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

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Executive Summary

This report synthesizes consumer behavior research as it pertains to the plug-in electric vehicle (PEV) purchase decision process. The purpose is to clarify what is known about the vital role consumers play in the U.S. PEV market as it matures to become less policy-reliant and more representative of the U.S., both spatially and demographically. A more representative PEV market will: help OEMs recoup more of their R&D investments in PEVs; help American consumers access the economic and performance benefits of PEVs; and help the U.S. become more energy independent while improving air quality-related public health and reducing greenhouse gas emissions.

This report draws heavily from the marketing literature for its organization and insights. Section 2 introduces the standard five steps of the purchase decision process used in consumer behavior research and introduces important internal and external factors that are likely to affect that decision process. Section 3 provides a review of transportation data and literature that is structured around these five purchase decision steps, namely problem recognition, search (both internal and external), alternative evaluation, purchase, and post-purchase behavior. The final section of the report, Section 4, highlights cross-cutting themes in consumer behavior research that are relevant to the maturation of the U.S. PEV market. It also provides a table that compiles a variety of research topics that would fill important knowledge gaps about the PEV purchase decision process.

The report identifies several challenges on the consumer side of the PEV purchase process. These include experience gaps and the need for consumers to make high investments of time and effort in the PEV purchase decision-making process and in post-purchase use. As is true for many purchase decisions, there is potential for negative emotions to arise throughout the PEV purchase decision process and for consumers to have negative purchase consequences. The vehicle purchase context can compound some of these challenges and/or differentiate how they play out with respect to PEV purchases versus traditionally-fueled light-duty vehicle purchases. Relevant contextual elements include: time constraints for purchase; rapid technological change in both PEVs and traditionally-fueled vehicles; and competition between PEVs and traditionally-fueled vehicles that are familiar, high-quality, and prominently advertised by OEMs.

Despite these challenges, the report makes clear that there is an increasing value proposition for PEV purchase for a growing group of consumers based on the economic, performance, convenience, psycho-social, and societal benefits of PEVs. To increase public awareness of this value proposition, the report emphasizes the importance of emotional appeals and highlights the possible role of PEV owners in shaping these appeals.

Table of Contents

Table of Tables

Table of Figures

1 Introduction

Vehicles that are at least partially fueled by electricity are developing rapidly (Anair & Mahmassani, 2012). This vehicle category includes hybrid electric vehicles (HEVs), in which the electricity comes from the car's battery, as recharged by the car's systems. It also includes plug-in hybrid electric vehicles (PHEVs) and battery-electric vehicles (BEVs), in both of which the electricity to recharge the car's battery comes largely from stationary power sources.[1]

All three vehicle types provide environmental benefits, such as a reduction in the public health hazards of traffic-related air pollution for drivers and for those 30-45% of urban Americans who live near busy roads (Health Effects Institute 2010). But for PHEVs and BEVs – which we collectively refer to in this report as plug-in electric vehicles (PEVs) – the environmental benefits are more significant. This is because the electricity that powers PEVs is typically generated in centralized locations which can use cleaner-burning fuels or have emissions that are treated by sophisticated control technology.[2]

PEVs also provide economic value and performance benefits to consumers; these benefits have increased over the years thanks to public- and private-funded innovation. As recently as 2001, PEVs were considered to be poor substitutes for traditional internal combustion engine (ICE)-based light-duty vehicles (LDVs), with major concerns regarding price, limited range, long battery recharge, low speed and acceleration, and a lack of charging infrastructure (Garling & Thøgersen, 2001). By 2015, however, National Academy of Sciences (2015) recognized the major advantages of PEVs over ICE vehicles due to "lower operating costs, smoother operation, and better acceleration; the ability to fuel up at home; and zero tailpipe emissions when the vehicle operates solely on its battery." Depending on the vehicle, today's PEVs are: convenient to charge, as they are typically fueled overnight at consumers' residences rather than at public stations; inexpensive to fuel[3] and to maintain (e.g., electric motors have less parts than traditional engines, electric vehicle (EV) "consumables" like brakes tend to last longer, etc.); fun to drive, as electric drivetrains provide full torque quickly; and safe to drive, as battery weight tends to lower the vehicle's center of gravity and improve handling.

Despite the consumer and environmental benefits of PEVs, the U.S. PEV market is not mature.[4] As illustrated in *Figure 1.1*, U.S. PEV sales are often located in relatively affluent "neighborhood clusters" in specific parts of the country in which sales have benefited from both Federal and State policy efforts of different types, including California's long-standing Zero-Emission Vehicle (ZEV) program. Outside these neighborhood clusters, it can be difficult for

[1] Gasoline is still consumed in PHEVs, however.

[2] In instances in which the electricity that fuels PEVs is instead generated in more distributed locations, it is usually from renewable, non-emitting sources. See Dijk et al. (2013) regarding developments in PEV technology, infrastructure, and the policy environment.

[3] This depends on use and electricity prices.

[4] Several references provide helpful information in the PEV market. For information on worldwide electric vehicle sales over time, see, e.g. Deschamps (2010). For information on the interplay between location, drive cycle, and the marketability of HEVs and BEVs, see, e.g., Santini et al. (2008). For information on projections of adoption of "zero emission vehicles," including BEVs and PHEVs, in the near term, see, e.g., Greene et al. (2014). For policy-relevant analysis of the early PEV market, see, e.g., the Indiana School of Public and Environmental Affairs (2011). Note that a more mature PEV market could benefit U.S. industry, particularly in the automotive and electricity sectors, as well as consumers and the environment.

potential consumers to gain the direct experience with PEVs that is invaluable in vehicle purchase decisions.

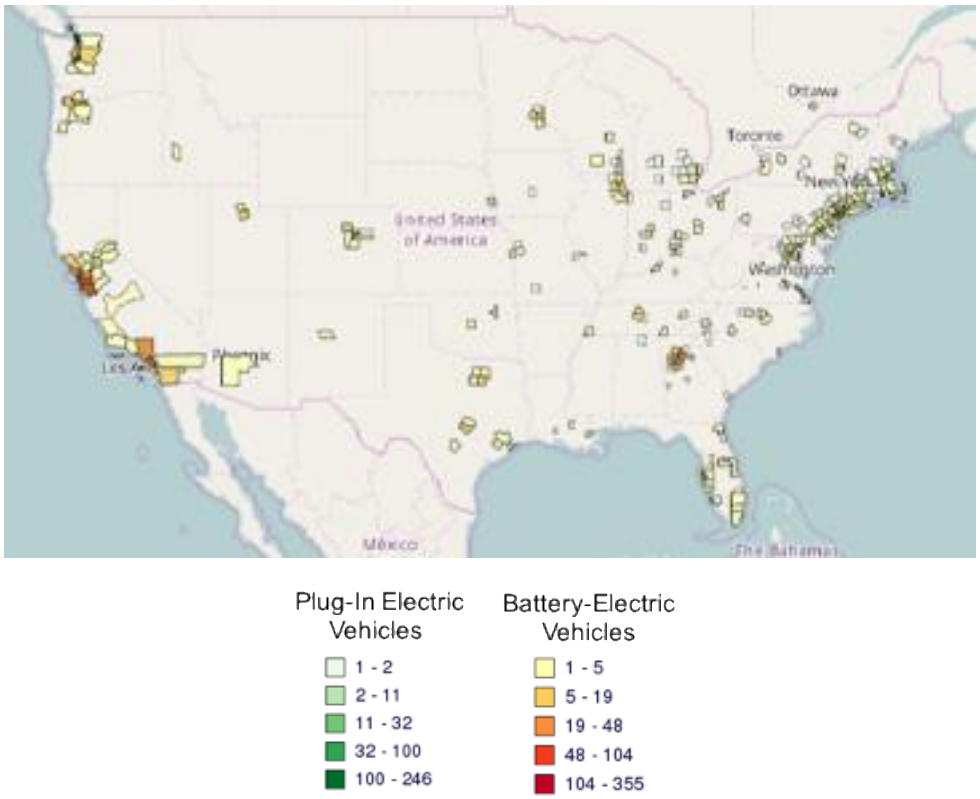


Figure 1.1: U.S. PEV density in number of vehicles per 5 square miles.
Source: Alternative Fuels Data Center Transatlas, based on May 2017 data.

Consumer purchase decisions are key to the rate at which the U.S. PEV market grows and the overall demographic and geographic shape of that market. The purpose of this report is to highlight what is understood and what critical knowledge needs remain regarding consumer behavior and the PEV purchase decision process. The report provides a broad, interdisciplinary review of the various literatures (e.g., academic journals, government agency reports, manufacturer publications, etc.) that address the purchase process for PEVs as well as traditionally-fueled vehicles and HEVs, as tied to a structure drawn from a well-regarded marketing framework developed in academia and widely applied in practice. This five-step, purchase problem-driven framework is novel in the context of the PEV purchase, but resonates with the subjects of several consumer-related social sciences (e.g., economics, psychology, sociology, and anthropology) and interdisciplinary traditions in transportation research.

This report is divided into four sections and includes three appendices. Section 2 introduces the five-step purchase decision process research framework and how it relates to insights in the broader consumer behavior literature. Section 3 uses this framework to structure a research synthesis of relevance to consumer behavior and the PEV purchase decision process. Section 4 highlights cross-cutting themes in consumer behavior research that are relevant to the maturation of the U.S. PEV market. It also provides a table that compiles a variety of research topics that would fill important knowledge gaps about the PEV purchase decision process. Appendix A provides a table that connects curiosity-driven, “man-on-the-street” questions about consumers and PEV purchase decision-making to specific subsections of the report where they are

addressed. Appendix B provides supplemental tables and figures. Finally, Appendix C provides a list of supplemental references.

2 Consumer Behavior and the Framework for this Report

Here we provide a brief introduction to the general field of consumer behavior research, which draws tools and insights from economics, psychology, sociology, and social anthropology, and combinations of these fields (e.g., marketing, behavioral economics, etc.).[5] We present definitions, outline some of the major topics considered in the field that are relevant to our study, and touch on some methodological issues, including how consumer behavior insights are generated and structured.

Our focus in this section is primarily on consumer behavior as it relates to the five-step consumer decision-making process we will use to structure the transportation-focused review in Sections 3 and 4 and the factors – both consumer-related and external to the consumer – that influence this process.

2.1 Major topics in consumer behavior research

The full scope of the interdisciplinary field of consumer behavior research includes "the processes involved when individuals or groups select, purchase, use, or dispose of products, services, ideas, or experiences to satisfy needs and desires" (M. Solomon, 1995). We do not attempt to cover the entire field here, however. For example, we exclude the research strain that focuses on the societal and economic impacts of consumer behavior, as well as the research strain that focuses on product disposal. We also generally proceed in this report as if there is only one decision maker who undertakes the purchase process and confronts resource tradeoffs regarding money, time, effort, etc. We acknowledge, however, that this can be a limiting assumption (e.g., if multiple members of a household take on such roles as initiating a purchase decision-making process, influencing the product choice set under consideration, making the purchase decision, purchasing the product, using the product, etc.).

2.1.1 Purchase decision-making process

Consumer behavior researchers generally depict the purchase decision making-process as having five steps: (1) problem recognition; (2) search; (3) alternative evaluation; (4) purchase; and (5) post-purchase behavior. Although these steps generally occur sequentially, there are opportunities for feedback between these steps; this feedback can inform new iterations of purchase decision-making (e.g., during the consideration of alternatives, a consumer may redefine the purchase problem and his or her evaluation criteria). Here we provide brief discussions of each step.

Problem Recognition

Problem recognition is the step in the purchase decision-making process in which a consumer identifies a gap between his or her current situation and his or her needs and/or desires (i.e., the consumer's "ideal situation"). Problem recognition drives the purchase process and occurs in one of several ways, including: (1) a currently-owned product is almost depleted (e.g., the car's gas

[5] The three leading consumer behavior journals are generally considered to be the *Journal of Consumer Research*, the *Journal of Marketing*, and the *Journal of Marketing Research*.

tank is almost empty); (2) a product is regularly/habitually purchased (a consumer regularly leases a new car every few years); (3) a currently-owned product is not satisfactory (e.g., the car breaks down); (4) the consumer has a new need for a product (e.g., a new job that requires commuting away from public transportation)[6]; (5) a currently-owned product has a desired complementary/related product (e.g., a roof rack for a car); and (6) a consumer has a new expectation for satisfaction tied to a newly introduced product (e.g., the excitement tied to the introduction of the Segway scooter). See Punj and Srinivasan (1992) for more detail.

Search

The second step of the purchase decision-making process is for the consumer to seek and integrate information about possible solutions to the problem in order to generate a list of potential purchase options (the "consideration set"). This step affects a consumer's perception of the available purchase choices and the ways to evaluate the differences between them. The search process is shaped by such factors as: the complexity of the choice; the significance of the perceived differences between brands; the level of involvement the consumer feels in the search; the time available to make a purchase; the value of the purchase; and uncertainty. During the search process, consumers consult both internal sources (i.e., information already in the consumer's mind) and external information sources (e.g., friends and family, third-party reviews, official business sources, direct experiences with products, online resources, etc. (see, e.g., Klein & Ford, 2003, for discussion of online and offline information sources)). Consumers typically weight internal information and information from friends, family, and other consumers more highly than information from business sources. Note that the shorthand "internal search" refers to a consumer's consultation of internal information sources, while "external search" refers to the consultation of external information sources; this distinction relates to dual process theory in psychology.

The consumer "integrates" the information gained in internal and external search through perception – a process through which the consumer senses, selects, and interprets information to derive meaning – and processes that help or hinder perception (e.g., selective exposure, selective attention, selective comprehension, and selective retention).[7] Important influences on perception include individual experiences, expectations, and conditions at a given moment. Note that the perception of brands is a particularly important topic in research on internal sources consulted in the search step of the purchase decision-making process, with the disciplines of cognitive psychology, social psychology, and sociology each focusing on brands as different types of "meaning-based assets," respectively: associative networks in memory, relational partners, and repositories of shared meaning (see, e.g., Avery & Keinan, 2015).

Alternative Evaluation

In the third step of the purchase decision-making process, the consumer evaluates the available options on: objective characteristics (e.g., product function, features, etc.) and subjective

[6] For more on the impact of specific life events on changes in travel behavior, see Clark et al. 2014. While the data in this study was collected in the U.K., its insights and analytical considerations can be applied elsewhere.

[7] These processes are all "selective" in that consumers decide how much to engage in them. Selective exposure involves choosing to be open to information sources. Selective attention involves choosing which messages to pay attention to. Selective comprehension involves choosing how to understand information with respect to consistency with a consumer's beliefs. Selective retention involves choosing to remember some information more than other information.

characteristics (e.g., feelings elicited from the product, aesthetics, etc.). Specific evaluation methodologies vary by consumer, but can be broadly categorized as compensatory and non-compensatory (Hauser, Ding, & Gaskin, 2009). A compensatory decision rule involves the consumer "trading off" good and bad attributes of a product (e.g., the low price of a vehicle might override an ugly color). A non-compensatory decision rule involves a non-negotiable attribute (e.g., a consumer will only consider an all-wheel drive vehicle). The results of the alternative evaluation step can be defined as follows: an "evoked set" (i.e., the set of potential purchases); an "inept set" (i.e., the set of products that the consumer will not consider purchasing); and an "inert set" (i.e., the set of products that the consumer is indifferent toward).

Purchase

The fourth step of the purchase decision-making process involves the customer's decision to buy (or not buy) a product from the evoked set. The transition between alternative evaluation and purchase actualization is influenced by a variety of factors, ranging from the internal (e.g., consumer beliefs, attitudes, and intentions) to the external (e.g., the quality of the retail experience, the availability of promotions, the offered terms and conditions for sale or lease, etc.). The product choice can change at the time of purchase for several reasons, including: product availability; incentives for competing products; lack of necessary funds; and peer group opinions.

Post-Purchase

Post-purchase behavior is the fifth step of the purchase decision-making process. In this step, the consumer uses the product and evaluates, over time, his or her feelings about the purchase and whether it met his or her pre-purchase expectations. Consumer satisfaction or dissatisfaction, particularly as it contrasts with expectations, shapes a consumer's heuristics about a product, helping the consumer to simplify future product information search and alternative evaluation (e.g., around a brand). Consumer satisfaction/dissatisfaction also has an important influence on potential "customer citizenship behaviors," such as: (1 and 2) "Voice" and "Service Improvement," in both of which the consumer communicates with the product manufacturer/retailer, either about problems with the product (Voice) or about ideas/suggestions for ways for the organization can improve (Service Improvement); (3) "Display of Affiliation," or conveying to others the consumer's affinity for the product or brand (e.g., by putting an EV bumper sticker on the car); (4) "Policing," or ensuring that others behave appropriately with the product (e.g., enforcing PEV charging etiquette); (5) "Flexibility," or being adaptable to issues that arise with the product (e.g., waiting to charge a PEV at home until electricity rates are lower); (6) "Referral/Recommendation," or communicating to other consumers a favorable review of the product/service; and (7) "Act of Service," or helping employees of the product/service provider with their tasks (see, e.g., Bove, Robertson, & Pervan, 2003; Soch & Aggarwal, 2013).

The distance between expectations of a purchase and a negative consumer experience is particularly likely to associate an unsatisfactory product with the inept set in future purchases. To prevent such an adverse outcome, companies make significant investments to improve post-purchase experience, including offering product guarantees and providing customer service. Numerous studies have found that prompt responses to consumer complaints are associated with repeat purchase intentions (Cho, Im, Hiltz, & Fjermestad, 2002; Estelami, 2000; Technical Assistance Research Programs, 1979).

2.1.2 Consumer-related influences on the purchase decision-making process

A number of consumer-related factors influence the purchase decision-making process described above. We introduce several of these factors below, loosely dividing them according to whether they have a longer-term or shorter-term influence on decision-making.

Longer-Term Factors

Several of the "longer-term" factors that influence the purchase decision-making process relate to the consumer as an individual with a generally stable decision-making style. Consumer characteristics that researchers have shown to be relevant to purchase decision-making in different contexts include such demographic, psychological, and behavioral attributes as: age,[8] gender,[9] income, socio-economic status, occupation, lifestyle, geography, and personal values/beliefs. These attributes are often used as variables to segment the potential market for a product.

Consumer decision-making styles that researchers have identified and tested for explanatory power in different purchase settings include the commonly used eight-category Consumer Style Inventory ("CSI"; see Sproles & Kendall, 1986). The CSI decision-making styles, which are considered to be relatively stable, are: (1) "Quality conscious/Perfectionist," in which a consumer systematically shops around making numerous comparisons to get the best quality product; (2) "Brand conscious," in which a consumer develops product purchase quality heuristics from such things as brand, high price, and/or a higher-end retail channel; (3) "Recreation-conscious/Hedonistic," in which a consumer approaches the purchase process as an activity to be enjoyed for its own sake; (4) "Price-conscious," in which a consumer systematically shops around on the basis of price, discount size, value, etc. (5) "Novelty/fashion-conscious," in which a consumer seeks the latest products, often in a quest for variety or excitement; (6) "Impulsive," in which a consumer is typically not cognitively engaged with the purchase, instead buying spontaneously; (7) "Confused (by over-choice)," in which a consumer is overwhelmed by too much information and choice; and (8) "Habitual/brand loyal," in which a consumer uses past purchase patterns to help routinize purchases and reduce purchase effort. See Jain and Sharma (2013) for a review of research using the CSI.

Other relatively stable factors that influence the purchase decision-making process reflect on the consumer, not as an individual, but in relation to a given product or brand. One such factor is the consumer's cumulative experience with a product or brand can have a strong influence on product search and alternative evaluation. According to Carroll (2013), more experienced consumers: (1) have a richer set of internal sources to turn to in internal search; (2) have less motivation to conduct external search but are more adept at conducting it, often consulting a wider set of external sources and processing the information more efficiently; (3) may consider a wider set of alternatives (see, e.g., M. D. Johnson & Lehmann, 1992), given a lower perception of the risk of the purchase than a less experienced consumer; and (4) use more sophisticated heuristics to evaluate alternatives. A second stable factor that involves the consumer in relation to a product or brand is the consumer's attitude toward the brand, the study of which draws on

[8] Haustein and Siren (2015) and Vichitvanichphong et al. (2015) explore the connections between age and mobility.
[9] In the area of sustainable consumer behavior, Luchs and Mooradian (2012) considers the role of gender and personality. Moss (2009), meanwhile, investigates the connection between gender, product design, and marketing, while Perju-Mitrana and Budacia (2015) explores gender differences in modeling the influence of online marketing communication on behavioral intentions.

theoretical frameworks from social psychology (Spears & Singh, 2004). Brand attitude has predictive utility regarding consumer behavior and contributes to brand loyalty, in conjunction with patronage behavior (Dick & Basu, 1994).

Figure 2.1 depicts four types of brand loyalty that result from different combinations of brand attitude and patronage behavior, as experienced over time (Dick & Basu, 1994). These are: (1) True Loyalty, in which attitude towards a brand and patronage of that brand are high (e.g., the mid-1990s General Motors EV1 drivers depicted in the film *Who Killed the Electric Car*)[10]; (2) Latent Loyalty, in which attitude towards a brand is high but patronage is relatively low, due to situational factors such as inconvenience, lack of access, lack of alternatives, contractual or psychological commitment, learning effects, incompatible complementary goods (e.g., network externalities), etc. (e.g., there are no PEV-brand retail channels near a consumer who would be very interested in the PEV brand); (3) Spurious Loyalty, in which attitude towards a brand is low but situational factors make repeat patronage high (e.g., a consumer who regularly goes to a conveniently-located branded gas station despite the consumer's aversion to the brand); and (4) No Loyalty, in which attitude towards a brand and patronage of that brand are low, sometimes due to consumer perceptions that there is little difference between brands (e.g., consumers who are indifferent between brands of car or fuel and focus instead on other attributes like product cost). Note that two of the eight CSI decision-making styles mentioned above explicitly involve a customer's attitude toward a brand (CSI style 2) or loyalty to a brand (CSI style 8).

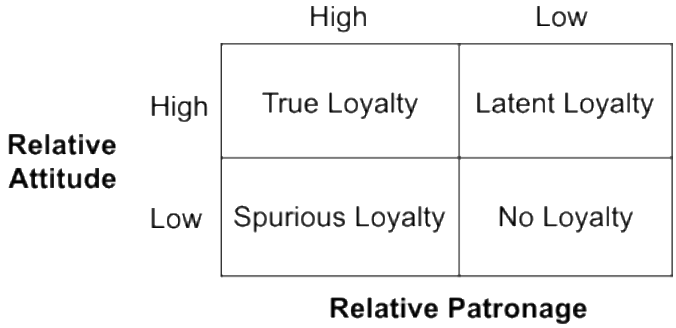


Figure 2.1: Types of brand loyalty, as related to attitude and repeat patronage
Source: Dick and Basu (1994)

Situational factors, such as those described above, can impose so-called "switching costs" that can help the dominant brand or product design become "locked-in" with respect to a consumer's decision-making, regardless of product/brand cost or performance. Switching costs can be monetary or related to time, effort, convenience, the presence of complementary goods, or other factors. Examples of products with high switching costs due to learning effects, network externalities, etc., include: Android cell phones versus iPhones; PC laptops versus Macs; top-loading clothes washers versus front-loading machines; and conventionally-fueled vehicles versus alternatively-fueled vehicles. Note that habits and emotional bonds to brands and/or products also make it hard for consumers to switch.

[10] True Loyalty is very valuable to firms. It is estimated that it costs 5-20 times as much to gain a new customer as retain a loyal customer. See, e.g., Gallo, A., "The Value of Keeping the Right Customers, Harvard Business Review Online, https://hbr.org/2014/10/the-value-of-keeping-the-right-customers

Shorter-Term Factors

The factors we identify as having a "shorter-term" influence on the purchase decision-making process are more changeable in the moment than the longer-term, relatively stable factors described above. They include a person's "affect" (i.e., the feeling of emotion) in different steps of the decision-making process and the "conative" (i.e., the translation of feeling and thought into action) phenomenon of impulsive purchasing.[11]

Affect is important to many aspects of consumer decision-making (see, e.g., Luce, Payne, & Bettman, 1999) although the relationship between affect and consumer behavior is generally considered to be under-researched (see, e.g., A. R. Johnson & Stewart, 2005).[12] Positive emotions are particularly tied to: processing information efficiently; making useful connections between pieces of information; generating creative solutions to problems; arriving at decisions more quickly; and being satisfied more readily with a purchase. With respect to the decision-making step of search, more specifically, affect relates to the faster intuitive (System 1) mental process of a consumer (see, e.g., D. Kahneman, 2003; Sloman, 1996; Stanovich & West, 2000) which tends to generate more lasting associations with a brand/product. The dual mental process of conscious reasoning (System 2), by contrast, is more time-consuming, more resource-intensive for a consumer, and more volatile with respect to a consumer's brand/product associations. The System 1 versus System 2 dichotomy is reflected in the way that consumers engage first in internal search and then external search, as the enduring associations a consumer has with a product and/or brand are very important internal sources of information. With respect to the decision-making step of alternative evaluation, neuro-economics research suggest that emotions hold primacy over neutral information (Murray, 2013). Finally, with respect to the decision-making step of post-purchase behavior, positive or negative emotions related to satisfaction with direct experience of a product and/or brand are particularly important to future purchase behavior.[13]

Affect is also one of several potential drivers of impulse buying behavior. Impulse buying was usefully defined in Bayley and Nancarrow (1998) as a "sudden, compelling, hedonically complex buying behavior in which the rapidity of an impulse decision process precludes thoughtful and deliberate consideration of alternative information and choices." The importance of affect as a driver of impulsive buying behavior is connected to the behavioral economics concept of prospect theory, in which immediate rewards and/or costs are weighted more heavily than future rewards and/or costs (see, e.g., Cohen, Pham, & Andrade, 2006). According to Muruganantham and Bhakat (2013), impulse buying behavior can be influenced by: (1) internal stimuli (e.g., affect, self-identity); (2) external stimuli (e.g., store characteristics); (3) situational and product-related factors (e.g., availability of time or resources); and (4) demographic and socio-cultural factors (e.g., gender, age, educational attainment, etc.). External stimuli that can

[11] Affect (the experience of emotion), cognition (the acquisition of knowledge), and conation (the translation of feeling and thought into action) are the three major divisions of psychology. Affect can be characterized by valence (subjectively positive or negative), arousal (elicitation of a physiological response), and motivational intensity (the urge to act).

[12] See, e.g., Sheller (2004) and Steg et al. (2001) for discussion of the important role that emotions play in the vehicle purchase decision. In addition, Moons and de Pelsmacker (2015) focus on the role of emotion in the intention to use a PEV.

[13] In a meta-analysis of the relationship between affect and satisfaction, Szymanski and Henard (2001) propose that emotions felt during consumption leave traces in memory that consumers access and integrate into their assessments of satisfaction.

influence impulse buying behavior include techniques that: (1) trigger a strong desire to buy a product (e.g., via discounted prices or extending to a consumer the opportunity to try/touch a product and imagine owning it); (2) remind a consumer of the need for a product; (3) suggest a product which the consumer has no prior knowledge about, helping he or she envision a use for the product; and (4) direct a consumer to a specific product or category once the consumer has a partial plan to buy (Stern, 1962).

2.1.3 Influences on the purchase decision process that are external to the consumer

External stimuli that can trigger impulse buying are one of several factors that are external to the consumer and can influence the purchase decision-making process. Such factors are the subject of this section. We focus here primarily on the perceived risk of a purchase and how consumers process that risk, but we also touch on other aspects of the context of a given purchase, as well as on the role of third parties in influencing consumer behavior.

Risk analysis provides a useful framework for considering some of the most important aspects of the purchase context that consumers react to. These are the consequences of a purchase (i.e., the significance of an outcome) and the probability that those consequences will occur. Potential negative consequences of a purchase include: financial loss (e.g., the feeling of "throwing money away" on a poor purchase); psychological loss (e.g., the purchase is shown after the purchase to conflict with the consumer's beliefs or values); a loss of social status (e.g., the purchase is not favorably viewed by the consumer's peers, social influencers, etc.); a performance/functional loss (e.g., the purchased product does not work as intended); and physical loss (e.g., the purchase might cause bodily harm to the consumer or his/her family) (see, e.g., Dowling & Staelin, 1994; Ross, 1975). Positive consequences of a purchase, by contrast, drive positive affect and the related search efficiencies, repeat buying behaviors, etc. described above.

The likelihood that a poor purchase will occur is something that a consumer must assess from available evidence. Some goods are more transparent about their likely quality before a purchase than others, according to a three-part economic classification of goods. The first category in that classification refers to "search goods," which have price and quality characteristics (including performance) that a consumer can readily evaluate before purchase through inspection, comparison shopping, etc.; these goods are often relatively substitutable, with high price elasticity of demand (Nelson, 1970).[14] The second category refers to "experience goods," the quality of which becomes apparent only as or after they are consumed. These goods – such as luxury goods (e.g., a bottle of wine), beauty products, health care, etc. – are prone to greater information asymmetry between the seller and the buyer, and often have less elastic demand than do search goods (Vining & Weimer, 1988). Consumers use several cues when deciding to purchase an experience good, including: price, with a heuristic equating lower price with lower quality; reputation, with a heuristic equating fame, etc. with higher quality; referral, with a heuristic that third-party judgments are trustworthy sources of information regarding such goods; and a consumer's own prior experience, as influenced by affect (as described above). The third category refers to "credence goods," which have quality characteristics that a consumer has

[14] The price elasticity of demand reflects how a change in the price of a good changes the quantity demanded by a consumer. It is higher (i.e., more elastic, or responsive) in several circumstances, including: when there are more substitutes available for the good; when the good is not a necessity; when the price change endures for a significant period of time; when the price of the good represents a higher proportion of a consumer's income; when the good is considered by consumers to be a narrow product category of its own rather than one of many goods in a category; and when brand loyalty does not influence the consumer's evaluation of the good.

difficulty evaluating even *after* purchase, such as vitamins or an oil change for a car. Many of the same cues used to inform experience good purchases also inform credence good purchases, and the two types of goods exhibit similarly low price elasticities of demand and information asymmetries between sellers and buyers. Credence goods, however, often involve an additional element of managing future risks; in both the vitamin and oil change examples, the consumer believes that the good is preventative of a future harm.

Consumers weight the probability of a poor purchase outcome against the intensity with which they expect to feel the loss from the poor outcome through a decision-making process described by prospect theory. Prospect theory – which is informed by experimental and neural-imaging evidence about how people really think and behave – breaks down a risk analysis problem into two stages. In the first stage, the decision-maker "edits" the outcomes of a decision according to a process through which he or she conceives of potentially equivalent decision outcomes, sets a reference point, and then frames other outcomes as losses or gains from that reference point. In the second stage, the decision-maker "evaluates" the outcomes and their possibilities.

A simple version of the evaluation formula is given in Equation 2-1 (Daniel Kahneman & Tversky, 1979):

Equation 2-1: *Simple form of the evaluation function in prospect theory. Source: Kahneman and Tversky (1979).*

$$V = \sum_{i=1}^{n} \pi(p_i) v(x_i)$$

In Equation 2-1, V is the expected utility of the outcomes; x_1, x_2, …x_n are the potential outcomes; and p_1, p_2, …p_n are the relevant probabilities. The function v – which a decision-maker uses to give value to outcomes – and the function π – which a decision-maker uses to weight the probability of outcomes – are derived from experimental and neural-imaging evidence. As depicted in *Figure 2.2*, the value function v passes through the reference point but is s-shaped and asymmetrical, with a steeper value for losses than for gains; this steeper value indicates that people are more averse to losses from a reference point than they are inclined toward gains.

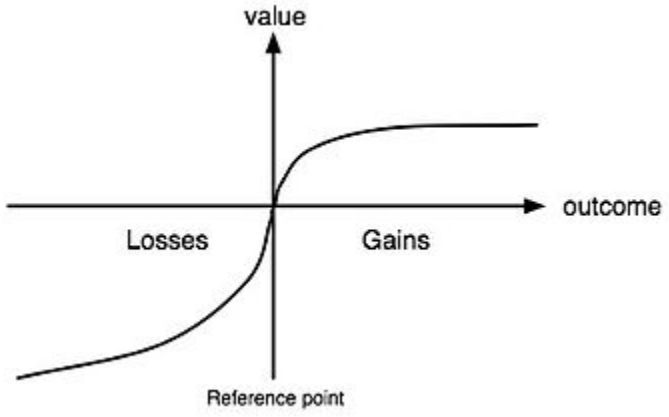


Figure 2.2: Value function of gains and losses compared to reference point
Source: Kahneman and Tversky (1979)

Meanwhile, the weighting function π reflects a phenomenon in which people tend to overreact to small probability events and underreact to large probability events.

The combination of the asymmetry of v and the over-/under-reactions associated with π lead to "risk averse" (i.e., interested in lower uncertainty outcomes, even with lower payoffs) and "risk seeking" (i.e., interested in higher uncertainty outcomes, even with lower payoffs) behaviors, as opposed to the "risk neutral" behaviors that would be expected by a perfectly rational actor. *Table 2-1* depicts risk averse and risk seeking behaviors in a 2x2 matrix that relates gains and losses to probabilities through the lens of human preferences. Note that the reduction in the probability of gain is important to risk aversion, but is even more significant when the reduction in probability goes from "a sure thing" to a less certain probability.

Table 2-1: Risk attitudes as related to consequences and probabilities in prospect theory
Source: Kahneman (2011)

	Gains	**Losses**
High Probability	Risk averse Fear of disappointment Ex: 95% chance to gain $10,000 or **100% chance to gain $9,499**	Risk seeking Hope to avoid loss Ex: **95% chance to lose $10,000** or 100% chance to lose $9,499
Low Probability	Risk seeking Hope of large gain Ex: **5% chance to gain $10,000** or 100% chance to gain $501	Risk averse Fear of large loss Ex: 5% chance to lose $10,000 or **100% chance to lose $501**

A consumer's assessment of the risks of a purchase plays an important role in his or her "involvement" in the purchase decision-making process, particularly in the consumer's motivation to spend time and resources (e.g., mental and physical effort) in the steps of information search and alternative evaluation. In general, purchase decisions in which consumers perceive that the financial and psycho-social consequences are high will prompt higher involvement and more extensive problem-solving. Automobile purchases are a classic example of a high involvement purchase, due to the cost (and infrequency) of the purchase as well as due to the social visibility of the purchase. By contrast, purchase decisions in which consumers perceive that the financial and psycho-social consequences are low will prompt lower involvement. In lower involvement purchases, problem-solving may be limited or even reduced to habit or routine. Impulse purchases, as described above, are made with almost no involvement.

The consumer's involvement in a purchase can be constrained by factors related to the purchase context or the consumer's psychology, with the perception of time a particularly important mediating variable. For example, consider the circumstance in which a consumer perceives that little time is available to make a purchase decision about an expensive, high social visibility product that the consumer considers necessary to everyday life; this circumstance regularly occurs in the case of a major car crash when a consumer has limited access to other transportation options to reach work, school, etc. In that circumstance, instead of engaging in an extensive problem-solving process that relies heavily on slower System 2 conscious reasoning, the consumer is likely to rely more heavily on faster, intuitive (System 1) mental processing. As discussed above, System 1 mental processing is heavily influenced by past affective experience with a brand and/or product which has created lasting impressions for a consumer.

A contrasting example related to time and vehicle purchases is given by a second circumstance, in which a consumer perceives that there is no time pressure for a purchase, while the attributes (e.g., performance, overall quality) of the potential options are changing rapidly, thereby increasing the consumer's perception that he or she could make a poor purchase decision. In this circumstance, the consumer is likely to procrastinate on the purchase – potentially beyond a rational replacement point (as defined by mounting repair costs, etc.) – and retain low involvement with the purchase decision-making process. The generalized decision science topics of decision avoidance and choice deferral apply to PEV purchase, given the prevalence of consumers "waiting for the technology to advance" (National Academy of Sciences 2015). These tactics include relying on the default option (Baron & Ritov, 2009; Heidenreich & Kraemer, 2015; E. J. Johnson & Goldstein, 2004), anchoring (Ben-Elia & Avineri, 2015), and engaging in inaction inertia (Mairesse, Macharis, Lebeau, Laurence, & Turcksin, 2012; Tykocinski, Pittman, & Tuttle, 1995). Greenleaf and Lehmann (1991) explored reasons for consumer delay in significant purchase decisions and revealed the following five major causes: task avoidance and unpleasantness, time pressure, uncertainty, difficulty of selecting the best brand, and perceived risk of product performance. This study found that difficulty of selection and time pressure are the most important causes of consumer delay (see also, Otto, Kardes, & Clarkson, 2014).

We conclude this section on external influences on the purchase decision-making process with a brief discussion of the role of third parties. These third parties can be grouped by their connection to a given transaction, either as seller associates, buyer associates, or independent entities. Seller associates include advertising agencies or other entities engaged in persuasive activities that may target the conscious reasoning of a consumer, the intuitive mental process of a consumer, or both. Buyer associates include members of a household and peer reference groups like neighbors, friends, etc. The opinions of buyer associates are often more highly valued by consumers than are the materials provided by sellers and their associates. Note that persuasive activities by sellers sometimes target buyer associates for their influence on a given consumer.[15] Marketers, for example, sometimes target children – who lack purchasing power – for the strong influence they exert on their parents, who have purchasing power. Finally, independent entities to a transaction – such as consumer interest magazines and websites, government offices whose mission involves consumer protection, news media, etc. – can heavily influence consumer decision-making. Independent entities that represent the consumer interest often do so in response to the information asymmetries present in a given transaction or because of the larger societal effects of poor purchase outcomes with respect to negative financial and/or physical consequences. The degree of independence of the entity is very important to the effectiveness of such organizations as trusted information sources for consumers.

2.2 Methodological issues in consumer behavior research

In this section, we touch on some methodological issues in consumer behavior research, including how insights are generated and integrated into models of the decision-making process. We also introduce our framework of the consumer decision-making process which we use in section 3 of this report to structure our review of literature relevant to the PEV purchase.

There are four main approaches to generating insight in consumer behavior research. The first approach involves the elicitation of stated preferences using qualitative research techniques

[15] Of relevance to effective marketing of PEV, Schulze et al. (2014) discusses viral marketing strategies for utilitarian products and Cooper (2007) discusses social marketing and changes in individual travel behavior.

including surveys, focus groups, and interviews. The second, third, and fourth approaches all involve more attention to revealed preferences. The second approach focuses on observing consumer behavior in naturalistic settings, and it draws on ethnographic research techniques developed in the field of anthropology. Examples of second approach techniques include: observed product usage, day-in-the life studies, accompanied purchases, and random observations in public settings. The third approach draws more heavily from psychology research traditions to understand revealed decision-making related to purchases in experimental settings; the prospect theory discussion above demonstrates how the insights from third approach techniques can generate useful insights. The fourth approach draws from neuroscience, and involves using techniques like electroencephalography, functional magnetic resonance imaging (fMRI), and eye-tracking to measure biological responsiveness to different aspects of consumer purchase decisions. Fourth approach techniques have been particularly useful in understanding how framing affects purchase decision-making, how consumers respond to too little/too much choice, and ways to motivate consumers to act on, rather than avoid, decisions.

As mentioned at the start of Section 2 of this report, and as reflected throughout this section, consumer behavior research draws tools and insights from many fields. To advance knowledge in this interdisciplinary field of research, it is helpful to have a way of organizing the relevant insights. The five-step purchase decision process has helpfully provided the basic outline of such a structure since at least Dewey (1910). Models informed by this decision process have developed over the years to incorporate the various insights brought to the field by different traditions. One of the most helpful of these models was the consumer decision process model described in Engel, Kollat, and Blackwell (1968) ("EKB Model"). In the remainder of this report, we adopt an approach similar to that used in Darley et al. (2010), which adapts and extends the EKB model (and its extension in James F. Engel, Blackwell, & Miniard, 1986) in order to use it as a yardstick with which to judge the comprehensiveness of consumer behavior research in a given area.[16]

[16] In Darley et al. (2010), the consumer behavior context was purchase through online channels rather than the purchase of a type of product, such as PEVs.

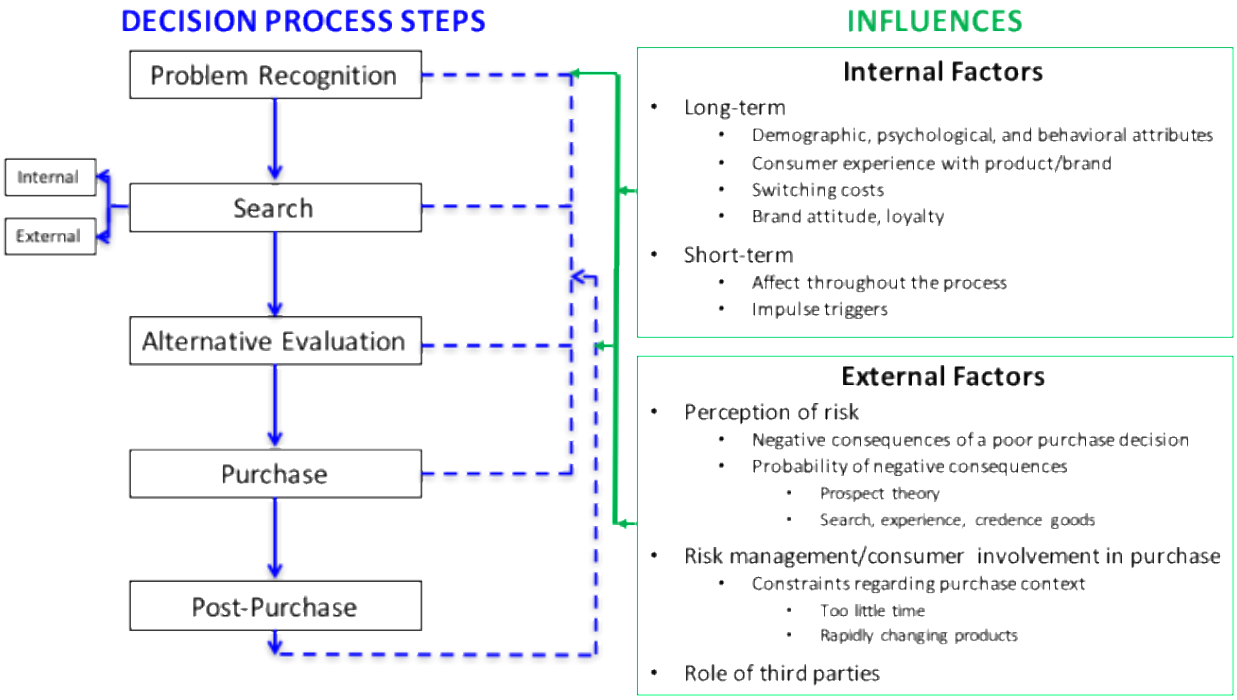


Figure 2.3: Modified EKB model of the consumer purchase decision-making process
Source: Adapted from Darley et al. 2010

3 Application to PEV Literature

We now turn to the state of knowledge about consumer behavior as it relates to the purchase of PEVs. We review a broad set of sources, including books, journal articles, government agency reports and databases, and trade publications, and we organize our review based on the modified EKB model of the purchase decision process. For each step in the EKB Decision Process, we consider first what we can learn from the literature on consumer behavior in the purchase of light-duty vehicles (LDVs) before we assess what is known specifically regarding PEVs as a vehicle category.

3.1 Problem recognition

As noted in Section 2, problem recognition is the step in the purchase decision-making process in which a consumer identifies a gap between his or her current situation and his or her needs and/or desires (i.e., the consumer's "ideal situation"). Problem recognition initiates the purchase process, and the other steps are dependent on it.

Problem recognition is generally considered to be under-researched, with few theoretical or empirical papers in the scholarly literatures. We found even fewer papers that are directly tied to vehicle purchase, generally, and none that were specifically tied to the PEV purchase process. We did, however, find several recent surveys in the so-called "grey literature" of government and consulting reports that hint at the relevance of problem recognition research to the PEV purchase process. Here we first discuss a seminal paper on problem recognition regarding the vehicle

purchase – which advances theory with empirical data – and then relate the results of this paper to current intimations about consumer purchase behavior regarding traditionally fueled vehicles and PEVs. Note that problem recognition in the vehicle purchase process is grounded in broader consumer decisions about travel behavior, residential location, etc., that we consider to be important but generally beyond the scope of this report.[17]

Punj and Srinivasan (1992) posited that an inadequate theory of problem recognition and a lack of empirical specification were holding back research on this important step of the purchase decision-making process. The authors addressed both issues by conducting an exploratory study using data on new car buyers in three geographically distinct metropolitan areas, which they used to help empirically ground their theoretical framework on problem recognition. We reproduce this framework in *Figure 3.1*.

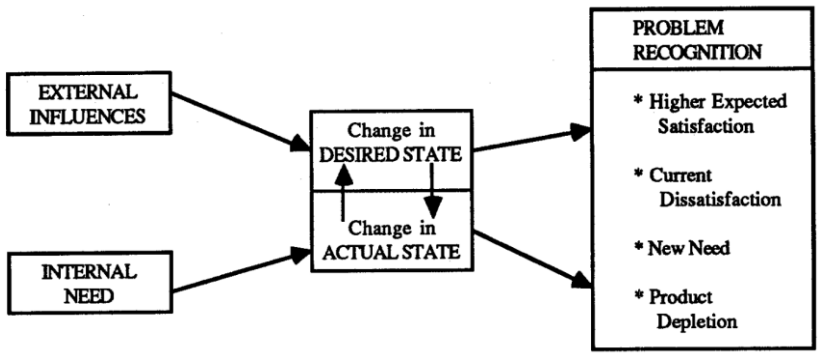


Figure 3.1: A model of problem recognition
Source: Punj and Srinivasan (1992)

Figure 3.1 shows the consumer segments that emerged from 1,056 responses to the survey described in Punj and Srinivasan (1992), which considered consumer's internal needs, external influences, and the effects these needs and influences have on the bi-directional relationship between changes in a consumer's actual vehicle situation and changes in a consumer's desired vehicle situation. The segments that emerged from the survey were grouped into four categories based on consumer motivations to undertake a vehicle purchase process (i.e., consumer approaches to vehicle purchase problem recognition). The four categories were: *new need* (14% of respondents); *product depletion* (19%); *higher expected satisfaction* (24%); and *current dissatisfaction* (43%). "New need" motivated consumers either had an existing car that "ran fairly well, but wanted a car for a different purpose – recreation, hauling things, carrying more people (or fewer people)" or "did not have a car and wanted to get one." "Product depletion" motivated consumers either had an existing car that "stopped running and had to be replaced" or "ran fairly well, but [the consumer believed] it is best to trade [a car] every two or three years."[18] "Higher expected satisfaction" motivated consumers either "had a car but wanted one more" or

[17] Clark et al. (2014) reviews empirical studies relating different types of travel behavior change and life events. Considered foundational to this literature is Salomon (1983), which "introduced the concept of a decision hierarchy" with the three inter-dependent levels of lifestyle choice (the longest term decisions, such as family formation), mobility choice (e.g. car ownership) and activity/travel choice. References regarding vehicle ownership and residential location and tenure include: Bhat & Guo (2007); Eluru et al. (2010); Paleti et al. (2013).

[18] The first group in this segment, which had a car that stopped running, is likely to have time pressures related to replacement.

thought that even though the consumer's existing car "ran fairly well… the new models had better styling" or could get better gas mileage. "Current dissatisfaction" motivated consumers felt their "old car needed repairs too often and was not reliable" or were concerned that if their existing car (which "currently ran fairly well") "broke down, it would not be worth fixing."

The authors then tested whether these consumer segments exhibited statistically significant differences in later steps of the purchase decision-making process. They tested: the number of makes consumers considered before visiting a dealership; the degree of pre-decisions that consumers made before going to a dealership (e.g., OEM, model, dealership); the purchase decision time; the number of search activities undertaken (note that this study occurred before the advent of the internet, when search costs were higher);[19] the hours of search invested outside a dealership; the hours spent visiting dealerships; the use of a "purchase pal" in the decision process; the number of aggregate models consumers shopped for across all dealership visits; the number of dealership visits; consumer certainty about the purchase; and overall consumer satisfaction with the purchase decision.

The results were interesting, both for which of the four consumer segments differed across these variables and for which did not. There was no difference between any of the consumer segments on overall satisfaction with the purchase decision, with the authors writing, that "as long as customers felt they did everything they deemed necessary and sufficient under the circumstances, they were content with the purchase." There was also no difference between the higher expected satisfaction and current dissatisfaction consumer segments on any variable, although the authors felt it remained important to distinguish between these two segments. The product depletion consumer segment, meanwhile, was statistically distinguished from the other segments on three variables; the product depletion segment considered the smallest number of makes before visiting a dealership, made the smallest number of pre-decisions, and shopped for the smallest number of aggregate models across dealership visits. Meanwhile, the new need consumer segment was statistically distinguished from the other segments on only one variable: it shopped for the highest number of aggregate models across dealer visits.

We could find no current study that applied the *Figure 3.1* framework to today's vehicle market or assessed both the problem recognition phase of purchase decision-making and related distinctions in the overall purchase process. We did, however, find several surveys of car buyers – both for traditionally-fueled vehicles and alternatively-fueled vehicles – that asked about reasons for vehicle purchase. These surveys lay potential groundwork for how one might replicate the empirical approach of Punj and Srinivasan (1992) to help identify consumer segments that might be more or less likely to purchase PEVs. We first describe some of the existing surveys and then consider a hypothetical situation in which we project some of the empirical results of Punj and Srinivasan (1992) to today's market to consider the implications for the purchase of PEVs.

Surveys of reasons for vehicle purchase are conducted by many entities, including vehicle-specific consulting firms like Strategic Vision, general consulting firms like the Mintel Group, Deloitte, etc., and independent third parties like non-profits (e.g., Consumers Union) and

[19] The search activities considered in the study were: talking to friends/relatives about new cars or dealers; reading books and magazine articles; reading advertisements in newspapers and magazines; reading about car ratings in magazines; reading OEM brochures and pamphlets; driving to and from dealerships; looking around showrooms; talking to salespeople, and test driving.

automotive news sources. In many instances, however, the presentation of survey results about reasons for purchase provide the evaluative criteria consumers use in the final purchase decision, rather than the reasons to initiate the purchase process. For example, in the major report, "Overcoming Barriers to Deployment of Plug-In Electric Vehicles" (NAS 2015), the reasons for purchase are drawn from a large-n survey of new vehicle buyers conducted regularly by Strategic Vision, with "the top five reasons consumers give for their vehicle purchase choices generally (not specific to PEVs)" listed as "reliability, durability, quality of workmanship, value for the money, and manufacturer's reputation." Questions related to new need, product depletion, higher expected satisfaction and current dissatisfaction, however, are clearly being asked, as evidenced in *Figure 3.2*. In this figure, we take questions from a regularly conducted Mintel group survey and translate them to the Punj and Srinivasan (1992) definitions of consumer segments. We highlight in red the questions linked to product depletion and new need, the segments in Punj and Srinivasan (1992) that showed the largest distinctions in the subsequent purchase process.

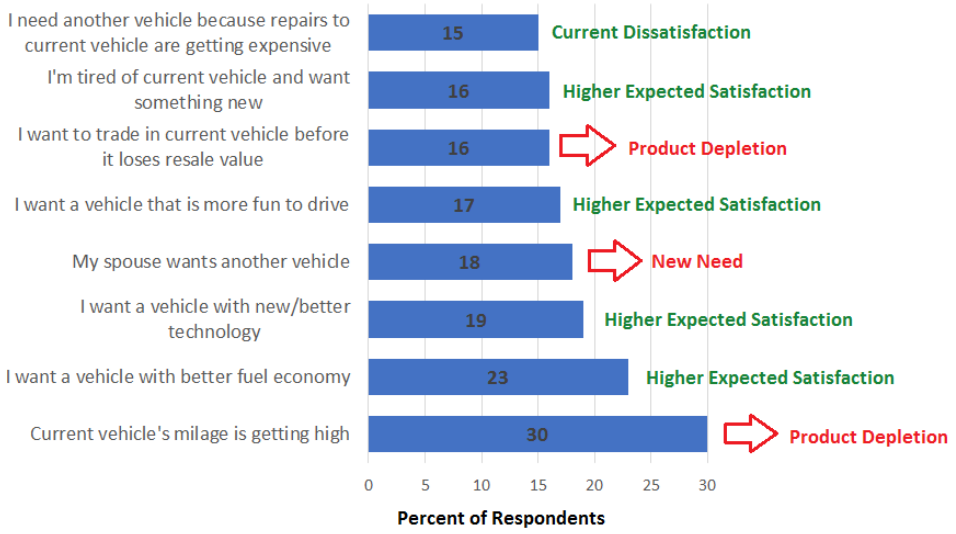


Figure 3.2: Reasons for Purchasing a Vehicle
Source: Mintel Group 2015

Although respondents to the Mintel (2015) survey could provide more than one answer, it is interesting to note how high the proportion of today's car buyers is that fits in the product depletion category; at least 30% cited a product depletion reason as important to their desire to buy a new vehicle.[20] This high level of product depletion matches several other statistics: (1) the average age of the U.S. vehicle fleet in 2013 was 11.4 years (Mintel Group, 2015): (2) Americans in 2011 bought "new vehicles every 6-8 years on average, as compared with every 3-4 years before the recession" (LeBeau, 2012); and (3) the average trade-in vehicle at dealerships in 2011 was 6.5 years old, 1 year older than the 2007 average (Henry, 2012). *Table 3-1* provides more detailed statistics of the average age of U.S. cars, as sorted by the number of cars owned by a given household (in 2009).

[20] This is significantly higher than the Punj and Srinivasan (1992) finding of 19%, although we do not have a perfect basis for comparison.

Table 3-1: 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%			

The bottom row of Table 3-1 provides the percentage of U.S. households with a given number of vehicles in 2010 (which is the closest year to that of the vehicle age-breakdown data (2009) for which we could find overall ownership statistics). Almost 20% of U.S. households have three or more vehicles; as Table 3-2 shows, this is the result of a small but steady percentage increase since 1990. Adding the proportion of households with two vehicles – the highest of the household vehicle ownership categories in 2010, at 37.6%, the same as in 1990 – to the proportion of households owning three+ vehicles, we see that about 57% of U.S. households are multi-car households; the National Academy of Sciences (2015) pointed to this group as possibly constituting a very "favorable PEV market." Single vehicle households, meanwhile, represented 33.8% of U.S. households in 2010, which is the same proportion as in 2000. This is despite an overall growth in the percentage of single-person households in the U.S. during that period; in 2000, single-person households represented 25.8% of U.S. households, but by 2010 they represented 26.7% (U.S. Census Bureau, 2013). Note that the percentage of households owning zero vehicles declined between 2000 and 2010, although the U.S. population continued to grow. This would seem to indicate that more single-person households today own multiple vehicles.[21] This is more likely to be true in less urban areas, however. As depicted in Table 3-2, in general, rural households have more vehicles than urban households, and in several major U.S. cities, the number of households without a vehicle is higher than 25%. According to University of Michigan data reviewed by the National Academy of Sciences (2015), these cities include (as ordered largest to smallest, by population): New York, Chicago, Philadelphia, San Francisco, Detroit, Washington DC, Boston, and Baltimore. Note that these U.S. cities are in the top ten most densely populated U.S. cities, with the exception of Detroit (#16).

[21] Despite being headed by a single person, these households could have children, given that the average number of vehicles for households with children held constant between 1990 and 2010 (see Table 3-2; this is also generally true of vehicles in households without children).

Table 3-2: Household vehicle ownership statistics
Source: Transportation Energy Data Book (2016) Tables 8.5 and 8.8

	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

There is a considerable literature that links household vehicle ownership with variables such as household fleet size, vehicle type, and usage. Anowar et al. (2014a) provides a very useful review of these studies, which they characterize according to four methodological types: (1) exogenous static models that predict vehicle holdings at a particular moment in time; (2) endogenous static models that jointly model vehicle ownership and other decision processes like composition and usage; (3) exogenous dynamic models that consider how vehicle ownership decisions (including disposal) evolve; and (4) endogenous dynamic models that consider both the endogeneity of household fleet size, composition, and usage decisions as well as dynamics associated with the vehicle acquisition process. Of the 83 studies Anowar et al. (2014a) reviews (which have occurred since 1990), the majority: (1) rely on cross-sectional travel behavior surveys; (2) consider vehicle ownership as a static exogenous choice; and (3) consider the exogenous variables of household demographics and the built environment (e.g., land use, urban form, street network attributes, etc.). The impact of transit attributes on the ownership decision process has also become an important exogenous variable in a significant number of studies (32) in recent years. Clark et al. (2016), meanwhile, notes that "panel studies reveal that the number of cars owned is state dependent" with stability associated with ownership in a previous period predicting ownership in a later period (see, e.g., Hanly & Dargay, 2000; Simma & Axhausen, 2003; Thorgersen, 2006). Clark et al. (2016) posits that this may be explained, in part, by habit formation that tends to preclude consideration of alternative travel behaviors, and support this contention via a citation to Verplanken et al. (1997).

Returning to the Punj and Srinivasan (1992) categories, we note that at least 18% of today's car buyers cite a new need as an important reason to initiate a vehicle purchase process, according to Figure 3.2).[22] New need consumers frame their vehicle purchase problem around their life circumstances, rather than around the state of their vehicle. There is an important handful of studies that focus on the relationship between life events and changes to household vehicle ownership (see, e.g., B. Clark, 2012; Dargay & Hanly, 2007; Oakil, Ettema, Arentze, & Timmermans, 2014; Prillwitz, Harms, & Lanzendorf, 2006; Rashidi, Mohammadian, & Koppelman, 2011; Yamamoto, 2008). Fewer studies consider the different types of car ownership level changes (i.e., zero to one, one to two, two to one, one to zero, etc.). Notable

[22] This is higher than the 14% found in Punj and Srinivasan (1992), but the difference is small and error introduced by incompatible methodologies could make the difference even smaller. If the difference could be considered credible, the increase in the new need consumer segment may be tied to the increased proportion of multiple vehicle households since 1992; in 1990, 54.7% of U.S. households had multiple vehicles, as opposed to 57.1% in 2010.

exceptions include: 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; and Clark et al. (2016).

Clark et al. (2016) is distinguished by its focus on types of car ownership level change and a broad range of life events, as well as by the authors' access to a large-n (40,000 household) panel dataset in the United Kingdom in which adult household members are interviewed annually.[23] The authors analyzed two-waves of data on households in England (n=19,334 households), which is a much larger sample than previous studies of car ownership change and life events. Some of the interesting correlations reported in Clark et al. (2016) between car ownership, life events, and spatial context include: (1) changes in household composition and driver's license availability were the strongest predictors of changes in car ownership; (2) households were more likely to give up a car when their income shrank than they were to acquire a car when their income grew; (3) 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; and (4) 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. In general, Clark et al. (2016) is consistent with the framework encapsulated in *Figure 3.3*, which considers how household car ownership relates to: the process through which household members come together (e.g., partnership "formation and dissolution," having children, children reaching driving age, children leaving home, etc.); the life stages of household members; and car ownership needs/desires. According to Clark et al. (2016), exceptions to consistency with *Figure 3.3* (which was drawn from qualitative data in Clark 2012) include: (1) "younger households (16–29) are the most likely age group to experience vehicle relinquishments (1–0 and 2–1 cars)"; and (2) "there is heterogeneity in household car ownership within life-stage groups which is not explained in the models." For this second point, the authors provide the example that "while 85 % of mid-aged (45–59) households with children in the sample own at least one car, 15% of these households do not own a car." The authors explain that although the variation can be partially explained by socio-economics and spatial context, the model fits "imply that there are other factors that play a role—for instance life-style preferences or attitudes."

[23] Another distinction of the data assessed in Clark et al. (2016) is it provides detail on the built and social environment.

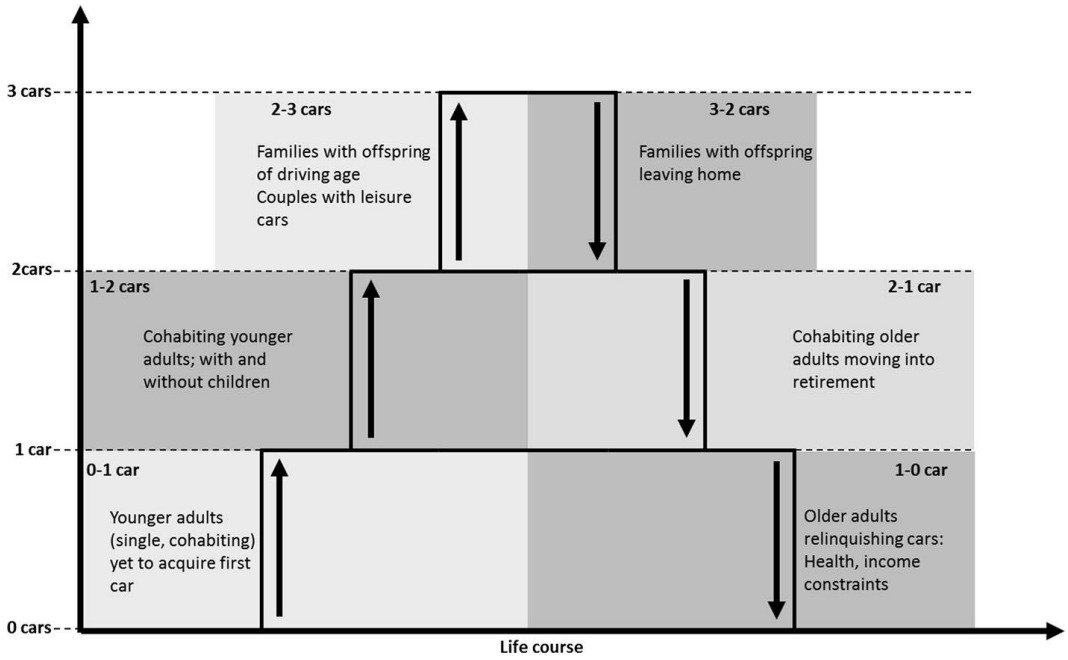


Figure 3.3: Car ownership level changes and the household life cycle
Source: Clark (2012)

What are the implications for the PEV purchase of this discussion of consumer segments that frame their problem recognition step of the vehicle purchase process on either product depletion or new need? First, if the Punj and Srinivasan (1992) findings regarding the product depletion consumer segment hold today, we might expect to see a significant proportion of U.S. car buyers (30%, according to Figure 3.2) considering the smallest number of makes before visiting a dealership, making the smallest number of pre-decisions, and shopping for the smallest number of aggregate models across dealership visits. The proportion of this consumer segment that is replacing a car that won't run is unknown, based on the data presented in this section, but this group of consumers is likely to be under considerable time pressure in the purchase process. They are likely to turn to the more efficient, emotional/intuitive, and prior-experience grounded System 1 mental process, particularly for internal search and alternative evaluation. Reaching these consumers to help them understand the value proposition of PEV ownership would therefore be expected to be difficult without an emotional or experience-based connection to PEVs. It is this segment of consumers that would appear to particularly benefit from a memorable advertisement campaign that appeals to the emotions or from driving/charging experience events.

Second, if the Punj and Srinivasan (1992) finding regarding the new need consumer segment holds today, we might expect to see almost a fifth of U.S. car buyers (18%, according to Figure 3.2) consider the highest number of aggregate models across dealership visits. These consumers would appear to be more likely to engage with the slower, conscious reasoning System 2 mental process that can be appealed to through informative persuasive activities. As in other areas of marketing, these new need consumers could be targeted at different time periods tied to life events; the birth of a child is frequently considered to be an important time for marketers to influence future consumer behavior.

Third, if the Punj and Srinivasan (1992) finding regarding the overall satisfaction of consumers with their purchase decisions, no matter their consumer segment, is any indication, we should not be surprised to see the high levels of consumer satisfaction reported about today's PEVs.

3.2 Search

As noted in Section 2, search, which is the second step of the purchase decision-making process, involves the consumer seeking and integrating information about possible solutions to his or her purchase problem. During the search process, consumers consult both internal sources (i.e., information already in the consumer's mind) and external information sources (e.g., friends and family, third-party reviews, official business sources, direct experiences with products, online resources, etc.). The outcomes of the search process are a list of potential purchase options known as the consideration set and a more informed understanding of the purchase criteria the consumer will use in evaluating the consideration set.

In this section, we assess the literature related to PEV search by considering separately "internal search" – which refers to a consumer's consultation of internal information sources – and "external search" – which refers to a consumer's consultation of external information sources. We found significantly more material related to search than to problem recognition, but most of the PEV-specific literature relates to external search. For this reason, our discussion of internal search draws heavily on the broader consumer behavior and traditionally-fueled vehicle purchase process, as well as on inferences from current PEV research.

3.2.1 Internal Search

As mentioned in Section 2, consumers engage first in internal search and then external search. In purchase decision-making processes that are under time pressure, or in purchases of experience goods, internal search – based on memory, reputation, association, affect, etc. – is particularly important. This can be problematic for the introduction of a new product if, for example, consumers feel that they lack relevant analogous experience with that product or its brand.

In some ways, PEVs are not as hindered by problems associated with internal search as other clean energy technologies. A comparison to residential photovoltaic (PV) systems is illustrative. Compared to potential consumers of PV systems, potential consumers of PEVs have analogous purchase and use experience with traditionally-fueled vehicles and some familiarity with brand distinctions (other than for new automotive entrants like Tesla) that can influence associative networks. This means that potential PEV consumers – in contrast to PV consumers – will have a richer set of internal sources to turn to (in part due to the memory traces left from the emotion of experiencing driving/riding in other vehicles; Szymanski & Henard, 2001), less motivation to conduct external search, more adeptness in conducting external search, and more likelihood of consulting more external information sources (Carroll, 2013). In addition, today's PEVs have previous generations of HEVs and PEVs for which consumers might find experience analogous. Previous research finds that knowledgeability, positive experiences, and satisfaction reinforce PEV purchase decisions (see, e.g., N. D. Caperello & Kurani, 2012; Giffi, Joe Vitale, Drew, Kuboshima, & Sase, 2011; Golob & Gould, 1998; Idaho National Laboratory, 2015; Rauh, Franke, & Krems, 2014).

The comparison that consumers make between traditionally-fueled vehicles and PEVs, however, can have contradictory implications. On one hand, the more a PEV is perceived by a consumer to be like a traditionally-fueled vehicle, the more the sticker price disadvantage of PEVs stands out,

especially since the financial incentives for PEVs and countervailing financial benefits of PEVs are not well known.[24] See, for example, Ingram (2013), which states that 75% of people in 21 of the largest U.S. cities were unaware of the fuel cost and maintenance cost savings of PEVs, or Kurani et al. (2015), which finds limited consumer awareness of PEVs, electric drive range, charging infrastructure, and incentives. On the other hand, the less a PEV is perceived to be like a traditionally-fueled vehicle, due to its fueling infrastructure, range limitations, etc., the riskier its purchase is likely to seem to a consumer, whether the potential negative consequences of the purchase are perceived as financial or psycho-social. Riskier purchases tend to inspire higher consumer involvement in the product purchase, with consumers spending considerable time and effort in information search as a risk management strategy. Recall that automobile purchases are already typically a high involvement purchase, due to the cost and infrequency of purchase, as well as the high social visibility of the purchase. Time pressures work against risky purchases. As mentioned in Section 2, lack of time can increase emphasis on intuitive mental processes grounded in familiar experience, versus conscious reasoning processes which are more volatile and open to new products. In addition, if a risky product is rapidly evolving, there will be consumer pressure to "wait-and-see" how the product evolves rather than regret making an investment in it.

Survey data is unclear on whether consumers, in their internal search processes, look at PEVs as substitutes for traditionally-fueled vehicles or as new products. NAS (2015) reports on a Pike Research (2012) study that found that 55% of vehicle shoppers had "favorable" or "very favorable" impressions of PEVs (a decline from 62% in 2009), despite much lower purchase rates. Singer (2015) also finds that a relatively high percentage of consumers (52%) said that PHEVs were "'just as good or better than' traditional ICEs," with a similarly high percentage (45%) saying the same for BEVs. Singer (2015) also finds that 48% of survey respondents can name a specific PEV make and model and 49% report having seen PEVs in parking lots (see *Table 3-3*). However, more than 40% of respondents believed they had never been in or near a PEV and very few (18%) were aware of charging stations on their regular driving routes. In addition, only 20-24% of respondents said they were likely to consider a PEV for their next vehicle purchase.

The indication in *Table 3-3* that 52% of consumers are unfamiliar with PEV makes and models implies that these consumers have limited internal information sources for a PEV purchase, outside of analogy to non-PEV vehicles and brands. As consumers typically weight internal information and information from friends, family, and other consumers highly, it is worth considering how the spatial context of PEV diffusion might matter to internal information search. Anowar et al. (2014b) cites Adjemian et al. (2010) regarding how a consumer's decision of vehicle type might be heavily influenced by a neighbor's choices, and provides analogous references regarding the neighborhood diffusion of hybrid electric vehicles (Chan, Miranda-Moreno, Patterson, & Barla, 2011; Paleti, Bhat, Pendyala, & Goulias, 2013). Although consulting a neighbor is more typically considered an example of an external source of purchasing information, the simple act of seeing PEVs on the road, parked in neighbors' driveways, etc., can be an internal information source somewhat akin to the purchase reminders prompted by product shelf placement.

[24] See discussions in Alternative Evaluation and Purchase, below.

Table 3-3: Consumer knowledge regarding PEV availability and performance
Source: Singer (2015)

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

3.2.2 External Search

Figure 3.4 depicts the popularity of several external information sources that consumers consult to inform their vehicle purchase decisions. In the next three sub-sections, we discuss how three of the more popularly consulted external information sources – test drives, *Consumer Reports* ratings, and personal recommendations – relate to PEVs. In the fourth sub-section, we discuss various PEV-specific online sources of information.

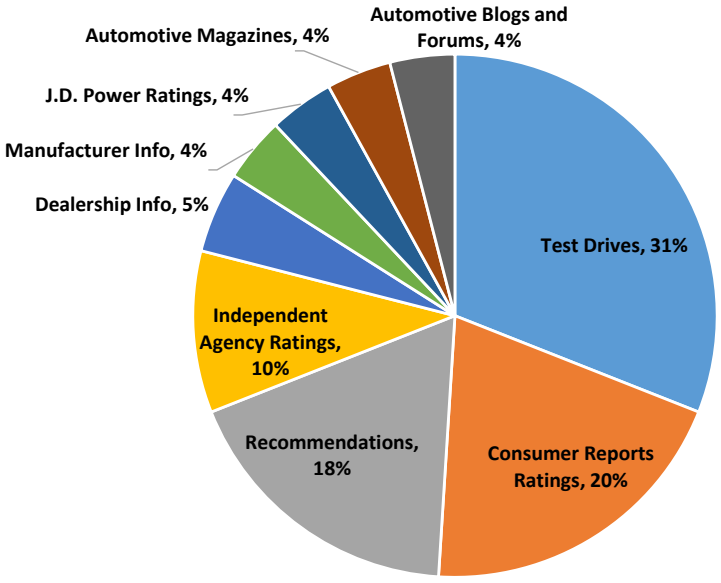


Figure 3.4: External information sources consumers consult in vehicle purchase
Source: Adapted from the Emprecis Blog (2011)

3.2.3 External Search Resource: Test Drives

Test drives are an important source of external information for potential PEV buyers, as they are for all consumers. But the utility of test drives as an experiential external information source for PEVs has been questioned, given that the consumer is unable to experience the charging process

that most distinguishes a PEV from a traditionally-fueled vehicle. In an academic stated choice experiment, direct experience with BEVs, as implemented in the form of a three-month trial, significantly increased consumer preference for the vehicles (see, e.g., Jensen, Cherchi, & de Dios Ortuzar, 2014). Manufacturers have also conducted test drives and experiential opportunities to test their PEVs over multiple months. General Motors (GM), for example, did this for the EV1 in the 1990s and more recently, has worked with the Department of Energy to place Chevy Volts in the fleets of public utilities for months-long trial periods (see, e.g., Francfort et al., 2015). GM has also conducted test drives of shorter duration that still exceed the length of a typical dealership test drive (see NAS 2015 discussion of GM's 3-day test drives for Chevy Volts).

As will be discussed later, PEVs are unevenly distributed amongst U.S. dealerships, with many dealerships having few or no PEVs, even in states that follow the California Zero-Emission Vehicle mandate (see, e.g., Cahill, 2015). This makes it difficult for a consumer to be able to rely on access to the experiential information provided by a test drive at a dealership with any given brand of manufacturer. Manufacturers, government agencies and non-profits, such as Plug-In America, have been experimenting with other ways to offer potential consumers a test drive experience. These include: PEV "ride-and-drive" events at corporate campuses, malls, etc.; regional "experience centers"; providing regional pools of a wide range of test cars for dealers to have access to; and introducing PEVs into corporate, government, rental, and point-to-point car-sharing fleets.[25] For more information, see NAS (2015), Cahill et al. (2014) and Sierzchula (2014).

One concern about these experimental approaches to providing consumers with experiential information about the PEV driving (and charging) experience, however, is how the results of the experiments are analyzed. We were unable to find studies that assessed these experiments with the techniques associated with evidence-based policy-making (e.g., randomized control trials, etc.). We believe that such assessment, as well as more transparency in these experiments, would make it possible for the industry to improve its provision of high quality experiential information regarding PEVs.

3.2.4 External Search Resource: *Consumer Reports* Ratings

Figure 3.4 shows that the ratings provided by the *Consumer Reports* magazine published by Consumers Union, a non-profit organization founded in 1936, are the second most common external information source turned to by car buyers. *Consumer Reports* scores are also "the most commonly used measure of objective quality in the consumer behavior literature" (Langhe, Fernbach, & Lichtenstein, 2016a). Consumers Union conducts rigorous scientific testing of products, including automobiles, which it buys itself. Accepting no advertising, and relying for its revenue on donations, subscriptions (on the order of 7 million), and a "paywall" for its online

[25] According to NAS (2015), vehicle fleet sales comprise 20-22% of the U.S. market, with rental car companies the most prominent buyer (~80% of fleet purchases) and governments one of the smallest (~4%). Rental car companies appear to provide a significant potential experiential information opportunity, but they often have a limited selection of PEVs which they charge higher rental rates for, in part due to uncertainty about a customer's driving range and ability to charge the vehicle, but in part due to uncertainty about resale value. (El-Moursi 2013). The federal government might potentially move the market for PEVs, to some extent, given that it is the largest fleet operator in the U.S., with 640,304 vehicles in FY2015, according to the 2016 Federal Fleet Report. Despite the cost savings associated with PEVs, however, the federal fleet only owned 4,656 plug-in hybrid and battery-electric vehicles at the time of the 2016 Federal Fleet Report.

ratings, Consumers Union's budget for product testing is on the order of $25 million (Hiebert, 2016). This financial arrangement has helped maintain Consumers Union's reputation for independence and quality, which is very important for a number of reasons, including the reliance on System 1 mental processing by a large number of consumers, whether due to the time pressure of a purchase, the nature of the good to be purchased (i.e., search, experience, or credence), etc. We note that there is, however, growing consumer trust in other online reviews that can be categorized as word-of-mouth or aggregations of word-of-mouth reviews, and there has recently been a lively academic debate about the quality associated with these word-of-mouth reviews that has raised interesting comparisons between the vehicle ratings of Consumer Reports and J.D. Power, as well as general comparisons with word of mouth reviews (see, e.g., Kozinets, 2016; Langhe, et al., 2016a; Langhe, Fernbach, & Lichtenstein, 2016b; Simonson, 2016; Winer & Fader, 2016).

Regarding PEVs, *Consumer Reports* and other sources of automobile ratings provide useful information about cost, quality, etc. But we are concerned about possible framing effects associated with the organization of that information. We note that *Consumer Reports*, *Ward's Automotive*, and similar resources tend to present information on vehicles in the order of traditionally-fueled vehicles first – arranged by smallest to largest – with PEV information presented last. This has the potential to reinforce consumer perceptions that PEVs are very different from other vehicles, and therefore riskier purchases. See Appendix B for an example of *Consumer Reports* PEV ratings.

3.2.5 External Search Resource: Personal Recommendations

As mentioned above, consumers tend to place high weight on word-of-mouth information from friends, family, and other consumers (see, e.g., Herr, Kardes, & Kim, 1991; Rosen, 2009; Michael Solomon, 2013). The importance of personal recommendations to prospective car buyers is somewhat problematic for PEVs given the low number of PEVs on the road. According to the *Transportation Energy Data Book*, HEVs fell to 2.2% of U.S. LDV sales in 2015, while PEVs – which were only approved for highway driving in 2010 – account for only 0.7% U.S. LDV sales (Davis, Diegel, & Boundy, 2015). Also, as mentioned above in the discussion of test drives, PEVs are not evenly distributed for sale across the U.S. The two panels in *Figure 3.5* demonstrate how this uneven distribution of vehicles for sale has translated to the density of HEVs and BEVs on the road in the U.S. Especially for BEVs, there are vast swaths of the U.S. that have very low density of vehicles on the road, which can affect the likelihood of personal recommendations and the prompting of curiosity about the cars.[26]

[26] Some, but not all, of this lack of density mirrors the lack of density of traditionally-fueled vehicles in these areas. Anowar et al. (2014) considers the mechanisms through which the decisions of neighboring households can affect PEV diffusion. "If the neighbors own and drive hybrid electric vehicles, that household might become more environmentally conscious and purchase a hybrid electric vehicle (Chan et al., 2011; Paleti et al., 2013). Spatial interdependence might also arise from unobserved attitudinal preferences such as peer pressure from social networks (Axsen & Kurani, 2012)."

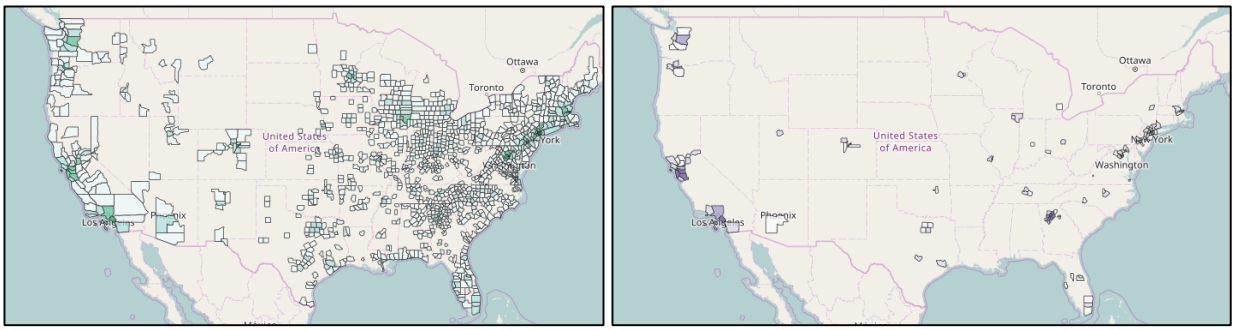


Figure 3.5: (a) HEV density in U.S.; (b) BEV density in U.S.
Source: Alternative Fuels Data Center Transatlas, March 2017.

A great deal of the sustainable transportation literature focuses on simulating PEV diffusion through neighborhood effects and choice modeling (see, e.g., Axsen, Mountain, & Jaccard, 2009; He, Wang, Chen, & Conzelmann, 2014; Maness, Cirillo, & Dugundji, 2015; Mau, Eyzaguirre, Jaccard, Collins-Dodd, & Tiedemanna, 2008; Zhu & Liu, 2013). Considering the highly uneven spatial distribution of PEVs, however, it might be valuable to investigate in greater detail the role of online – rather than offline – reviews and "virtual communities of consumption" with respect to PEV sales (Kozinets, 1999). Online user reviews have growing influence in consumer search (see, e.g., Chevalier & Mayzlin, 2006; Luca, 2011; Ye, Law, & Gu, 2009) and consumer behavior researchers have been using them for many years to better understand a wide range of topics, including how ratings affect demand (see, e.g., Archak, Ghose, & Ipeirotis, 2011; Chintagunta, Gopinath, & Venkataraman, 2010; Godes & Mayzlin, 2004; Moe & Schweidel, 2012; Senecal & Nantel, 2004). As a result of this research activity, a number of techniques have been developed (see, e.g., the practice of ethnographic research over the internet, as described in Kozinets, 2010) that could be leveraged to provide insight into the effects of and influences on the recommendations of online contributors to PEV-specific sites, such as the Prius Owners Group, PriusChat.

3.2.6 External Search Resource: Internet Sources of PEV Information

Generalizing from personal online reviews/ratings to other internet sources of information, we found two articles that were particularly helpful regarding online information and external search in the automobile purchase context. First, Ratchford et al. (2007) used field surveys of new car buyers in 1990, 2000, and 2002 to determine how internet sources of vehicle information fit into consumer search strategies. One of the study's more significant findings was that internet search substitutes for time spent at dealerships, including time spent negotiating prices. Online sources of information also substitute for print information from independent third-parties. Although the notion that the online version of *Consumer Reports* might trump the print version, as mentioned above, there is recent academic literature that raises concerns about how online peer reviews are growing at the expense of online *Consumer Reports* results, despite revelations that online reviews tend to more favorably review more expensive products and premium brands (Langhe, et al., 2016a). Second, Klein and Ford (2003) explored (drawing from Stigler, 1950) the implicit cost-benefit analysis consumers use to choose a search strategy in the vehicle purchase context. The authors explain that evaluation of consumer search efforts "leads to the inference that consumers perceive search costs to be quite high or alternatively, that the value of search is quite low." Measured in terms of amount (time) and breadth (number of sources), Klein and Ford (2003) found an inverted-u relationship between automobile knowledge and total time spent in

search. The study also found a positive relationship between both subjective expertise and education and the breadth of online search. Consumer satisfaction with the search process was not driven by the amount of search but by awareness of the consumer's own inefficiencies conducting online search.

In the PEV-specific literature, NAS (2015) provides a very comprehensive listing of internet resources for information on PEVs, which we replicate in Appendix B. These disparate websites provide considerable information on PEV purchase, operations, and the overall ownership experience. Note that of these resources, NAS (2015) found the Alternative Fuels Data Center and the DOE Clean Cities website to be particularly valuable, and the report includes suggestions on how to ensure that they appear as high as possible in search results.

3.3 Alternative evaluation

The third step of the purchase decision-making process, alternative evaluation, involves the consumer assessing the objective and subjective characteristics of the consideration set (i.e., the list of potential purchase options that emerged from search). In making this assessment, the consumer applies a unique set of decision rules which weigh product attributes based on criteria derived from search. These decision rules are characterized as "compensatory" if they involve trade-offs between criteria and "non-compensatory" if the consumer considers them to be non-negotiable. The outcomes of alternative evaluation are three sets of products: an evoked set (i.e., products which the consumer is willing to purchase), an inept set (i.e., products which the consumer is not willing to purchase), and an inert set (i.e., products which the consumer is indifferent between).

Many studies in the vehicle purchase and sustainable transportation literatures relate to alternative evaluation. These include stated preference studies that elicit the objective and subjective vehicle characteristics that consumers value and provide insight into the decision rules consumers expect to apply to a purchase decision. Other studies focus on consumer preferences as revealed in actual purchase decisions. Here we first discuss alternative evaluation in the context of general light-duty vehicle (LDV) purchases, then assess PEV-specific data and literature.

3.3.1 Evaluating General LDVs

T*able 3-4* presents the results of a regularly repeated consumer survey of the importance consumers place on five vehicle attributes which the DOE reports on in its *Vehicle Technologies Market Report*. These five attributes – vehicle price, fuel economy, safety, dependability, and quality – are presented in the table with the most objective attributes to the left and the most subjective attributes to the right. We group together the first two attributes, vehicle price and fuel economy, because of the stability and transparency of the information sources that make it possible for consumers to assess them. In both cases, stickers on the vehicles provide reliable information as an outcome of government policy.[27] The other three attributes, safety, dependability, and quality, are ordered by the reverse degree to which personal and post-purchase experience is needed so that consumers can assess them. Although all three attributes are at least partially dependent on how a vehicle performs with use, third party organizations, word-of-mouth, and online reviews can aid assessment of each, to varying degrees. Safety data,

[27] See, in particular, the Automobile Information Disclosure Act of 1958. The sticker contains the reference point of the Manufacturer Suggested Retail Price (MSRP), which bargaining often builds upon at dealerships.

for example, is often provided by government and non-governmental organizations (e.g., *Consumer Reports*) after these organizations conduct test crashes. Similarly, vehicle dependability is captured in large-n surveys that *Consumer Reports* conducts of its readership over the first five years after purchase; it also often comprises at least part of the content of online reviews. Quality assessment, however, has both objective elements (e.g., apparent workmanship) and subjective elements (e.g., design aesthetics) that can make third-party information appear imperfect to consumers.[28]

T*able 3-4:* Most important vehicle attributes and gasoline prices in select years.
Sources: DOE *Vehicle Technologies Market Report* Figure 18, DOE *Transportation Energy Data Book* Table 10.03, EIA Retail Gasoline Prices: https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.html

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
2016	9% (5)	15% (4)	24% (2)	33% (1)	19% (3)	2.25

The data contained in T*able 3-4* are notable for several reasons. First, as a proxy for the intensity of the consumer salience of an attribute, we highlight in red any cell in which more than 30% of consumers consider the vehicle attribute to be important and highlight in blue any cell in which less than 10% of consumers consider the vehicle attribute to be important. In the nineteen years for which data are presented, the 30% and above importance threshold is reached by: dependability in 13/19 years; vehicle price, fuel economy, and safety each in 2/19 years, and quality in 0/19 years. Meanwhile, the 10% and below importance threshold is reached by: price in 7/19 years, fuel economy in 4/19 years, quality in 3/19 years, safety in 2/19 years, and dependability in 0/19 years (in fact, dependability is always considered important by at least 22% of consumers).

[28] See Kumar and Noble (2016) on the value of product design. See Townsend and Sood (2012) on the "aesthetics premium" on consumer goods. See Heffner et al. (2006) on the symbolic meaning consumers assign to their automobiles.

Second, we provide the relative rank of the attributes in each year, in parentheses. This highlights the fact that consumer preferences regarding vehicle attributes appear to be generally stable, with: (1) vehicle dependability almost always the most important attribute (16/19 years); (2) safety often the second-most important attribute, particularly beginning in the 1990s (10/19 years); (3) quality often the third-most important attribute (10/19 years); and (4) price often the least important attribute, particularly beginning in the 2000s (10/19 years). The vehicle attribute that exhibits the most volatility in consumer perception over time, however, is fuel economy. Its distribution of relative rank order is as follows: (1) most important in 4/19 years; (2) second-most important in 3/19 years; (3) third-most important in 4/19 years; (4) fourth-most important in 3/19 years; and (5) least important in 5/19 years.

Third, the final column of T*able 3-4* presents the U.S. gasoline price in constant 2015$. Here, we highlight in red the six cells that exceed a threshold of $3.50 per gallon in constant 2015$ and highlight in blue the six cells that are below a threshold of $2.50 per gallon in constant 2015$ dollars. In the six years of high (>$3.50 per gallon) gas prices, fuel economy reached both of its 30% and above importance threshold moments (these were not the years with the overall highest gasoline prices). All of fuel economy's number-one relative rankings against the other vehicle attributes occurred during those six years, and two of its three number-two rankings also occurred during those years. In the six years of low (<$2.50 per gallon) gas prices, fuel economy reached three of its four 10% and below importance threshold moments. Four of its five least important relative rankings occurred during those years, as did two of its three fourth-most important relative rankings and one of its four third-most important relative rankings. Although nothing can be said definitively from these patterns, there is an indication here that gasoline prices might correspond more closely with consumer sentiment toward vehicle fuel economy when prices are high rather than when prices are low. It might be worth a more in-depth study to get a better sense of the shape of this relationship given that researchers often use oil prices to proxy the importance of energy to the public.

It might also be worth conducting a more detailed comparison of the five vehicle attributes DOE regularly collects consumer perception data on with those reported on in other studies. For example, NAS (2015) points to a Strategic Vision (2013) study of new vehicle owners which has approximately 300,000 respondents and a more disaggregated set of favorable vehicle attributes that contributed to consumer purchase decisions. In that study, the top five vehicle attributes were reliability, durability, quality of workmanship, value for the money, and manufacturer's reputation. Fuel economy was reportedly ranked lower in importance than reliability (a primary consideration for 45% rather than 68% of respondents), although we expect that that ranking is not stable over time.

3.3.2 Evaluating PEVs

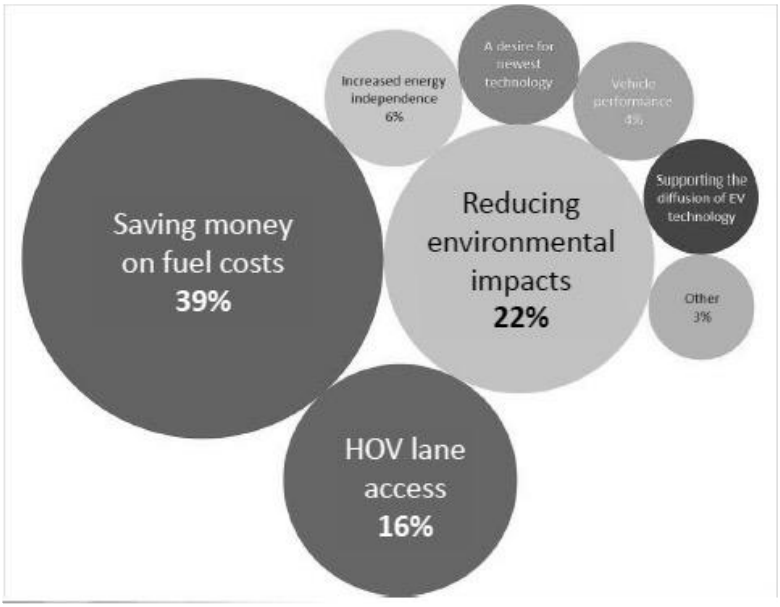
In the introduction to this report we discussed the benefits PEVs provide both to consumers and to the public at large. When compared to most traditionally-fueled LDVs, the benefits of PEVs to consumers include: (1) economic value (they are often inexpensive to fuel[29] and maintenance costs are low thanks to fewer parts and longer-lasting consumables like brakes, etc.); (2) impressive vehicle performance (e.g., smoother operation, better acceleration, improved handling with a lower center of gravity due to battery weight); and (3) the convenience of being able to fuel the vehicle at home. Benefits to the public at large include zero tailpipe emissions when the

[29] This depends on use and electricity prices.

vehicle operates solely on its battery and a contribution to national energy independence. In the introduction, we also discussed the speed with which PEVs have improved since 2001, when Garling and Thøgersen listed major concerns about PEVs. These concerns related to high prices, limited driving range, long battery recharge, low speed and acceleration, and a lack of charging infrastructure, all of which contributed to PEVs being perceived as poor substitutes for traditionally-fueled LDVs at the time.

Whether consumers understand these benefits or perceive that there are problems with the cars akin to those in the early 2000's is an open question. *Figure 3.6* tries to help address this question by presenting survey results regarding how consumers currently evaluate PEVs when they decide either to purchase or reject them. In the first panel of *Figure 3.6* we present a graphic converted from Santulli (2015) which provides the major reasons for PEV acquisition that consumers in California give when they submit paperwork to claim the state's financial incentive for vehicle purchase. These reasons can be characterized as: fuel cost savings (39%), contribution to environmental and energy policy goals (22%+6%), policy incentives (16%), vehicle performance (4%), and the combined reasons of "a desire for the newest technology," "supporting the diffusion of EV technology," and "other" (13%). Santulli (2015) points out that these reasons for purchase vary spatially, to some extent, even within California (e.g., fuel costs are more important in more rural areas of the State, while HOV lane access is more important in urban centers).

(a)



(b)

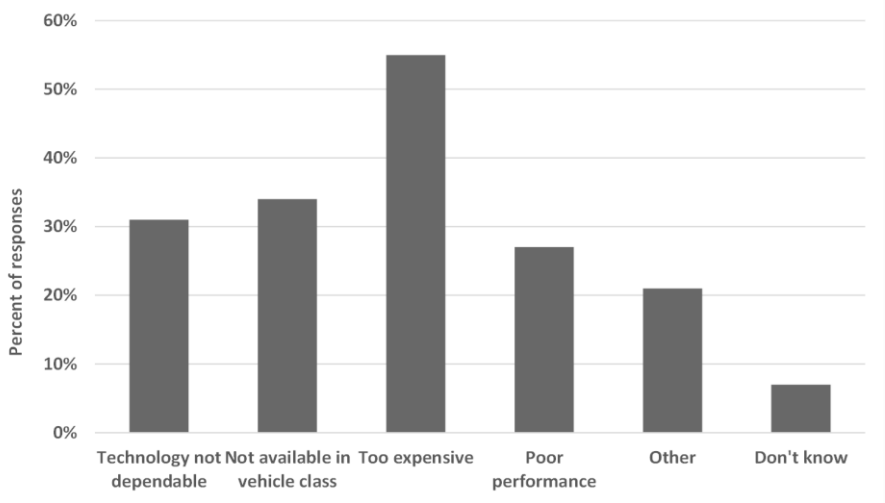


Figure 3.6: (a) Reasons for acquiring PEV in CA, 2014. (b) Reasons for rejecting PEV, 2015. *Sources:* Santulli (2015) and Singer (2016)

Comparing the overall set of reasons for PEV purchase to those listed in T*able 3-4* and in the Strategic Vision study mentioned in the sub-section above on evaluating general LDVs, we note that a number of the top-rated reasons why people buy LDVs, in general, are missing from the list of reasons why people buy PEVs (i.e., dependability, safety, price, quality, reliability, and manufacturer reputation). Two of the objective benefits of PEVs are also missing from the list of reasons why people buy PEVs, namely maintenance cost savings and the convenience of at-home charging. There are at least three possible interpretations for this: (1) the survey researchers aren't asking the right questions in the right ways; (2) consumers are rejecting PEVs if they are particularly interested in vehicles that are dependable, safe, inexpensive/good value, high quality, reliable, and made by manufacturers with a strong reputation; and/or (3) consumers are not aware of the specific benefits of PEVs, such as maintenance cost savings and the convenience of at-home charging, or are unaware of how favorably PEVs compare to LDVs with respect to acceleration and how smoothly they operate.

In the second panel of *Figure 3.6* we present a graphic converted from Singer (2016), which provides the major reasons consumers offer for rejecting the purchase of a PEV. In order, these reasons are: price, variety/availability, dependability, performance, and other/don't know. Comparing these reasons to those listed in T*able 3-4* and in the Strategic Vision study mentioned in the previous sub-section on evaluating general LDVs, we note that two of the top-rated reasons why people buy LDVs are included on this list of reasons why people *reject* PEVs, namely dependability and price. In what might be a good sign of consumer recognition of technological progress in PEVs, however, most of the Garling and Thøgersen (2001) concerns about PEVs, other than price, are missing from the list of reasons why people reject PEVs.[30] Finally, we note that performance is listed as both a reason for PEV purchase *and* a reason for PEV rejection in *Figure 3.6*; further investigation is necessary to better understand this.

In *Table 3-5* we go beyond individual survey results regarding PEV acquisition and rejection to catalogue a broad (but not exhaustive) set of academic studies that relate to how consumers

[30] On the other hand, Pike Research (2012) reports that "favorable" or "very favorable" impressions of PEVs declined between 2009 (62%) and 2012 (55%).

evaluate PEVs. We note that the academic literature tends to include more subjective reasons for PEV acquisition/rejection (e.g., what a vehicle communicates to others about its owner, what a vehicle reflects to the consumer about his/her self-perception, etc.) than the surveys in *Figure 3.6*, which tend to focus on objective vehicle attributes. *Table 3-5* is ordered to roughly match the priority given to reasons for PEV acquisition and rejection in *Figure 3.6*. We attempt to present the reasons given for PEV acquisition/rejection in a similar format, either focused on a characteristic of the technology or of the consumer.

Table 3-5: Studies covering reasons for PEV acquisition and/or rejection in *Figure 3.6*.

Reasons for PEV Acquisition	**Reasons for PEV Rejection**
Vehicle operating cost savings • **Fuel cost savings**: Santulli (2015), (Ingram, 2013); • **Maintenance cost savings**: (Ingram, 2013); • **Monetary savings**: part of Ozaki and Sevastyanova (2011a) Factor 5[31]	High price of vehicles • NAS (2015); Singer (2016)
Consumer contribution to societal/policy goals • **Environmental benefits**: Santulli (2015), (Krupa et al., 2014), Ozaki and Sevastyanova (2011) Factor 1[32] • **Supporting the diffusion of EV technology**: Santulli (2015) • **Energy independence**: Santulli (2015); Ozaki and Sevastyanova (2011) Factor 4[33]	Lack of variety/availability of vehicles • NAS (2015); Singer (2016); (T. Stephens, 2013; J. Voelcker, 2013; J. Voelcker, 2014)
Consumer receives policy incentives • **Financial incentives**: Ozaki and Sevastyanova (2011) Factor 5 (see footnote 31); Gallagher and Muehlegger (2011); Ingram (2013) on sales versus income tax credits; Sierzchula, Bakker et al. (2014); Lawrence (2015) • **Non-Financial incentives**: Wolf et al. (2015) on city zones; Santulli (2015) on HOV lanes; Ozaki and Sevastyanova (2011) Factor 4 (see footnote 33)	Dependability • **Vehicle, battery dependability**: NAS (2015); Singer (2016) • **Vehicle range**: NAS (2015); (Bonges III & Lusk, 2016; Bunzeck, Feenstra, & Paukovic, 2011; Daziano, 2013; Lin, 2014; T. Stephens, 2013)
Vehicle performance • **Vehicle performance**: Santulli (2015); (Cahill, et al., 2014) on "Peppy" drive, smooth acceleration, quiet, PEV SUVs maintain good towing capacity. Electric motors are about three times as efficient as gasoline engines.	Vehicle performance • Singer (2016)
Other • **Consumer desire for newest technology**: Santulli (2015)	Other • **Vehicle battery costs are high**: (Hidrue, Parsons, Kempton, & P.Gardner, 2011)

[31] With financial policy incentives, Factor 5 explains 6% of the variation in Prius buyer motivations in the U.K. See Appendix B for more detail.
[32] Factor 1 explains 22% of the variation in Prius buyer motivations in the U.K. See Appendix B for more detail.
[33] With personal energy price certainty and non-financial policy incentives, Factor 4 explains 8% of the variation in Prius buyer motivations in the U.K. See Appendix B for more detail

Reasons for PEV Acquisition	Reasons for PEV Rejection
• **Consumer's status is enhanced**: Ozaki and Sevastyanova (2011)[34] Factor 2; Saxton and Saxton (2014) • **Consumer's self-perception is enhanced**: Ozaki and Sevastyanova (2011)[35] Factor 3 • **Consumer is protected from energy price fluctuations**: Ozaki and Sevastyanova (2011) Factor 4 (see footnote 33) **Consumer perceives several instrumental, hedonic, symbolic attributes of vehicles**: Schuitema et al. (2013)	• **Consumer uncertainty about the technology**: (Egbue & Long, 2012) • **Consumer discounting of future fuel cost savings**: (Hidrue, et al., 2011) • **Consumer uncertainty about resale value**: (Lin, 2014; Zhou, Santini, Stephens, & Ward, 2016) • **Consumer difficulties in determining the "greenness" of the vehicle**: NAS (2015) • **Consumers do not understand the benefits of the vehicle**: NAS (2015) • **Consumers lack policy incentive information**: NAS (2015); Ingram (2013) • **Consumers are unfamiliar with charging and the complexities of installing home charging**: NAS (2015) • **Consumers place a wide range of values on fuel economy**: (Greene, 2010; Thomas S. Turrentine & Kurani, 2007) • **Consumer social and cultural values, business practices, and political interests are negatively associated with purchase**: Sovacool and Hirsch (2009) • **Consumers expect that imminent technological innovation will render current models obsolete**: Graham-Rowe et al. (2012)

In this broader literature, just as in the surveys presented above, we see no focus on consumer perceptions of some of the leading reasons for general LDV purchase, namely vehicle safety, quality, and manufacturer reputation. Meanwhile, both in the broader PEV-specific literature and in the PEV acquisition/rejection surveys we see an emphasis on price that is higher than that given by consumers in shopping for general LDVs and an emphasis on dependability/reliability that is lower than that given by consumers in shopping for general LDVs.[36] Finally, we see no research on how consumers perceive the convenience of at-home charging, with the charging-related PEV literature focused on charging as a barrier, rather than an incentive, to purchase.

Here we provide additional background information on some of the stated reasons for consumer rejection of PEVs provided in *Figure 3.6* and *Table 3-5*. We focus here on PEV price, model availability, the range needs and anxieties of consumers, and the resale value of cars (as discussed in de Langhe et al. 2016a, resale value is often used as a proxy for vehicle reliability). First, we see from *Table 3-6* that there are 23 2017 PEV models currently offered for sale in the U.S., according to *Consumer Reports*. Most of these models fall within the price deciles of the

[34] Factor 2 explains 16% of the variation in Prius buyer motivations in the U.K. See Appendix B for more detail.
[35] Factor 3 explains 13% of the variation in Prius buyer motivations in the U.K. See Appendix B for more detail.
[36] Our placement of the sizable literature on PEV range anxiety in the category of vehicle dependability increases the emphasis on dependability in Table 3-5.

majority of new cars sold in America in 2014, according to the DOE's *Vehicle Technologies Market Report* and *Car and Buyer Magazine* listings of MSRP. We note that the average price of a new car in the U.S. in 2015 was $24,355, according to the DOE *Transportation Energy Data Book*, and 7/23 2017 PEV models fit in that price range.

Table 3-6: Price range of 2017 PEVs in U.S. compared to sales of all LDVs in price range *Source: Consumer Reports (2014), Car and Buyer (2014), DOE Vehicle Technologies Market Report (2016).*

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

The 23 2017 PEV models currently offered for sale is a high-water mark for model availability. As depicted in *Figure 3.7*, electric vehicles represent a small but growing percentage of the number of LDV models offered for sale in the U.S. There is considerably more model availability for other alternative-fuel vehicles, especially those that are powered by ethanol (E85; 66 2016 models) and Compressed Natural Gas (12 2016 models).

Regarding the range needs of consumers, several academic studies of typical travel behavior using traditionally-fueled LDVs find that today's PEVs are objectively more than sufficient for most trips. For example, Khan and Kockelman (2012) find that 50% of one-vehicle households and 80% of multiple-vehicle households in Seattle, WA could meet their travel needs with a 100-mile range BEV. Similarly, Tamor and Milačić (2015) find that a BEV with 60-mile range would serve the needs of 90% of two-car households in the Puget Sound region. In less regionally-specific research, a large 2009 investigation of trip lengths by travel purpose finds that mean trip lengths for a variety of purposes (e.g., work commute, shopping or errands, travel to/from school, etc.) are in the range of 5 to 25 miles, well within the capabilities of many PEV models (Federal Highway Administration, 2011a; Plötz, Jakobsson, Sprei, & Karlsson, 2014; T.S. Turrentine, Garas, Lentz, & Woodjack, 2011; Williams, Martin, Lipman, & Kammen, 2011).[37] The general distribution of trip length has been characterized as 71% of trips are 10 miles or less in length and only 1% of trips cover greater than 100 miles (Federal Highway Administration, 2011b; NAS 2015; Smart, 2014b).

Range *perceptions* are more important to BEV-sales than are objective range needs (Franke & Krems, 2013a). Related research includes studies of how consumers construct their vehicle range criteria for evaluating vehicles in purchase decisions, with Franke et al. (2012) finding that

[37] Overall mean trip distance is slightly less than 10 miles in this study.

people base this on their most recent long trip, rather than everyday driving behaviors. Numerous studies consider how experience with PEVs changes the consumer perception of their range criteria. Shaheen et al. (2008) reports that high levels of PEV exposure lead to more realistic range expectations. Franke et al. (2012) finds that range anxiety decreases as drivers adjust to driving EVs over a 6 month period. Rauh et al. (2014) finds that experienced EV drivers had a lower threat appraisal, higher self-confidence, and less range stress. But Nilsson (2011) finds that range anxiety can increase as well as decrease with experience, and is heavily dependent on the personal traits of PEV drivers.

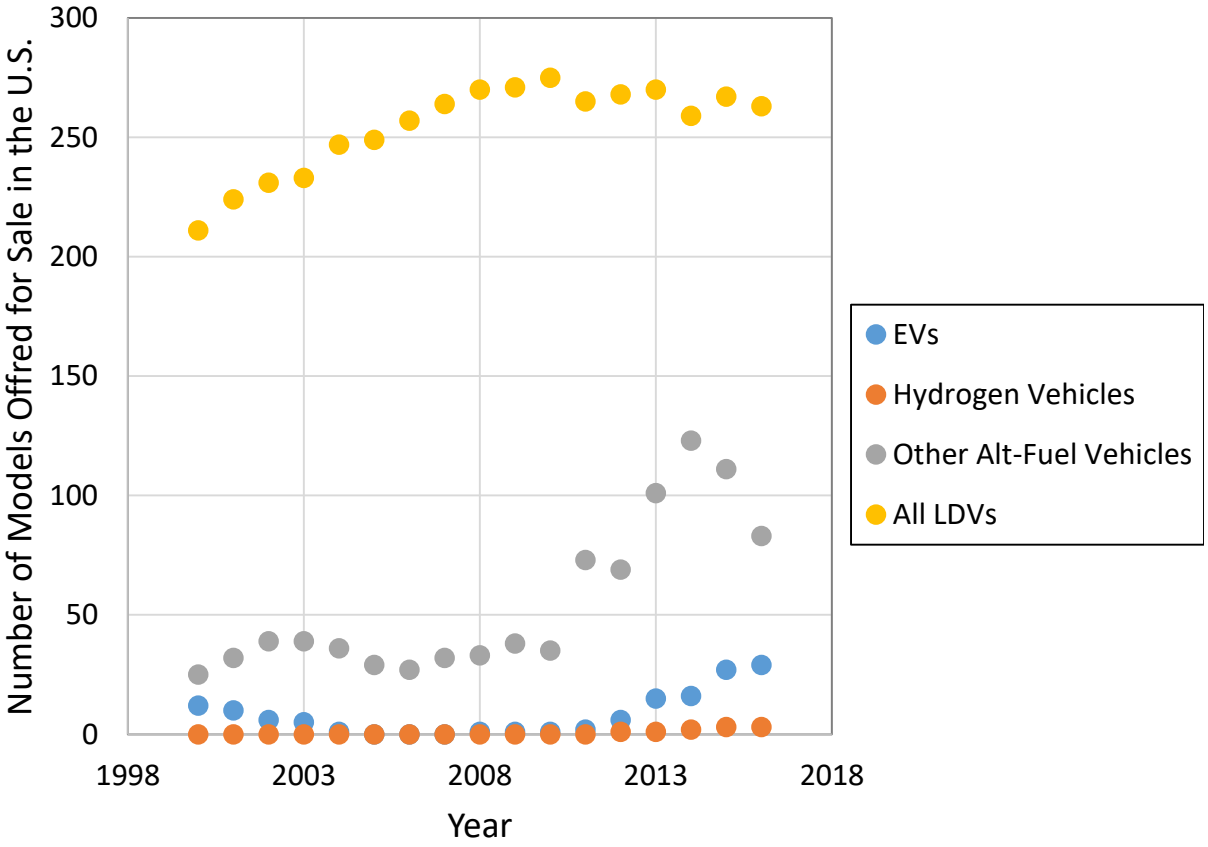


Figure 3.7: Number of models offered for sale in the U.S. by type
Source: Transportation Energy Data Book Table 6-8, Statista.

The resale value of PEVs is a concern for consumers in evaluating vehicles, both for future financial considerations and, perhaps more importantly, for what they signal about vehicle reliability. As PEVs were only certified for highway driving in 2010, there is little information on PEV resale value, to date, so the resale value of non-plug-in HEVs is the closest approximation of what might happen with PEVs. HEVs have historically depreciated at lower rates than most types of ICE vehicles, particularly during periods of high gas prices. The *Consumer Reports 2016 Annual Auto Survey* (2016) indicates very good reliability for HEV batteries and lists 16 used hybrids as "Good Bets," one of which includes the PHEV version: 2006-15 Toyota Prius, at #15, which it states is in "high demand in the resale market." The list is expected to grow as the current cohort of PEVs age and are sold by their original owners. We note that, as will be discussed below, the prevalent means of acquiring PEVs is through leasing.

We believe that the number of consumers who buy PEVs off-lease will be a valuable metric for understanding PEV dependability and quality over time.

We conclude this section on alternative evaluation with some general comments. First, there is a considerable literature that focuses on a basic compensatory decision rule in PEV purchase, which is the tradeoff consumers make between their financial resources and the environmental benefits associated with the car, which are an important (although not primary) motivation for PEV purchase. Sample findings from this "willingness-to-pay" literature, include: (1) in Shaheen, Martin et al. (2008), $5,000 was the maximum amount that most potential consumers would be willing to pay as a premium to a similar gasoline car; and (2) in Strategic Vision (2013), 5% of new vehicle owners were willing to trade off personal financial resources for vehicles that were more environmentally-friendly. We note, however, that there is considerable potential for additional willingness-to-pay research, given complications associated with other aspects of the LDV market which are tied to price premiums, including perceptions of brand and amenity quality, social image, etc., as well as the role of financing in vehicle purchases. Second, to the extent that consumers feel that PEVs are substitutes for traditionally-fueled LDVs, they set the attributes of traditionally-fueled LDVs as reference points to assess loss and gain associated with PEVs. As would be expected under loss aversion, (Carley, Krause, Lane, & Graham, 2013) find that consumer perceptions are particularly shaped by the negatives of PEVs. Third, we note that there are several "other" reasons for PEV rejection in *Table 3-5* that have to do with consumer perceptions and/or behaviors, including: consumer uncertainty about the technology; consumer discounting of future fuel cost savings; consumer uncertainty about vehicle resale value; consumer difficulties in determining vehicle "greenness," consumers not understanding the benefits of PEVs; consumers not knowing about policy incentives; consumer unfamiliarity with charging and the complexities of installing home charging; consumers placing a wide range of values on fuel economy; and consumer social and cultural values, business practices, and political interests that are opposed to PEV purchase. It is unclear to what extent each of these is, by itself, a barrier to PEV purchase, rather than a sign of a broader issue, namely that PEVs are perceived by many consumers to be a new vehicle product category with which they have little experience and therefore do not have considerable internal resources to draw upon in alternative evaluation.

3.4 Purchase

As noted in Section 2, the fourth step of the purchase decision-making process, the purchase itself, involves the consumer's decision to buy (or not buy) a product from the evoked set. Both internal factors (e.g., consumer beliefs, attitudes, intentions, etc.) and external factors (e.g., the quality of the retail experience, the availability of the product, incentives for a product and/or its competition, the offered terms and conditions for sale or lease, available resources, peer group opinions, etc.) affect the final purchase.

The overall outcome of PEV acquisition by U.S. consumers is vehicle sales. Figure 3.8 presents U.S. PEV Sales by Model in 2011-15, as reported by the DOE's Alternative Fuels Data Center. As of 2015, the volume of PEV sales had more than quadrupled from their introduction as highway-worthy vehicles. The Nissan Leaf, the Chevy Volt, and the Tesla Model S accounted for about half of PEV sales in 2014-15, and a much higher percentage in 2011-13.

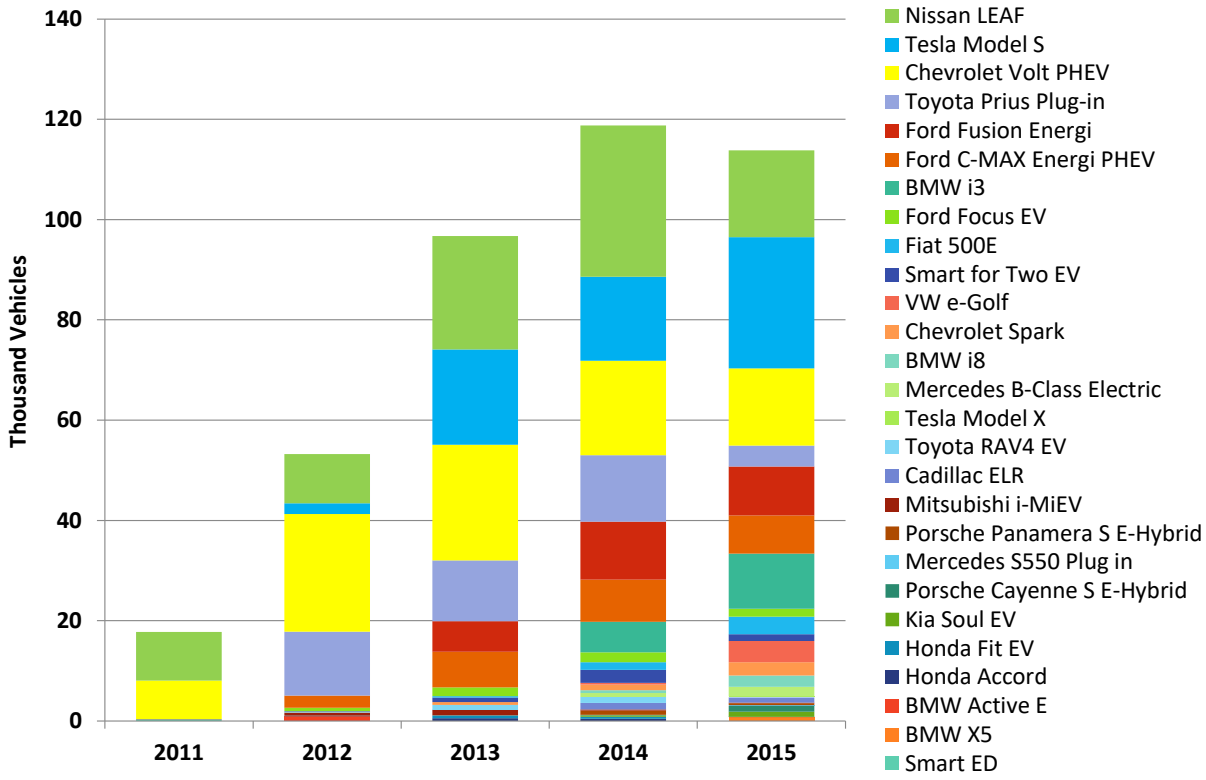


Figure 3.8: U.S. PEV sales by model, 2011 – 2015
Source: Alternative Fuels Data Center, https://www.afdc.energy.gov/data/10567

Here we introduce data and literature on (1) how factors specific to (i.e., "internal to") consumers affect PEV purchase decisions; and (2) how factors that are external to consumers affect those decisions.

3.4.1 Internal Factors

We begin by considering who the consumers are that buy PEVs versus other LDVs. *Table 3-7* compares a number of demographic characteristics of the buyers of BEVs, PHEVs, and traditionally-fueled LDVs, as presented by Strategic Vision (2013) and reported on by NAS (2015). We note that of the three groups of buyers, BEV buyers are the most: male (77%), married (81%), youthful (average age 48), college educated (86% graduates), professional (42%), and wealthy ($148,158 household income) of the three groups of buyers. By contrast, ICE-vehicle buyers are the least: male (60%), married (66%), college educated (59% graduates), professional (25%), and wealthy ($83,166 household income) of the three groups of buyers. PHEV buyers fall in between BEV buyers and ICE-vehicle buyers on every characteristic except for average age, for which they tie ICE-vehicle buyers at 52 years old. These results are consistent with other studies, including: (de Haan, Peters, & Mueller, 2006), which compares the characteristics, preferences, and previously-owned vehicles of HEV and ICE-vehicle consumers; and Ozaki and Sevastyanova (2011), which finds that early adopters of the Prius in the U.K. were predominately wealthy, male, over 50 years old, and lived in a household without children. Appendix B includes additional tables describing the attributes of buyers of PEVs versus ICE-vehicles.

Table 3-7: Comparison of new BEV buyers, PHEV buyers, and ICE-vehicle buyers
Source: NAS (2015) presentation of Strategic Vision (2013) results [38]

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

A number of studies link various demographic characteristics of vehicle consumers to other consumer-specific factors that affect vehicle purchase and use. For example, Carley et al. (2013) and Garling and Thøgersen (2001) consider a wide set of demographic and other characteristics on the intent to purchase PEVs. Jakobsson et al. (2014) consider the behavior of multi-car households with respect to the PEV purchase. And Caperello et al. (2014) finds that men are more likely to display traits of "early market adopters" while women have a tendency to display a greater reluctance to experiment, focusing on practical concerns more typical of mainstream adopters.

This characterization of the relationship between a consumer's gender and his/her likelihood of PEV purchase raises the larger issue of how to reconcile the attributes of today's PEV purchasers, who are, by definition, early consumers of this vehicle product category, with the potential "mainstream" purchaser of future PEVs. The viewpoint of Kurani et al. (2007), is generally upheld in the literature; it suggests that while current PEV adopters may not perfectly represent current mainstream consumers, their behavior and viewpoints provide reasonable insights into the future valuation and use of PEVs by other consumers. On PEV purchase and early adoption, generally, Green et al. (2014) suggest that greater policy effectiveness could be achieved by targeting early adopters and institutional/shared fleets with PEV incentives, rather than mainstream consumers.

3.4.2 External Factors

Here we focus on two external factors on the PEV purchase: the quality of the retail experience and the policy incentives available for PEV purchase.

The retail experience for traditionally-fueled vehicles and PEVs is built around the dealership franchise model. The primary exception to this sales channel, which is shored-up through U.S. law, is the approach used by Tesla, which uses a combination of retail bricks-and-mortar and online sales. T*able 3-8* presents the number of franchised new LDV dealerships in the U.S. and number of LDV sales per dealership in 5-year intervals since 1970s. Between 1970 and 2015 the total number of dealerships almost reduced in half while the number of LDV sales per dealership more than tripled. This provides a backdrop for understanding the growing importance of

[38]Strategic Vision (2013) presents the results of its "New Vehicle Experience Study of Vehicle Registrants," as conducted between October 2013 and June 2014.

individual dealerships as gateways to consumers and the growing difficulty for consumers of comparison shopping across multiple dealerships.

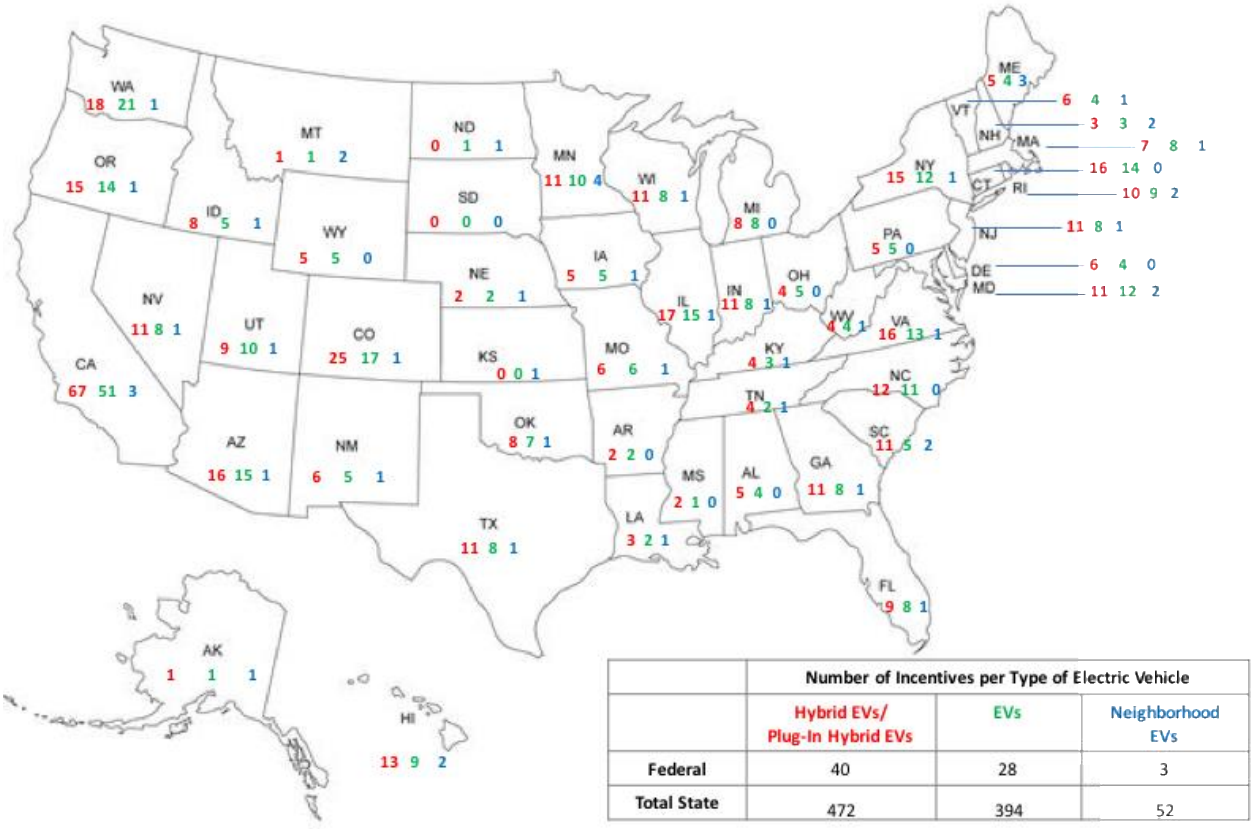
T*able 3-8:* New light vehicle dealerships and sales, 1970–2015
Source: Transportation Energy Data Book Table 4.17

Year	Number of Franchised New LDV Dealerships	New LDV Sales (thousands)	New LDV Sales per Dealership
1970	30,800	9,856	320
1975	29,600	10,677	361
1980	27,900	10,909	391
1985	24,725	14,667	593
1990	24,825	13,851	558
1995	22,800	14,673	644
2000	22,250	17,164	771
2005	21,640	16,774	775
2010	18,460	11,394	617
2015	16,545	17,103	1,034

This backdrop is important considering the small but significant literature on the consumer purchase experience for PEVs at dealerships. This literature generally finds that PEVs are unevenly available across the U.S. Evarts (2014), for example, finds that only 15 of 85 dealers, covering California, New York, Maryland, and Oregon, had ten or more PEVs on their lots. Within the leading state for PEV sales, California, 65% of dealerships were found to have no PEVs for sale, according to another study (U.C. Davis, 2014). Voelcker (2013; 2014) similarly reports that many dealers do not offer PEVs.

For those dealerships that do sell PEVs, the literature finds that the knowledge level about PEVs is generally low (see, e.g., Evarts 2014, Voelcker 2013 and 2014, Lunetta and Coplon-Newfield 2016), and that the purchase is more complex for both consumers and dealers than for a traditionally-fueled vehicle. This complexity includes a range of public and private incentives, including manufacturer and dealership discounts, sales tax waivers, income tax deductions, high-occupancy vehicle lane access stickers, etc. As an illustration of some of this complexity, *Figure 3.9* presents the number of federal and state incentives for HEVs, PHEVs, EVs, and Neighborhood EVs, as compiled by the DOE in its Transportation Energy Data Book; there is particular variation across states in the number of incentives offered.[39] Another factor that adds to the complexity of PEV sales is the prevalence of leasing, which is used more often in PEV acquisition than in all new vehicle acquisition (see, e.g., Rai & Nath, 2014; Tal, Nicholas, Woodjack, & Scrivano, 2013). One reason for the high rate of PEV leasing may be that leasing agencies are able to incorporate federal tax incentives more rapidly than a consumer who tries to independently navigate tax deductions after purchase (NAS 2015). In addition, leasing provides an opportunity to test out PEV technology in everyday use at a substantially reduced level of risk as compared to an outright purchase. We note that Tesla is a notable exception to the prevalence of PEV leasing, according to (Strategic Vision, 2013).

[39] Regarding the rationale of offering PEV incentives, see, e.g., Lane et al. (2013).



	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

Figure 3.9: Number of incentives for hybrid/plug-in hybrids, EVs, and neighborhood EVs
Source: 2016 Transportation Energy Data Book Tables 10-8 and 10-9

The impact of low PEV availability, high complexity, and low dealership PEV knowledge levels can be measured in time and repeat dealership visits, as well as in overall consumer satisfaction with the purchase experience. (Cahill, et al., 2014) find that 56% of PEV buyers in California make three or more visits to dealerships, twice the average of buyers of traditionally-fueled vehicles, and finds that of prospective PEV buyers, 45% report that they are "very dissatisfied" and 38% "dissatisfied."

There are some reasons for optimism, however. Most simply, the probability of PEV purchase can be increased by providing consumers with a total cost of ownership comparison (Dumortier et al., 2015; Eppstein, Grover, Marshall, & Rizzo, 2011). Meanwhile, large volume PEV dealerships have found a "best practice" that might be replicated across other dealerships, which is to incorporate within a dealership's sales force one or two "gurus" who can serve as customer points-of-contact for PEV-related questions (Evarts, 2014). Along a similar line of reasoning, Moore (2014) suggests that the consumer experience can be improved, and the risk to dealers of lost sales can be mitigated, if dealers help customers manage the whole process of PEV research and purchase.

3.5 Post-purchase

As noted in Section 2, post-purchase behavior, which is the fifth step of the purchase decision-making process, involves the consumer using the product over time and evaluating his or her feelings about it. An important element of consumer satisfaction with a purchase is how a

consumer's feelings about a purchase compare to his or her expectations about that product. The distance between expectations of a purchased product and a negative consumer experience is particularly likely to negatively affect future purchases of that product, both by the affected consumer and his/her peers.

As the product category of PEVs is fairly new, there is not much material on consumer satisfaction with PEVs and how it affects future purchases. Exceptions include: (1) studies that consider the reinforcing influence of knowledgeability, positive PEV experiences, and satisfaction on PEV purchasing (see, e.g., N. D. Caperello & Kurani, 2012; Giffi, et al., 2011; Golob & Gould, 1998; Idaho National Laboratory, 2015; Rauh, et al., 2014); and (2) the consulting report Giffi et al. (2011), which explicitly focuses on comparing expectations to actual experience.

We focus instead here on introducing the growing literature related to PEV use. This literature covers consumer behavior related to charging the vehicles and a diverse set of other topics, including vehicle miles traveled with PEVs in multi-car households, consumer interaction with vehicle instrumentation, and more.

3.5.1 Charging Behavior

PEV drivers have two options to charge their vehicles: charge the vehicle at home or charge it away from home. Most existing PEV drivers charge their vehicles at home, and many do not need to charge them away from home at all (see the range estimate studies discussed in the Alternative Evaluation section above). One recent report, however, estimated that up to 46% of potential new PEV buyers lack convenient home-charging access because they park on the street or live in multi-unit housing (John Axsen & Kenneth S. Kurani, 2012). In addition, total average costs of home-charging infrastructure (i.e., installation plus permitting costs) can potentially be prohibitive for some households. Although they are generally in the range of $1,000-$2,000 (this varies somewhat by region and the specific configuration of a household's electricity system), these costs can be prohibitive for some households (Smart, 2014a).

Home charging is very convenient and consumers who can afford it and have access to it appreciate it. We expect that the economic value of the convenience of home charging is estimable, although we have not found any studies that have done the calculations. There is likely to be spatial variation in how much consumers value the convenience of home charging, however, with some of that variation likely to be explained by the locations of U.S. gas stations, which have been declining overall since 1993 (see *Table 3-9*).

Table 3-9: Number of conventional fueling stations in the U.S. since 1993
Source: Transportation Energy Data Book.

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

Figure 3.10 shows the current map of public electric vehicle charging station locations in the U.S, as provided by both public and private entities. Panel 1 shows the location of public Level 1 chargers, Panel 2 shows the location of public Level 2 chargers, and Panel 3 shows the location of more expensive DC Fast chargers. It is interesting to note the contrast between this figure and Figure 3.5, particularly when considering the location and quantity of public Level 2 charging infrastructure and national BEV density.

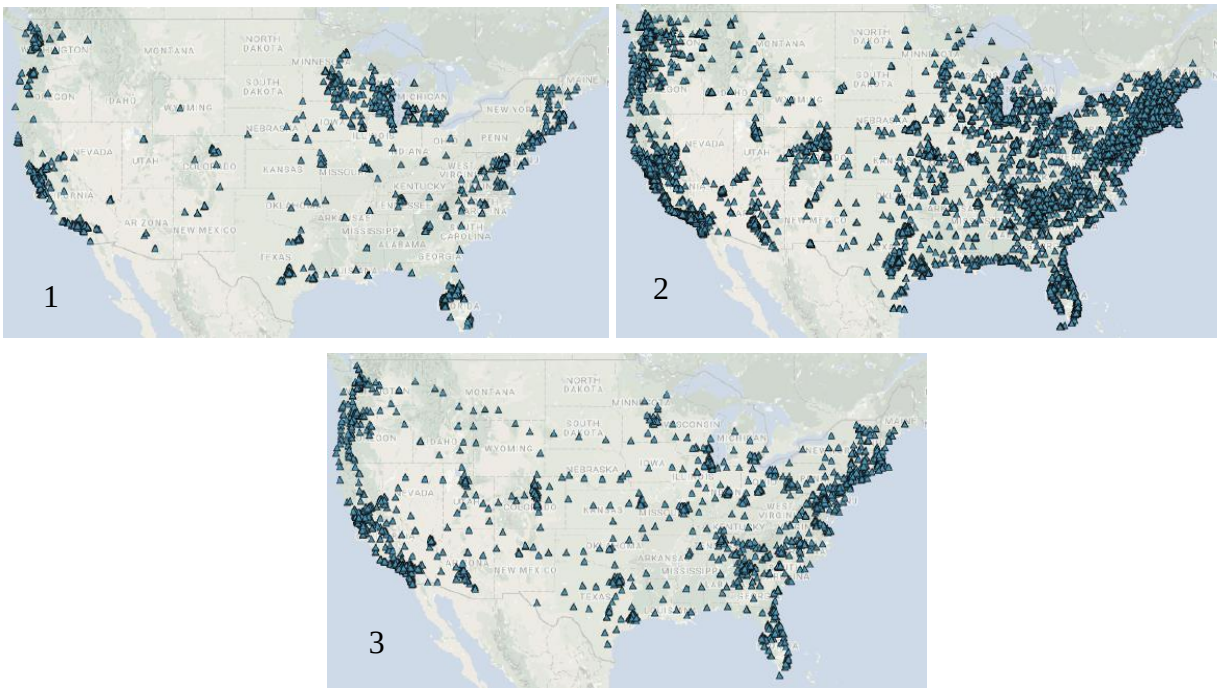


Figure 3.10: Public charging infrastructure provided by public and private entities.
Panel 1: Level 1 chargers; Panel 2: Level 2 chargers; Panel 3: DC fast chargers
Source: Alternative Fuels Data Center, April 2017

This is primarily due to the policy interest in promoting PEVs nationally, as numerous studies indicate that increasing public charging infrastructure availability can promote PEV purchase and use (e.g., Dong & Lin, 2014; Dong, Liu, & Lin, 2014; Javid & Nejat, 2017). Workplace

charging is particularly favored in the literature. Smart (2014b), for example, finds that Volt and Leaf drivers with access to workplace charging have considerably higher annual electric vehicle miles traveled (eVMT) than average for all Volt and Leaf drivers in their study, and the eVMT of these drivers even exceeded the national average annual total vehicle miles traveled (VMT). In addition to workplace charging, PEV drivers also have access to charging at many other locations, including public parking lots and garages, retailer parking lots, transportation hubs (e.g., subway stations, airports, etc.), hotels, and educational facilities (Smart 2014). This is a growing trend as urban centers substantially expand their charging networks. The hope is that increased charger density and visibility will allay the range concerns of potential consumers, as they gain confidence that they will not be stranded somewhere with a discharged battery. Critics, however, have raised questions about whether potential consumers recognize chargers when they pass in close proximity to them. Other concerns relate to whether the degree of charging infrastructure build-out underway represents over-capacity, especially when contrasted with the spatial pattern of BEV density depicted in Figure 3.5. Given the other issues raised about the purchase decision-process in this report, it is not clear that building charging infrastructure is sufficient to spur PEV purchase, although the evidence suggests it does play a role.

Beyond issues related to charger availability are several other post-purchase consumer behavior issues related to charging that can potentially pose a barrier to consumer satisfaction and future PEV use and purchase. The cost to charge, perceptions of charging etiquette, and network effects of charging have all been topics of study in the literature (Nicolette Caperello, Kurani, & TyreeHageman, 2013b; He, et al., 2014; Wua, Aviquzzaman, & Lin, 2015). These topics are representative of two broader categories of issues that can prompt negative emotions associated with public charging: (1) issues related to the tangible attributes of charger installations; and (2) issues related to driver behavior and public charging. Barriers related to the physical set-up of charging installations can include: uneven charging unit reliability and maintenance; heterogeneous charging fees that are not very visible to consumers (particularly in comparison to gas station price displays); varying hours of operation; varying ways in which charging access might be restricted, including through parking fees; and installations that are not compliant with the requirements of the Americans with Disabilities Act (ADA). Barriers related to driver behavior and public charging can include: non-PEV vehicles occupying charger parking spots, PEVs occupying charger parking spots when they are not actively charging, and general uncertainty about the etiquette of away-from-home charging (e.g., uncertainty about how to interact with other PEV drivers, how long to park and charge in a public spot, how acceptable it is to unplug another driver's PEV, etc.). See, e.g., Caparello, Kurani et al. (2013a) for more information.

3.5.2 Consumer Mobility Patterns

We conclude this section with a brief discussion of two additional threads of the literature regarding consumer mobility patterns and practices after a PEV purchase. First, there is growing interest in deepening consumer behavior research regarding PEVs in order to improve prediction about PEV use (see, e.g., Moons and De Pelsmacker (2015) on predicting PEV usage intention). This interest is, in part, a recognition that the empirical finding that consumers exhibit considerable heterogeneity in both travel and charging behavior over time (see, e.g., Wua, Aviquzzamana, & Lin, 2015) has important policy implications, including implications for grid stability and targeted emissions reductions. We note that according to Anowar et al. (2014), there is growing evidence that internal consumer factors that influence a vehicle purchase decision

(e.g. proclivity toward a vehicle, perception of comfort, environmental consciousness, etc.) also impact usage decisions for that vehicle. Second, a number of studies focus on a suite of behavior changes that consumers exhibit after they purchase a PEV. As consumers become accustomed to using a PEV over time, they learn "competences" such as how to manage vehicle batteries and identify convenient charging practices, they improve their interaction with "material" related to the PEV, such as vehicle instrumentation[40] and charging station feedback, and they develop "meanings" associated with an internalized, personal identification with the vehicle. These new competences, material interactions, and meanings contribute to increased consumer satisfaction with PEVs, according to studies like Pierre and Fulda (2015) and Rauh et al. (2014).

4 Conclusion

The purpose of this report is to clarify what is known about the vital role consumers play in the U.S. PEV market as it matures to become less policy-reliant and more representative of the U.S., both spatially and demographically. A more representative PEV market will: help American consumers access the economic and performance benefits of PEVs; help OEMs recoup more of their R&D investments in PEVs; and help the U.S. become more energy independent while improving air quality-related public health and reducing greenhouse gas emissions.

Unlike other reviews that consider consumer acceptance of PEVs (e.g., Rezvani et al. 2015), we draw heavily from the marketing literature and structure our review according to the five-steps of the purchase decision process depicted in the EKB model of consumer decision-making. We introduced this model in Section 2, along with internal and external factors that are likely to affect that decision process. In Section 3, we reviewed transportation data and literature as they pertain to the vehicle purchase decision process steps of problem recognition, search (both internal and external), alternative evaluation, purchase, and post-purchase behavior.

In this fourth section of the report, we consider cross-cutting themes in consumer behavior research as they apply to PEV purchase decisions. We also provide a table that compiles the open research areas noted in Section 3 of the report. We organize these research topics by the step of the decision process they most directly relate to, as we did in Section 3.

4.1 Consumer Behavior Themes of Relevance to PEV Purchase Decisions

Here we highlight four consumer behavior research themes of relevance to the PEV purchase process that cut across Section 2 and Section 3 of the report. These themes are: the role of experience in the purchase decision process for clean energy technologies; the role of affect in the PEV purchase decision-process; the importance of purchase context, especially as it relates to the consumer's current vehicle situation and time for the purchase; and the role of risk perception and switching costs in the PEV purchase decision.

4.1.1 Experience and the purchase decision process for clean energy technologies

As mentioned in Section 2, a consumer's cumulative experience with a product or brand can have a strong influence on product search and alternative evaluation. More experience implies

[40] PEV instrumentation indicating the remaining electricity stored is often imprecise, according to Turrentine et al. (2011). Accuracy of any "miles-to-empty" indicator is also complicated by the impact of speed, driving style, and ambient temperature on battery capacity and the rate of discharge.

that a consumer has: (1) a richer set of internal sources to draw from in search; (2) less motivation for external search but more facility at conducting it, often across a broader range sources; (3) a lower perception of purchase risk and a higher likelihood of considering a wider set of alternatives; and (4) more sophisticated heuristics to evaluate alternatives.

For a new clean energy product, there is an inherent question of how a consumer's past cumulative experience with other technologies crossover to the new product. To the extent that the new product is a substitute for an old, higher-polluting product, it seems reasonable that cumulative experience with the old product will be transferable to the new product, at least by analogy, and the associated benefits of experience will accrue to search, alternative evaluation, etc. with respect to the new product. To the extent that a consumer perceives a clean energy product to be totally new, or at least a new category of an older product, however, it is not clear how transferable the benefits of experience will be. In the internal search discussion in Section 3, we illustrated this by considering the contrast between residential photovoltaic (PV) systems, which do not have a clear past analogy, and PEVs, which have analogous designs in traditionally-fueled vehicles and HEVs.

Although there are benefits to decision-making when a consumer is experienced with purchasing an analogous product, there are also potential pitfalls associated with the way the earlier product set the reference points for the expected attributes of the newer product. This is because consumers react more strongly to losses in relation to reference points than they do to gains in relation to reference points. The implication of this is that the losses associated with PEVs, such as higher prices and limited ranges, will be heavily weighted in consumer perceptions of PEVs. Studies such as Ingram (2013) and Kurani et al. (2015), which document a lack of consumer awareness of the gains associated with PEVs, such as fuel cost savings, maintenance cost savings, charging infrastructure, and incentives, suggest that there are additional challenges ahead in growing the national market for PEVs.

One clear challenge is the uneven distribution of PEVs across the U.S., as illustrated in Figure 3.5 and in the findings of studies like Evarts (2014) and UC Davis (2014) with respect to product availability across dealerships. Because of this uneven distribution, consumers in many parts of the country are unlikely to have direct experience with driving PEVs and developing first-hand knowledge of their more subjective attributes, like improved performance, unless they can benefit from third party programs like ride-and-drives, etc. In addition, these consumers will probably not be prompted to think about PEVs as candidates for their next vehicle purchase by seeing a car at a neighbor's driveway or on the road, or by listening to a peer evangelize for a PEV as a result of his or her direct experience.

4.1.2 Affect and the PEV purchase decision process

One of the factors that influences the purchase decision-making process is the affective state of the consumer. Positive emotion is particularly important to such System 1 mental process benefits as: processing information efficiently; making useful connections between pieces of information; generating creative solutions to problems; and arriving at decisions quickly. It is also tied to being readily satisfied with a purchase, which has implications for future purchases. Positive emotion in the experience of using a product is more likely to anchor a purchase in a consumer's memory, where it will help ground consumer heuristics for future internal search and evaluative criteria generation and application in subsequent purchases. In addition, neuro-economics shows that emotions hold primacy over neutral information in alternative evaluation.

In several steps of the PEV purchase decision process, there are apparent opportunities for negative emotions to arise for consumers. In search, for example, having only analogous internal information sources and potentially no direct experience of driving PEVs or having neighbors who have driven PEVs could lead to frustration. In addition, NAS (2015) brings up concerns about consumer emotions as they relate to PEV-specific websites that are an important external source of information. The committee was particularly concerned that the large number of websites might lead to consumer information overload and confusion (see Herbig and Kramer 1994), especially as search results do not lead to the most credible information first, and even include some misinformation on PEVs.

With respect to the purchase step of the decision-making process, a significant percentage of California's PEV consumers have already been shown to be "dissatisfied" (38%) or "very dissatisfied" (45%) with their purchase experience (Cahill, et al., 2014). Not many dealerships have PEVs to show consumers, and many dealership personnel have low levels of knowledge about purchases that have additional layers of complexity due to policy incentives, lease terms, etc. Cahill, Davies-Shawhyde et al. (2014) further reports that 56% of PEV buyers in California make three or more visits to dealerships, twice the average of buyers of traditionally-fueled vehicles. Note that any significant delay in acquiring a purchase is likely to prompt negative emotions, given the human proclivity to weigh immediate rewards more heavily than future rewards.

Finally, with respect to post-purchase behavior, any frustrations around charging infrastructure, such as poorly maintained chargers or poorly behaved fellow PEV drivers, can lead to negative emotions that can negatively affect future purchase decisions, either by the consumer or through his or her recommendations to others.

4.1.3 Purchase context and the consumer's current situation

The context of a purchase shapes the problem recognition step of the purchase decision-making process and can also introduce important constraints on the overall process. These context-dependent constraints include the time available for purchase, the speed with which the alternatives are changing with respect to cost, performance, features, etc., the consumer's financial resources for purchase, and more. Here we focus primarily on purchase context as it relates to problem recognition and the time available for purchase.

In the under-researched problem recognition step, which drives the rest of the purchase decision-making process, the consumer identifies a gap between his or her current situation and his or her needs and/or desires. There are several commonalities between consumers who choose to address their vehicle purchase problem through the purchase of a PEV. Most PEV owners are in multi-car households, and according to Strategic Vision (2013), they also tend to be: male (77% of BEV buyers, 70% of PHEV buyers), married (81% of BEV buyers, 78% of PHEV buyers), middle-aged (average age 48 for BEV buyers, 52 for PHEV buyers), college educated (86% of BEV buyers, 77% of PHEV buyers), professional (42% of BEV buyers, 37% of PHEV buyers), and wealthy ($148,158 median household income of BEV buyers, $127,696 of PHEV buyers). The numbers for the buyers of new traditionally-fueled vehicles are lower for each of these demographic indicators except one: they are also, on average, 52 years old.

For however much PEV buyers differ from the average buyers of new traditionally-fueled vehicles – and it is important to recall that about two-thirds of vehicle sales are used-cars – all LDV buyers share common vehicle problems related either to life events or to the physical

condition of their existing vehicles that will prompt the purchase decision-process. Several studies speak to this. Clark et al (2016), for example, analyzed a rich U.K. panel study to derive a number of results that may also hold true in the U.S. context, including: (1) changes in household composition and driver's license availability were the strongest predictors of changes in car ownership; (2) households were more likely to give up a car when their income shrank than they were to acquire a car when their income grew; (3) having children increased the probability of a carless household acquiring a car but also increased the probability that a two-car household would give up a car; and (4) poorer access to public transit predicted a higher probability that a carless household would acquire a car and a lower probability that a single-car owning household would give up a car. In another example, Dargay and Hanly (2007) found that second car ownership is more volatile than first car ownership; this finding is particularly relevant to the 57% of American households with two or more vehicles (according to 2010 data).[41]

Memorably, Punj and Srinivasan (1992) identified four consumer segments based on motivations to undertake a vehicle purchase: *new need* (14% of respondents); *product depletion* (19%); *higher expected satisfaction* (24%); and *current dissatisfaction* (43%). "Product depletion" motivated consumers either had a car that stopped running or believed that cars should be traded in every 2-3 years; these consumers considered the smallest number of makes before visiting a dealership, made the smallest number of pre-decisions, and shopped for the smallest number of aggregate models across dealership visits. "New need" motivated consumers, who either had no car or wanted a new car for a different purpose than their existing car, shopped for the highest number of aggregate models across dealer visits. There was no difference between the higher expected satisfaction and current dissatisfaction consumer segments on any variable related to the rest of the purchase decision-making process, and there was no difference between any of the consumer segments on overall satisfaction with the purchase decision. According to the authors, "as long as customers felt they did everything they deemed necessary and sufficient under the circumstances, they were content with the purchase."

These circumstances include the time available for the purchase decision process. Consumers under time pressure for their vehicle purchase are more likely to turn to the more efficient, emotional/intuitive, and prior-experience grounded System 1 mental process, particularly for internal search and alternative evaluation. These time pressures can come from many sources, including a depleted product (e.g., if an existing car is damaged in an accident in an area with limited alternative mobility options), an imminent need (e.g., an expected new addition to a household), or an aspect of the conditions of purchase that is of limited duration (e.g., a financial incentive to buy a particular vehicle is about to expire). Reaching these consumers to help them understand the value proposition of PEV ownership is likely to be difficult without their having an emotional or experience-based connection to PEVs. Consumers without time pressure, meanwhile, are more likely to engage with the slower, conscious reasoning System 2 mental process that can be better appealed to through logic and facts. One concern about these consumers, however, is that they may procrastinate on a purchase, particularly when the alternatives under consideration are rapidly changing or there is an overwhelming amount of information to assess about the options. NAS (2015) highlighted that a sizable number of

[41] According to Clark et al. (2016), "panel studies reveal that the number of cars owned is state dependent" with stability associated with ownership in a previous period predicting ownership in a later period.

potential PEV consumers explain they are "waiting for the technology to advance," which is in keeping with concerns about decision avoidance and choice deferral.

4.1.4 Risk assessment and switching costs

The possibility that PEV technology will significantly advance after a consumer has bought a PEV is an example, in the electric vehicle context, of one of the potential negative consequences of purchase decisions that consumers seek to avoid. Others are, as illustrated with hypothetical PEV examples: (1) financial loss (e.g., the feeling of "throwing money away" on a PEV, perhaps due to concerns about high price, range limitations, a potential mismatch to a consumer's idealized lifestyle, or the chance it will become obsolete quickly); (2) psychological loss (e.g., if the PEV was found after the purchase to be less "green" than the consumer expected, thereby conflicting with the consumer's beliefs or values); (3) a loss of social status (e.g., the consumer's peers are dismissive of the PEV, perhaps because, as in some instances, their social and cultural values, business practices, and political interests are negatively associated with the vehicles (see Sovacool and Hirsch 2009); (4) a performance/functional loss (e.g., the PEV does not achieve the driving range or the recharging time the consumer expected, perhaps due to cold weather); and (5) physical loss (e.g., the PEV is found to be unsafe to drive). We note that these PEV-specific illustrations of types of negative purchase outcomes differ from similar illustrations using traditionally-fueled vehicles primarily in their psychological and social status aspects, rather than in their financial, performance, and safety aspects.

Consumers try to minimize all types of potential negative purchase consequences, which they feel with varying intensity in patterns established in prospect theory, by being highly involved in the purchase decision-making process. Automobile purchases, in general, are typically high involvement purchases in which consumers invest significant time and effort due to their infrequency, high cost, and social visibility. Findings such as that of Cahill, Davies-Shawhyde et al. (2014), however, that 56% of California's PEV buyers make at least three visits to dealerships – twice the average of buyers of traditionally-fueled vehicles – signal that PEV purchases are even higher involvement that traditional LDV purchases. In high involvement purchases, consumers have the goal of better understanding the likelihood that the purchase decision will have positive versus negative consequences. Consumers are, therefore, more thorough in internal and external search and alternative evaluation, and are more attentive to the details of the final purchase decision.

Consumers also prefer to reduce the risks of their purchase decisions by having as much information about a potential purchase as possible. This is easier in the case of "search goods," in which features, quality, performance, etc. are transparent, as opposed to "experience goods." *Consumer Reports* ratings, online user reviews, and peer recommendations all work to reduce the information asymmetry between manufacturers and consumers on product attributes that consumers value but find difficult to objectively assess before use. Consumers often use these external sources of information in combination with several additional cues when deciding to purchase a product with experience good attributes. These cues include: price, with a heuristic equating lower price with lower quality; reputation, with a heuristic equating fame, etc. with higher quality; and a consumer's own prior experience, as influenced by affect and analogy. The heuristic that equates price with quality may be one reason why LDV purchasers often list price as the least important of five vehicle attributes associated with purchase, below the attributes of dependability and quality (see Table 3-4). It is also a potential positive associated with what is

generally perceived as a negative about PEVs, which is their higher average MSRP than traditionally-fueled vehicles.

The time and effort investments consumers make in the purchase decision may be compounded, in the case of PEVs, by the investments they expect to make in post-purchase use of the vehicles. This is because there are "switching costs" associated with acquiring PEVs, rather than incumbent traditionally-fueled LDVs. In general, switching costs can be monetary or related to time, effort, convenience, the presence of complementary goods/network externalities, or other factors like learning effects, habits, and emotional bonds to products and/or brands. In the PEV purchase context, switching costs include learning to deal with new dashboard instrumentation and adapting household mobility practices to accommodate range limitations (e.g., through using additional cars in a household's portfolio in different ways, occasionally renting an additional vehicle, etc.). Switching costs may also involve overcoming brand loyalty, if a favored OEM does not offer a suitable PEV option,[42] or changing service station habits if the consumer's habitually used station does not service vehicles from that manufacturer. Most notably, switching costs are associated with changes in fueling practices. These switching costs include: investing time, effort, and financial resources in setting up home charging; learning how to charge the vehicle rather than fill it with gasoline; learning how public charging works physically and with respect to other charging customers; and changing habits associated with purchasing gasoline (e.g., routing options, errand chains, etc.).

4.1.5 Concluding Thoughts

There are clearly a number of challenges involved in the PEV purchase process. These include: consumer experience gaps; multiple opportunities for negative emotions to occur throughout the decision process; potentially different negative consequences of PEV purchases than those of traditionally-fueled vehicle purchases; and high investments of time and effort in the purchase decision-making process and in post-purchase use. When coupled with time constraints that are often part of any vehicle purchase, rapid technological change in PEVs, and competing traditionally-fueled vehicles that are familiar, high-quality (and also rapidly changing to accommodate more autonomous features), and prominently advertised by OEMs, it is not surprising that studies show low willingness-to-pay for PEVs.

Still, there is an increasing value proposition for PEV purchase for a growing group of consumers based on the economic, performance, convenience, psycho-social, and societal benefits of PEVs, although this value proposition is not well-known by all consumers (see, e.g., Table 3-3). Those consumers who have purchased PEVs express a different prioritization of their reasons for acquisition than buyers of traditionally-fueled vehicles, with the top reasons for PEV purchase reported in Santulli (2015): fuel cost savings (39%), contribution to environmental and energy policy goals (22%+6%), policy incentives (16%), vehicle performance (4%), and the combined reasons of "a desire for the newest technology," "supporting the diffusion of EV technology," and "other" (13%). By contrast, Strategic Vision (2013) lists the top five reasons for acquisition as: "reliability, durability, quality of workmanship, value for the money, and manufacturer's reputation."

When a consumer successfully overcomes the challenges of the PEV purchase decision-making process and makes a PEV purchase with positive outcomes, social science theory suggests that

[42] There is evidence that many consumers overcame brand loyalty to purchase Nissan Leafs (Tal et al. 2013).

these consumers are likely to become particularly loyal to the vehicles and may exhibit important consumer citizenship behaviors.[43] This is because people are generally averse to abandoning the costs they have sunk into an investment.[44]

It is particularly likely, therefore, that there will be a disproportionate number of PEV evangelists within the group of people who have bought PEVs. Besides the likelihood that they will have already helped shape virtual communities of consumption that provide valuable information about the PEV purchase to potential buyers, there is probably additional value to the growth of the PEV market that could be had by leveraging their proclivity to consumer citizenship. In particular, these consumers may be helpful in providing input to the sorts of emotional, memorable appeals to potential PEV consumers that would really assist potential PEV buyers who are hampered by time constraints and rely on System 1 mental processing in their vehicle purchase process.

4.2 Areas for Additional Research

In *Table 4-1* we present a compiled list of open research topics that would advance the state of knowledge regarding the PEV purchase decision-making process, according to the five main steps of that process.

Table 4-1: Open topics for new research

Decision Process Step	Open Research Topics
Problem Recognition	• Replicate Punj and Srinivasan (1992) to gain a better understanding of consumer segments today and if/how they behave differently in the vehicle decision-making process • Research to improve understanding of the connections between problem recognition and PEV purchase decisions
Search	• Research to gain a better understanding of whether consumers perceive of PEVs as substitutes for traditionally-fueled vehicles or as a new LDV product category. Relevance is to the role of experience, internal search in PEV purchase decisions • 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 vehicles in fleets, etc.) • Investigate potential framing effects associated with the way PEVs are described in general car-buying information sources like Consumer Reports, Kelley Blue Book, Wards Automotive, etc. A-B testing of websites would be a valuable approach • Investigate different approaches to seeding new clusters of PEVs in areas of the country with low PEV density • Investigate how existing "virtual communities of consumption" for PEVs compare to other such communities, and consider their role in advancing the market for PEVs • Follow-up on suggestions of NAS (2015) with respect to data on external search.

[43] These include voice, service improvement, display of affiliation, policing, flexibility, referral/recommendation, and act of service.

[44] There is a related social science theme of organizational loyalty driven by the difficulty of membership tasks that is also likely to play a role (see, e.g., social science research on hazing rituals at fraternities, etc.).

Decision Process Step	Open Research Topics
Alternative Evaluation	• Deepen the understanding of the connection between gas prices and the consumer salience of vehicle fuel economy over time • Compare the five vehicle attributes DOE collects against the more extensive vehicle attribute data reported on in studies like Strategic Vision (2013 and the quite different surveys of reasons for PEV purchase carried out by other entities (e.g., Santulli 2015, Singer 2016, etc.) • Estimate the economic value to consumers of the convenience of at-home charging and how this value may vary spatially and across demographic groups • Apply a prospect theory framework to better understand how consumers perceive the attributes of PEVs
Purchase	• Determine with more rigor the differences between today's and tomorrow's buyers of PEVs • Estimate the effects of declines in the number of dealerships across the country, as well as differing PEV availability across dealerships, on the growth of the PEV market • Strengthen understanding of the differential complexity of the PEV purchase at dealerships (e.g., need for knowledge about policy incentives, leasing details, etc.) and determine the effectiveness of different practices to overcome this complexity
Post-Purchase Behavior	• Study how a consumer's feelings about PEV purchases compare to expectations, and how this affects their heuristics about future purchases and product recommendations • Test the degree to which potential PEV consumers recognize chargers when they pass in close proximity to them • Test with more rigor the strength of the effect of the presence of public charging infrastructure to the likelihood of PEV purchase. The point of this is to critically consider whether the degree of charging infrastructure build-out represents significant over-capacity

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Appendix A. Answering Questions about PEV Consumers

Questions re: Marketing and Purchase	SECTION(S), NOTES
What are the key determining factors of conventional vehicle and PEV purchase?	3.1; 3.2.2; 3.2.4; 3.3.2; 4.1.1; 4.1.2
Where do "fuel" efficiency (miles per gallon versus ICE gasoline) and other factors (e.g., styling, brand loyalty, etc.) rank?	3.3.2; 4.1.1
To what degree is cost savings (e.g., payback from fuel costs; federal/state incentives) a behavioral motivator?	3.3.2; 3.4.2
Are the capital costs the largest hurdle for PEVs?	3.3.2; 3.5.1; 3.5.2; 3.5.4; 4.1.4
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?	3.3.2; more information needed, some information in safety literature
What PEV facts/factoids are most useful in persuading consumers to purchase a PEV?	3.1; 3.2.4; 3.2.5; 3.3.2
What motivated PEV buyers to make their purchase?	3.1; 3.2.4; 3.3.1; 3.3.2; 3.4.2; Appendix B

Questions re: Driving PEVs	**SECTION(S), NOTES**
Will PEVs meet the vast majority of potential PEV buyers' daily transportation needs?	3.5.1; 3.5.2; 3.5.3
If PEVs do meet these needs, do consumers understand this?	3.2.1; 3.3.1; 3.5.2
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?	3.5.3; more information needed
What are “typical” PEV drive cycles?	3.5.2
How do PEV drive cycles affect PEV attitudes? How do PEV drive cycles differ by driver? How do PEV drive cycles vary by PEV model?	More information needed
How do PEV drive cycles differ by BEV vs. PHEV?	3.5.2
Questions re: Charging	**SECTION(S), NOTES**
How do [innovative/TOU/other] EVSE/charging pricing models affect re-charging behavior?	3.5.1; 3.5.2; more information needed

Questions re: Customer Satisfaction	**SECTION(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?	3.5.2; 3.5.4; Appendix A; 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? Is there qualitative data about this involving current car owners?	3.3.1; 3.3.2; more information needed
Do current PEV operators "believe" that their PEV is the best option and superior to other vehicle choices?	Appendix A; more information needed
Questions re: Market Size, Characteristics, and Potential	**SECTION(S), NOTES**
How homogenous/heterogeneous are PEV buyers?	3.4.2; 3.4.3; 3.4.4; 4.1.3
What are the characteristics of PEV drivers as an overall group?	3.4.3; 3.4.4; 4.1.3
What are the characteristics of PEV drivers by PEV model?	3.4.3; 3.4.4
What are the most significant differences between early PEV adopters and PEV mass market purchasers?	3.4.3; 3.4.4; 4.1.4

Appendix B. Additional Figures and Tables

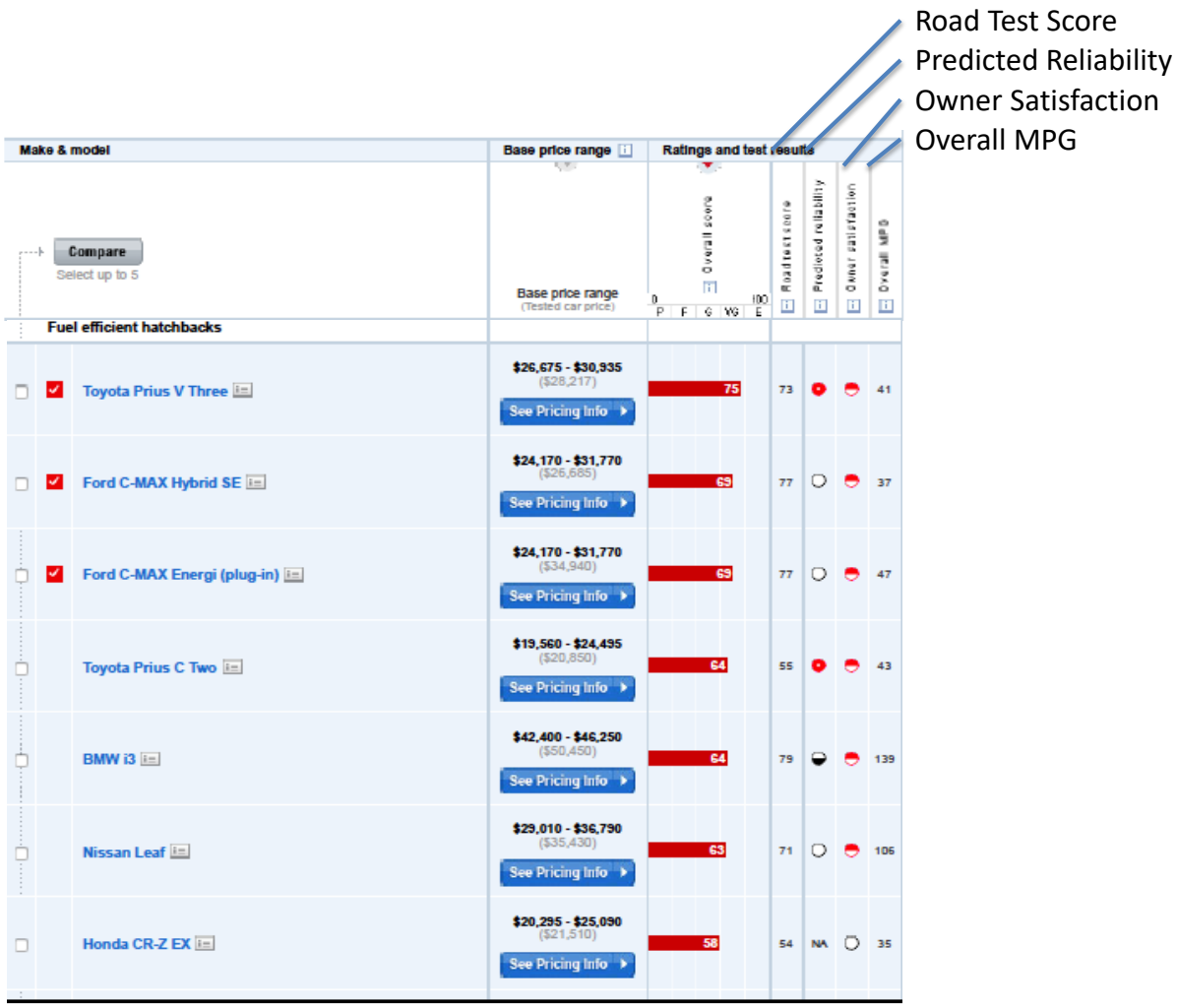

Figure B.1 Example of *Consumer Reports* rating of PEV

Table B. -1: Comparison of buyers of BEV, PHEV, and ICE
Source: (Strategic Vision, 2013)

Characteristic	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

NOTE: BEV, battery electric vehicle; ICE, internal-combustion engine; PHEV, plug-in hybrid electric vehicle.
SOURCE: Strategic Vision New Vehicle Experience Study of Vehicle Registrants, October 2013-June 2014.

Table B. -2: Demographics of vehicle buyers
Source: (Strategic Vision, 2013)

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 (5%)	Chevrolet Volt (8%)
Number of respondents	237,235	285	2,257	556	169

[a] Entries are provided as percent of respondents.
SOURCE: Strategic Vision New Vehicle Experience Study of Vehicle Registrants, October 2013-June 2014.

Table B. -3: ANOVA factor analysis of Prius buyer motivations
Source: (Ozaki & Sevastyanova, 2011b)

	Variables[a]	**Variance explained (%)**
Factor 1	• Driving the Prius reduces the effects of climate change	22.10
	• Driving the Prius reduces the carbon footprint	
	• Driving the Prius preserves the environment	
	• Driving the Prius reduces pollution level	
	• Driving the Prius reduces the consumption of natural resources	
	• Driving the Prius means I am doing the right thing	
Factor 2	• Driving the Prius will characterize me as a person who shares technological knowledge	16.04
	• Driving the Prius will characterize me as a person who likes to try something different	
	• Driving the Prius will characterize me as a person who is able to educate others about a new type of vehicle	
	• Driving the Prius will characterize me as a pioneer in the technological sphere	
	• Driving the Prius will characterize me as a person who enjoys the benefits of innovation	
Factor 3	• Driving the Prius means being a trendsetter for environmentally friendly technologies	12.60
	• Driving the Prius means being considerate to others	
	• Driving the Prius means sharing the common values	
	• Driving the Prius means being socially responsible	
Factor 4	• Driving the Prius contributes to gaining independence from oil producers	8.21
	• Driving the Prius makes me less exposed to fuel price fluctuations	
	• Driving the Prius will give me free access to the town center	
	• Driving the Prius will give me free parking	
Factor 5	• Driving the Prius will help me spend less on fuel[b]	5.88
	• Driving the Prius will give me other government incentives	

Table B. -4: Variety of websites providing PEV information
Source: Table 3-7 in NAS (2015)

Category	URL	Information Type
Vehicle reviews	http://www.edmunds.com/hybrid/ http://www.kbb.com/electric-car/?vehicleclass=newcar&intent=buy-new&filter=hasincentives http://www.consumerreports.org/cro/cars/hybrids-evs.htm http://www.cars.com/guides/all/all/?prop63=Electric%20Powered&highMpgId=1836&sf1Dir=ASC	Reviews, technical specifications, make and model availability
Vehicle industry blogs and websites	http://www.greencarreports.com/ http://www.epri.com/Our-Work/Pages/Electric-Transportation.aspx http://www.electrificationcoalition.org/ http://www.plugincars.com/ http://www.howtoelectriccar.com/is-an-electric-car-right-for-me/ https://www.aepohio.com/save/ElectricVehicles/EVRight.aspx http://www.electricdrive.org/ http://www.electriccarbuyer.com/guide/ http://insideevs.com/ http://www.pluginamerica.org/ http://driveelectricweek.org/ http://green.autoblog.com/ http://evsolutions.avinc.com/electric_vehicles/ http://cleantechnica.com/category/clean-transport-2/electric-vehicles/ http://chargedevs.com/ http://www.thecarconnection.com/category/new,electric-car http://www.huffingtonpost.com/news/electric-cars/ http://www.tva.com/environment/technology/electric_transportation.htm https://www.alamedamp.com/types-of-electric-vehicles http://transportevolved.com/	Market trends, including sales volumes, PEV news, reviews
Nonprofit organizations	http://www.nrdc.org/energy/vehicles/green-car-tech.asp http://www.edf.org/transportation/fuel-economy-standards http://content.sierraclub.org/evguide/	Environmental impacts of PEVs, incentives, policy, dispelling myths
Charging-infrastructure locators	http://www.plugshare.com/ http://www.afdc.energy.gov/fuels/electricity_infrastructure.html http://www.nrgevgo.com/ http://www.chargepoint.com/ www.juicebarev.com	Maps and search tools to find charging infrastructure, availability of chargers, subscription plans
Cost of ownership calculators	http://www.afdc.energy.gov/calc/ http://energy.gov/maps/egallon http://www.electrificationcoalition.org/	Calculators for cost of ownership of PEVs based on local and individual variables
Federal government resources	http://avt.inel.gov/ http://avt.inel.gov/hev.shtml www.fueleconomy.gov http://energy.gov/maps/egallon http://www.evroadmap.us/ http://www.afdc.energy.gov/vehicles/electric.html http://www1.eere.energy.gov/cleancities/ http://energy.gov/eere/vehicles/vehicle-technologies-office-hybrid-and-vehicle-systems http://energy.gov/eere/vehicles/vehicle-technologies-office-information-resources http://energy.gov/eere/vehicles/vehicle-technologies-office-ev-everywhere-grand-challenge http://www.epa.gov/greenvehicles	Incentive information, regulation information, data on PEVs, government research, and deployment initiatives
State government resources	https://energycenter.org/ http://www.westcoastgreenhighway.com/electrichighway.htm http://www.in.gov/oed/2675.htm http://www.plugandgonow.com/	State-specific incentives and policies, consumer guides, resources for advocates, state, local and regional charger maps

Appendix C. Additional References

Stage/Actor	References
Household mobility	• Residential location, VMT, emissions (Lindsey, Schofer, Durango-Cohen, & Gray, 2011) • Perceptions of hydrogen as vehicle fuel source (Hardman, Steinberger-Wilckens, & Horst, 2013; Ricci, Bellaby, & Flynn, 2008; Yetano Roche, Mourato, Fischedick, Pietzner, & Viebahn, 2010) • "Informal travel" patterns (Salomon & Singer, 2014) • Household energy-related behaviors (Abrahamse, Steg, Vlek, & Rothengatter, 2007; Musti, Kortum, & Kockelman, 2011; Niemeyer, 2010) • "Eco-driving" strategies (Barkenbus, 2010; Barth & Boriboonsomsin, 2009; Beusen et al., 2009; Saboohi & Farzaneh, 2009) • Personal driving practices (Carrico, Padgett, Vandenbergh, Gilligan, & Wallston, 2009) • Consumer sustainability preferences (Attari, DeKay, Davidson, & Bruin, 2010; Daziano & Chiew, 2012; Feng, Fullerton, & Gan, 2013; Gould & Golob, 1997; Li, Clark, Jensen, Yen, & English, 2013; Marigny Research Group, 2006; Sheth, Sethia, & Srinivas, 2011) • Vehicle choice and travel modeling (Hess, Fowler, Adler, & Bahreinian, 2011; K. S. Kurani, Turrentine, & Sperling, 1994; K. S. Kurani, Turrentine, & Sperling, 1996; Vyas, Santini, & Johnson, 2009) • Cycling for personal mobility (Bigazzi & Figliozzi, 2014; Handy, van Wee, & Kroesen, 2014)
Commercial/Institutional mobility	• Automation in heavy duty vehicles (Aghabayk, Sarvi, & Young, 2015) • Logistics and globalization (Akyelken & Keller, 2014) • Fleet manager adoption of PEV (Sierzchula, 2014)
Vehicle OEM/dealer supply chain	• Knowledge and innovation diffusion in the auto industry (A. Schulze, Paul MacDuffie, & Taube, 2015) • Electric vehicle production strategies (Zhang, 2014) • Industry structure and automotive innovation (Parente & Geleilate, 2015) • Technology adoption life cycle (D. Santini & Vyas, 2005) • Vehicle scrappage and replacement options (Jacobsen & van Benthem, 2013; Marell, Davidsson, & Gärling, 1995)
Public transit	• Influence of gas price on transit ridership (Lane, 2010, 2012) • Ridership and proximity to transit (Lindsey, Schofer, Durango-Cohen, & Gray, 2010) • Effects of fares, service quality, income, car-ownership on ridership demand (Paulley et al., 2006) • Bus rapid transit, land development, and property values (Stokenberga, 2014) • Determinants of transit ridership (Chiang, Russell, & Urban, 2011; Taylor, Miller, Iseki, & Fink, 2009) • Transit demand elasticities (Tsai, Mulley, & Clifton, 2014) • Bus transit reliability (Ehab I. Diab, Madhav G. Badami, & Ahmed M. El-Geneidy, 2015; Ehab I Diab, Madhav G Badami, & Ahmed M El-geneidy, 2015) • Passenger perspective on train delay (Cheng & Tsai, 2014)

Stage/Actor	References
Retail & services sector	• Freight transport (Beuthe, Jourquin, & Urbain, 2014; Browne, 2014; Cui, Dodson, & Hall, 2015; Environmental Protection Agency; Jothi Basu, Subramanian, & Cheikhrouhou, 2015)
Information & communication technologies sector	• Demand responsive transportation (Ronald, Thompson, & Winter, 2015) • Traffic sounds and bicycle safety (Stelling-Kończak, Hagenzieker, & Wee, 2015) • Use of social media during transit disruptions (Pender, Currie, Delbosc, & Shiwakoti, 2014) • Connected transport and "smart cities" (Cuddy et al.)
Infrastructure sector	• Facilitating on-ramp merging (Scarinci & Heydecker, 2014, 2015) • Smart parking field trial (S. Shaheen & Kemmerer, 2008) • Urban environment and shared street space (Barrington-Leigh & Millard-Ball, 2015; Karndacharuk, Wilson, & Dunn, 2014) • Traffic congestion management (Grant-Muller & Xu, 2014) • Built environment and travel patterns (Frank, Saelens, Powell, & Chapman, 2007; Næss, 2015) • Highway travel time prediction (Oh, Byon, Jang, & Yeo, 2015) • Pedestrian traffic (Frank, Greenwald, Winkelman, Chapman, & Kavage, 2010; Gupta & Pundir, 2015; Kalakou & Moura, 2014; Karash, Coogan, & Adler, 2007; Karndacharuk, et al., 2014)
Electric fuels sector	• Vehicle to grid issues (Habib, Kamran, & Rashid, 2015; Miranda, Borges, Valério, & Mendes, 2015; Mohseni & Stevie, 2009)
Additional background on the transportation sector	• Travel behavior research techniques and methodologies (Bachmann, Kennedy, & Roorda, 2014; Bueno, Vassallo, & Cheung, 2015; Button, 2015; Nicolaisen & Driscoll, 2014; Raposo, Rodrigues, Silva, & Dentinho, 2015; Shen & Stopher, 2014; T. S. Stephens, 2015; Thomas S. Turrentine & Kurani, 1998; White, 2014; Witlox, 2015; Woxenius, 2015) • Transport contribution to greenhouse gas emissions (Bakker, Zuidgeest, de Coninck, & Huizenga, 2014; Cambridge Systematics, 2009; Handy & Krizek, 2012; Knittel & Sandler, 2010; Kockelman, Bomberg, Thompson, & Whitehead, 2008; Lee-Gosselin, 2009; Millard-Ball & Schipper, 2011; Poudenx, 2008; Yang, Ogden, Sperling, & Hwang, 2011)