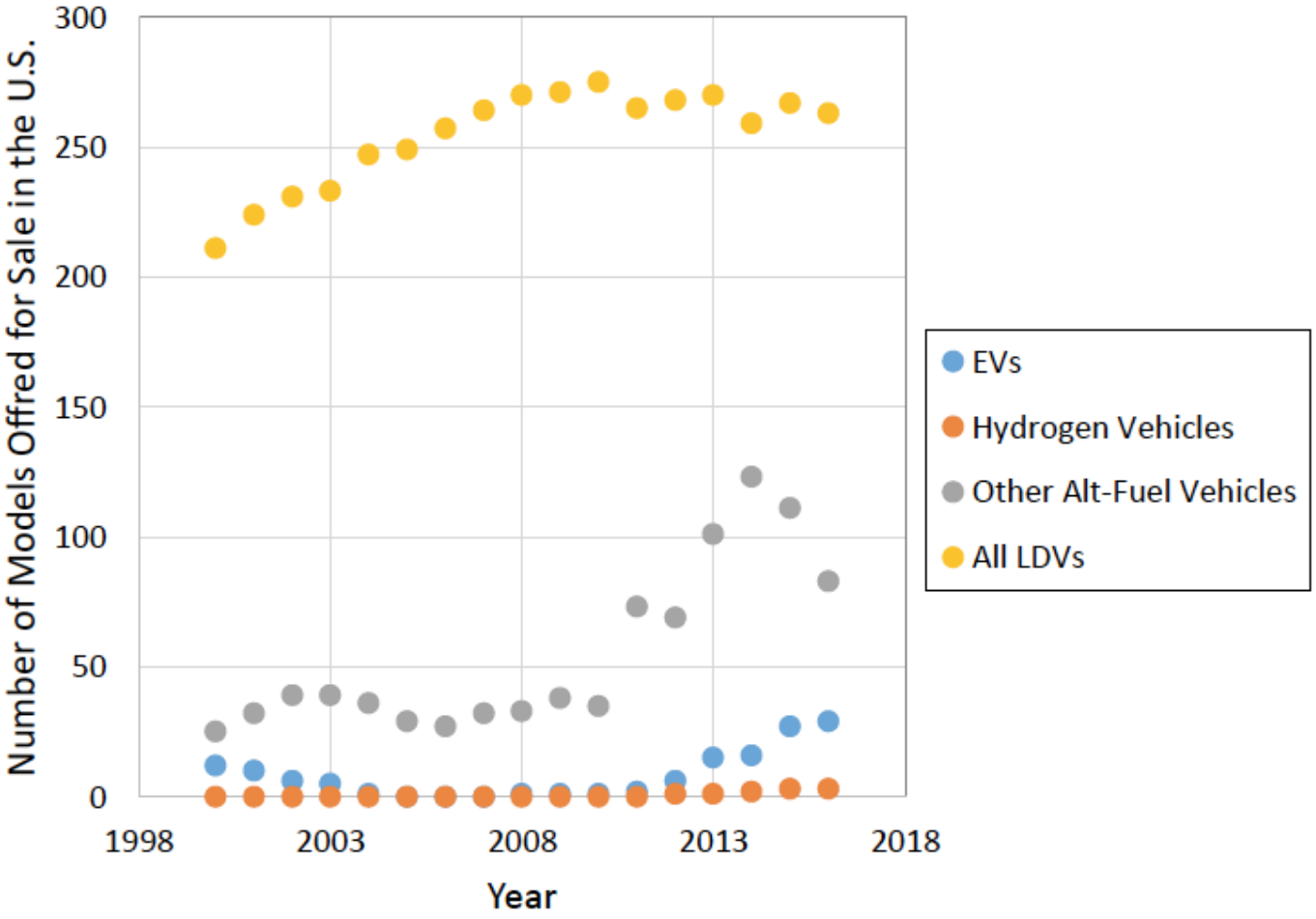
DOE *Vehicle Technologies Market Report* Figure 18 and
DOE *Transportation Energy Data Book* Table 10.03

Alt Eval Backup 2: Price range of 2017 PEVs in U.S. compared to sales of all LDVs in price range

Price Range	Number of 2017 PEV Models
Under $20,000 6% of U.S. New Car Sales in 2014	0
$20-30,000 47% of U.S. New Car Sales in 2014	7
$30-40,000 33% of U.S. New Car Sales in 2014	10
$40-50,000 7% of U.S. New Car Sales in 2014	2
Over $50,000 6% of U.S. New Car Sales in 2014	4

Consumer Reports (2014), Car and Buyer (2014), DOE Vehicle Technologies Market Report

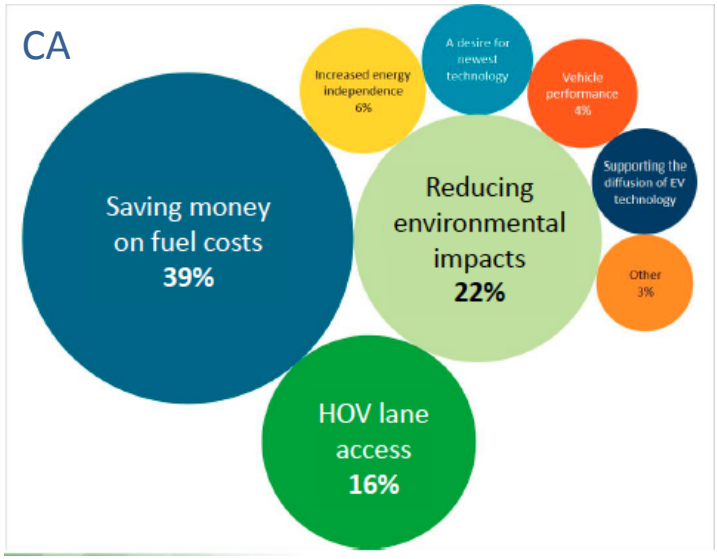
Alt Eval Backup 3: Number of vehicle models offered for sale in the U.S. by type and year



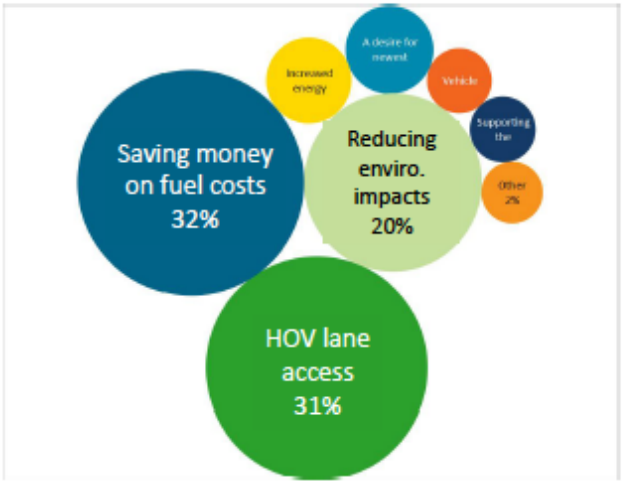
Transportation Energy Data Book Table 6-8 and *Statista*

Alt Eval Backup 4: Reasons for PEV purchase differ spatially

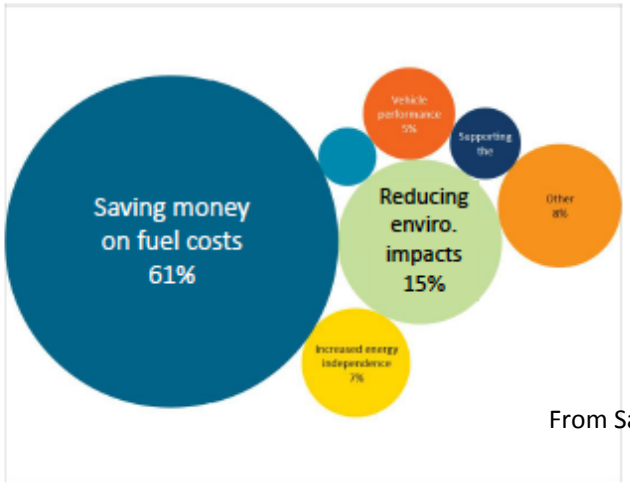
Reasons for Acquiring a PEV in CA, 2014



Santa Clara County

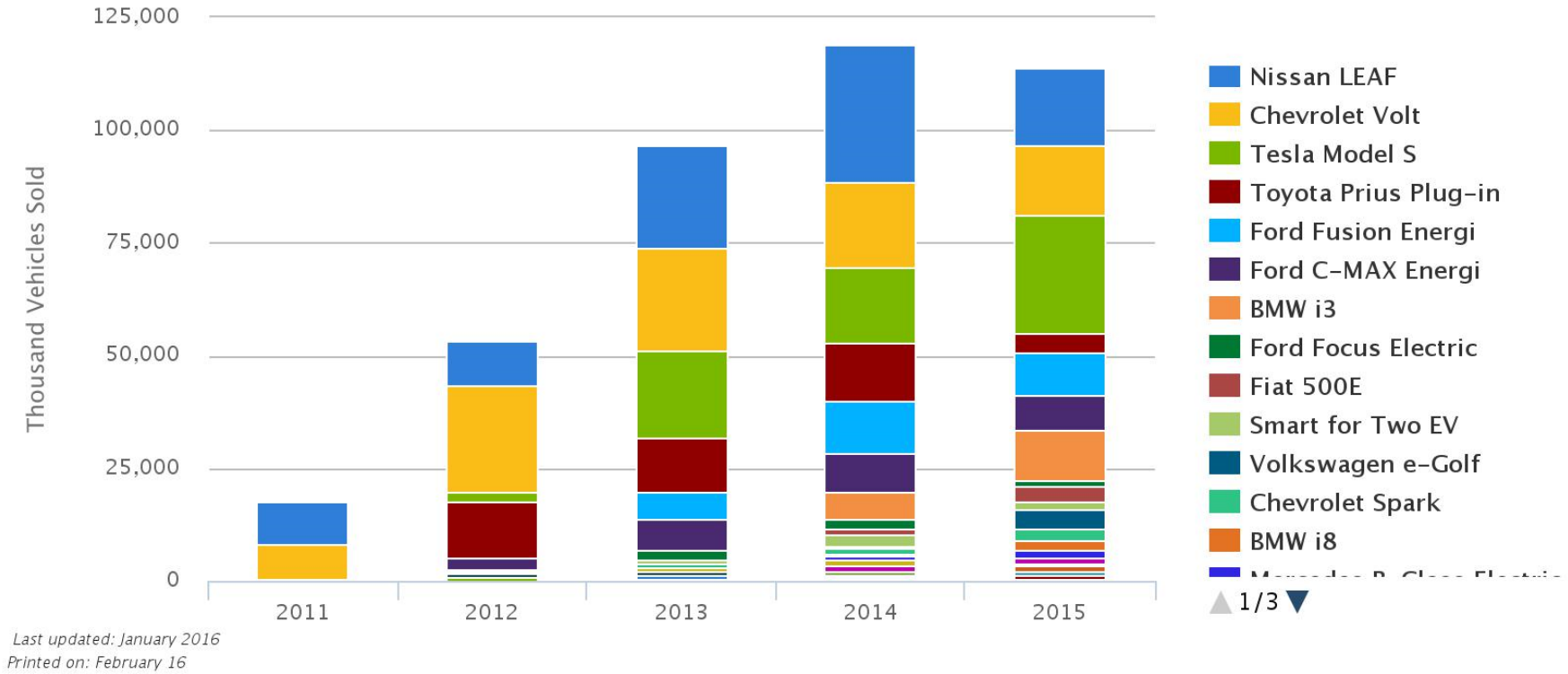


Fresno County



From Santuli (2015)

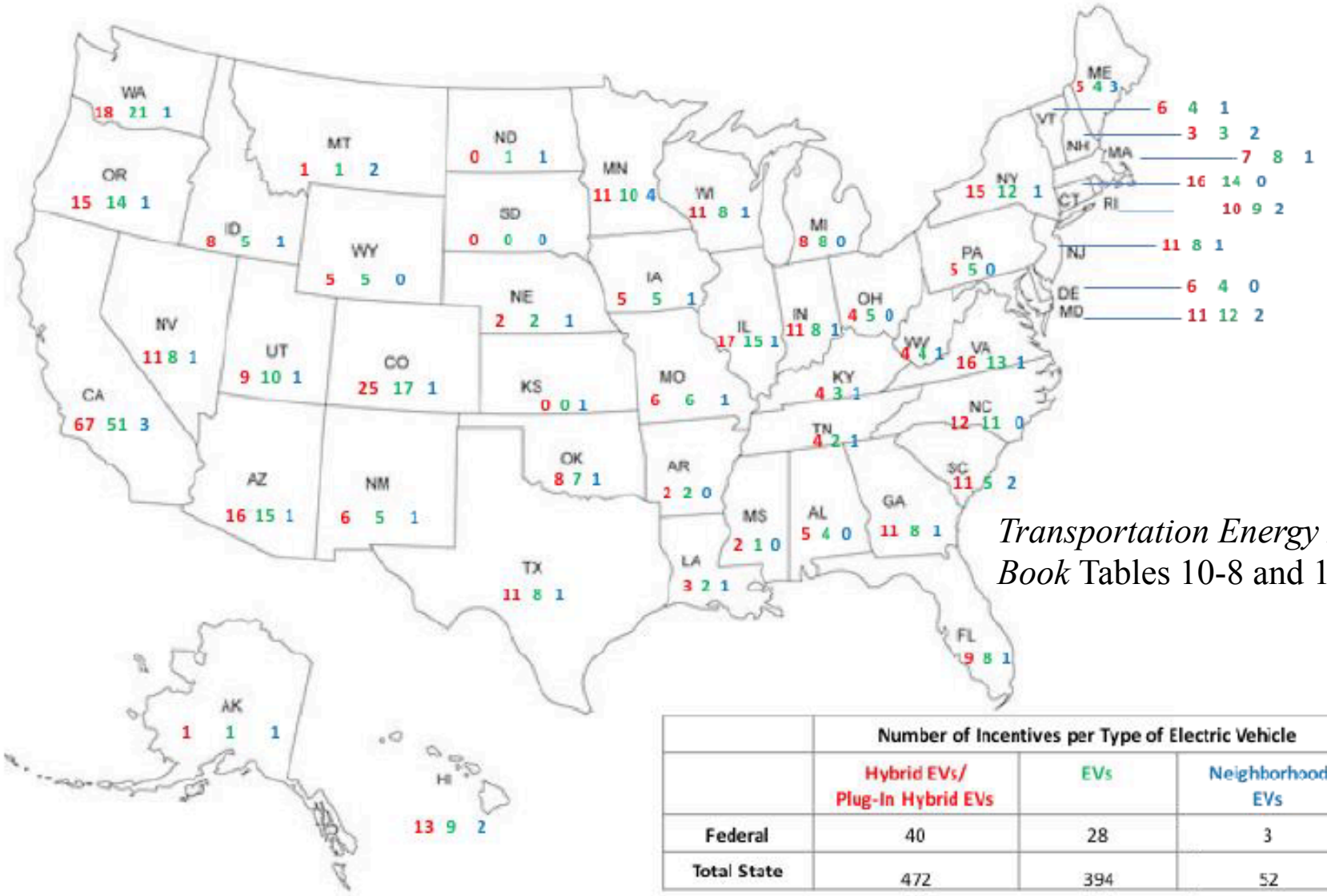
Purchase Backup 1: U.S. PEV sales by model, 2011 – 2015



Crossed the 500,000 EV threshold recently

Alternative Fuels Data Center

Purchase Backup 2: Heterogeneous state-level incentives



Transportation Energy Data Book Tables 10-8 and 10-9

	Number of Incentives per Type of Electric Vehicle		
	Hybrid EVs/ Plug-In Hybrid EVs	EVs	Neighborhood EVs
Federal	40	28	3
Total State	472	394	52

Purchase Backup 3: More demographics on vehicle buyers by type

Characteristic	All New-Vehicle Buyers	Tesla Model S	Nissan Leaf	Chevrolet Volt	Toyota Prius Plug-in
Gender (M/F)	61/39	82/18	77/23	74/26	66/34
Married or partnered	71	83	87	82	76
Age 50+	56	68	37	61	39
Household size of 1 or 2	58	56	35	53	46
College grad or more	59	87	86	77	83
Income +$100K	40	88	66	63	62
Caucasian	79	86	70	82	56
Purchased/leased	78/22	95/5	14/86	56/44	68/32
Paid cash	14	36	5	12	2
Received special financial incentives	64	24	76	73	88
Did not seriously consider any other vehicle	NA	62	50	42	48
Seriously considered other models	NA	Chevrolet Volt (1%)	Chevrolet Volt (10%)	Toyota Plug-in Prius (3%)	Chevrolet Volt (8%)
Number of respondents	237,235	285	2,257	556	169

[a] Entries are provided as percent of respondents.

Strategic Vision (2013)

Post-Purchase Behavior Backup: Number of conventional fueling stations in the U.S. since 1993

Year	Number of retail outlets	Gas stations (per 1,000 vehicles)
1993	207,416	1.11
1995	195,455	1.01
1997	187,892	0.93
1999	180,567	0.86
2001	172,169	0.79
2003	167,571	0.74
2005	168,987	0.71
2007	164,292	0.66
2009	162,350	0.65
2011	157,393	0.63

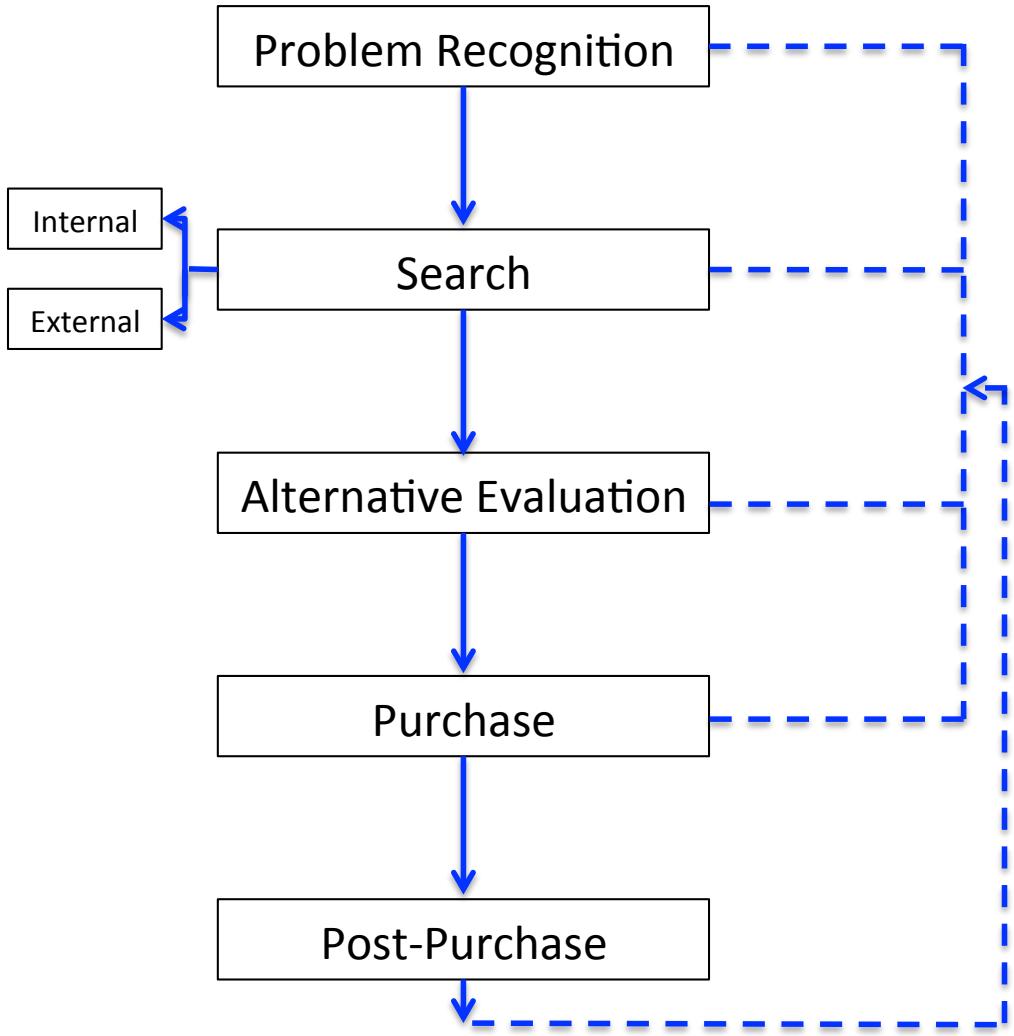
Transportation Energy Data Book

Other Backup

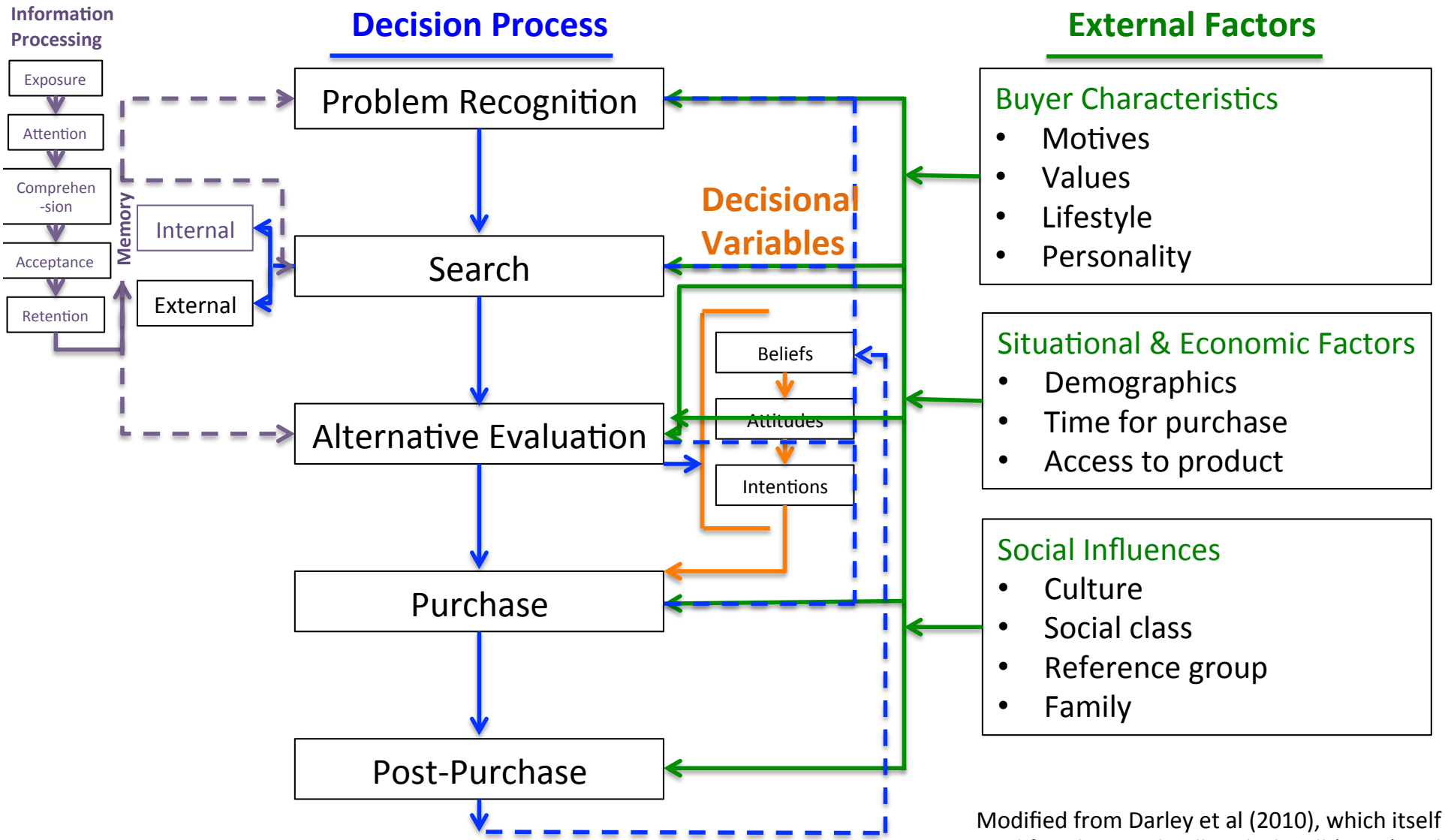
PEV Benefits beyond Fuel Economy

- Fun and safe to drive
  - Electric drivetrains provide full torque fast and the lower center of gravity brought on by battery weight improves handling
- Convenient to charge
  - Mostly fueled at home overnight
- Inexpensive to maintain
  - Many less parts to electric motors, and remaining "consumables" like brakes tend to last longer

A Framework for Structuring Literature Review and Communicating Results: Modified EKB Model of Consumer Decision Process



A Framework for Structuring Literature Review and Communicating Results: Modified EKB Model of Consumer Decision Process



Modified from Darley et al (2010), which itself modifies the Engel Kollat Blackwell (1978) and Engel Blackwell Miniard (1986) models

Concordance to EV Everywhere Questions

DOE QUESTIONS RE: MARKETING AND PURCHASE	SLIDE(S), NOTES
What are the key determining factors of conventional vehicle and PEV purchase?	23
Where do “fuel” efficiency (miles per gallon versus ICE gasoline) and other factors (e.g., styling, brand loyalty, etc.) rank?	23
To what degree is cost savings (e.g., payback from fuel costs; federal/state incentives) a behavioral motivator?	23
Are the capital costs the largest hurdle for PEVs?	24, 25, 39
What is the reason for the purchase of high capital cost SUVs, Pick-up trucks with long term financing? Could this be a potential benefit for PEV market?	23; more information needed, some information in safety literature
What PEV facts/factoids are most useful in persuading consumers to purchase a PEV?	13, 23, 24
What motivated PEV buyers to make their purchase?	12, 13, 23, 24, 29

DOE QUESTIONS RE: DRIVING PEVS	SLIDE(S), NOTES
Will PEVs meet the vast majority of potential PEV buyers' daily transportation needs?	33, 35, 36, 37, 38
If PEVs do meet these needs, do consumers understand this?	17, 19, 24, 39
If PEVs don't meet all those needs, what work-arounds can enable PEV ownership (e.g., occasional car borrowing, occasionally getting a ride with others, thinking of specialization within a household's car portfolio, etc.)? How widely known are these work-arounds?	38; more information needed
What are “typical” PEV drive cycles?	33, 34
How do PEV drive cycles affect PEV attitudes?	More information needed
How do PEV drive cycles differ by driver?	More information needed
How do PEV drive cycles differ by BEV vs. PHEV?	33, 34
How do PEV drive cycles vary by PEV model?	More information needed

DOE QUESTIONS RE: CUSTOMER SATISFACTION	SLIDE(S), NOTES
Are PEV drivers happier than drivers of other cars?	More information needed
Consider third-party (i.e. Consumer Reports) data on the quality attributes of PEVs. How does Tesla do? How do other PEVs compare? Is there a comparison that could drive a similar positive response?	39, 40, 41, 42, 43, 44, more information needed
Beyond third-party data, is there another positive sales opportunity that could be grounded in the non-energy attributes of non-Tesla PEVs?	23, 24, more information needed
Is there qualitative data about this involving current car owners?	23, 24, more information needed
Do current PEV operators “believe” that their PEV is the best option and superior to other vehicle choices?	41, 42, 43, 44, more information needed

DOE QUESTIONS RE: MARKET SIZE, CHARACTERISTICS, AND POTENTIAL	SLIDE(S), NOTES
How homogenous/heterogeneous are PEV buyers?	28, 29
What are the characteristics of PEV drivers as an overall group?	28, 29
What are the characteristics of PEV drivers by PEV model?	28, 29
What are the most significant differences between early PEV adopters and PEV mass market purchasers?	28, 29
DOE QUESTIONS RE: CHARGING	**SLIDE(S), NOTES**
How do [innovative/TOU/other] EVSE/charging pricing models affect re-charging behavior?	34, 35, 36, more information needed