Consumer behaviour and the plug-in vehicle purchase: A research gap analysis

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Keywords

electric vehicles, policy, research review, consumer motivation

Abstract

With mass adoption and a "cleaner" electric power mix, battery electric vehicles (EVs) and plug-in-hybrids (collectively plug-in electric vehicles, PEVs) can significantly reduce the CO_2 emissions from transportation and the local air pollution hazard confronting a large number of Americans who live near busy roads. While fuel costs and tax breaks are the most oft-cited incentives for PEV ownership, PEVs bring additional benefits to consumers. Depending on the vehicle, PEVs can be: convenient to charge, as they are typically fueled overnight at consumers' residences rather than at public stations; inexpensive to fuel and to maintain (e.g., electric motors have less parts than traditional engines, 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 these benefits and considerable investments by OEMs in PEVs, plus great interest by U.S. electric utilities, U.S. market expectations for PEVs are dampened by concerns about low consumer salience, given sustained low oil prices and the improved fuel economy of traditionally-fueled vehicles, as well as reduced incentives at the State and Federal level. Under these circumstances, growing the U.S. market for PEVs to increase their public and private benefits requires understanding how consumer behavior relates to the PEV purchase process. In this paper, we structure a research review on this subject using a framework that is well-established in academic marketing circles but is novel in the context of the PEV purchase process. The purpose of this approach is to highlight what is well known about this process and reveal important knowledge gaps for future research.

Introduction

U.S. energy and environmental policy has long been shaped by a recognition that light duty vehicles (LDVs) are both a significant consumer of U.S. petroleum imports and a significant source of air pollution that contributes both to immediate public health hazards as well as to longer-term threats like climate change. Policy responses to the energy security and environmental challenges posed by traditionally-fueled LDVs have generally taken forms that target the technology or the economics of transportation energy (see, e.g., Eckard 2012). Such technocratic policy approaches have had many successes, including a substantial increase in LDV fuel efficiency and reduction in tailpipe and evaporative emissions.

There has also been significant progress in the development of alternative-fuel vehicles, and in particular, vehicles that are at least partially fuelled by electricity (Anair and Mahmassani 2012). These "plug-in electric vehicles" (PEVs) include hybrid electric vehicles (HEVs), in which the electricity comes from the car's battery, as recharged by the car's systems, as well as plug-in hybrid electric vehicles (PHEVs) and battery-electric vehicles (BEVs), in both of which the electricity to charge the car's battery comes primarily from stationary power sources. From an air pollution mitigation perspective, PEVs have greater potential than HEVs because lower-carbon sources can be used to generate their electrical fuel (Axsen and Kurani 2013). Meanwhile, according to the National Academy of Sciences

(2015), the consumer value proposition underlying PEVs is now superior to traditionally-fueled vehicles on criteria such as: "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." Contrast this to the situation as recently as 2001, when PEVs were considered to be poor substitutes for traditionally-fueled LDVs, with major concerns regarding high price, limited range, long re-charge, lower capacity, low speed and acceleration, and a lack of charging infrastructure (Garling and Thøgersen 2001).

Despite this tremendous progress in PEVs, the U.S. market has not grown at the rates hoped for by those who see significant PEV substitution for traditionally-fueled LDVs as at least necessary, if not sufficient, for a more sustainable transportation sector (e.g., U.S. Department of Energy 2011). Although the U.S. has the world's largest fleet of PEVs, there are worrying signs in the market. EV sales dropped 6% from 2015 to 2016 (Shepardson 2016) while a noticeable number of HEV and PEV owners traded in their vehicles for traditionally-fueled vehicles over the same time period (LeSage 2016). These trends are often attributed to lower and more certain gas prices since mid-2013 or to the improved fuel efficiency of traditionally-fueled vehicles in compliance with tighter fuel economy regulations (see, e.g., Santulli 2015). These possible explanations focus on technical and economic reasons for weak consumer demand for PEVs, but other forces may also be at play. For example, consumer decisions are often influenced by both consumer-specific factors (e.g., demographic, psychological, emotional, etc.) and by factors external to the consumer (e.g., the context of the purchase, the influence of other people/society, etc.). Qualitative research specific to sustainable transportation has shown that a range of non-technical and economic factors can be particularly important to PEV consumers (e.g., symbolism of PEV purchase, environmental prioritization, "perks" of PEV purchase, such as car-pool passes; see, e.g., Egbue and Long 2012).

The policy relevance of such "soft" aspects of consumer behaviour is becoming more obvious to transportation policymakers, in part due to several co-existing trends. First, behavioural economics has captured the public imagination through popular books and other media (e.g., Thaler and Sunstein 2009, Heath and Heath 2010). Second, the power of behaviour and decision science insights to shape good policy outcomes gained institutional acceptance within the federal government under the Obama Administration, through innovations like the White House Social and Behavioural Sciences Team. Third, a number of "clean" technologies are starting to reach a level of maturity that makes consumer acceptance a greater barrier to purchase than vehicle cost and performance. Finally, recent U.S. consumer behaviour change in the area of transportation has been noticeable in trends like declining per capita vehicle miles travelled, increased public transit ridership, increased utilization of car-sharing options, and declining driver's license rates amongst younger Americans (Greenberg et al. 2010).

Research framework

This paper uses a decision science framework drawn from consumer behaviour research to provide structure to a broad, interdisciplinary review of the various literatures (e.g., academic journals, government agency reports, manufacturer publications, etc.) that address the traditional vehicle and PEV purchase process. The purpose of this approach is to highlight what is well known about the purchase process and reveal important knowledge gaps for future research. Note that consumer behaviour research draws from several social sciences applicable to the analysis and modelling of the PEV market, such as economics, psychology, sociology, and anthropology, disciplines which provide theories, models, and lenses that can be used to reveal the complex relationships and tensions at play in any given consumer decision.

CONSUMER DECISION PROCESS MODEL

The consumer decision process model we use here is a modified version of the framework described in Engel, Kollat, and Blackwell (1968) and Darley et al. (2010) (the "EKB" Model). In general, this framework (Figure 1) disaggregates the vehicle purchase process into five distinct steps, which we briefly describe below: problem recognition, search, alternative evaluation, purchase, and post-purchase (Johnston 2016).

Problem recognition is the step in the purchase process in which the consumer identifies a gap between his/her current and ideal situations. Considered relatively under-researched, problem recognition initiates the purchase process, and the other steps are dependent on it. Internal and external stimuli can motivate a consumer to undertake a purchase (Johnston 2016). As framed by Punj and Srinivasan (1992), consumer purchase motivations can be divided into: new need (e.g., due to a life event); product depletion; expected satisfaction with a newly introduced product; and current dissatisfaction with an existing product.

Search is the second step in the purchase process; it is the step in which a consumer seeks and processes information about possible solutions to his or her purchase-related problem. This step affects a consumer's perception of the available alternative purchase options and evaluative criteria (see, e.g., Glowa 2001). During the search process, consumers consult various internal and external information sources and process the resulting information as a partial function of the quality of their connection to that information (e.g., exposure, attention, comprehension, acceptance, retention, etc.). Note that internal information sources are those in the consumer's mind, where memories may be based on direct experience or on other factors (e.g., advertising). Meanwhile, external information sources include: friends and family, third-party reviews, official business sources, direct experiences with products (e.g., test drives), and online resources (see, e.g., Klein and Ford 2003). Consumers typically weight internal information and information from friends, family, and other consumers more highly than information from business sources. The search process, and the level of involvement a consumer has with the process, is shaped by such factors as: choice complexity, significance of perceived differences between brands, value of purchase, and level of uncertainty.

Alternative evaluation is the third step in the purchase process. In it, consumers compare available options on objective characteristics (e.g., product function, features, etc.) and subjective characteristics (e.g., feelings elicited, product aesthetics, etc.). Specific evaluation methodologies vary by consumer, but can be broadly grouped into compensatory and non-compensatory decision rules (Hauser, Ding et al. 2009). A compensatory decision rule involves the consumer "trading off" good and bad attributes of a product (e.g., low price might

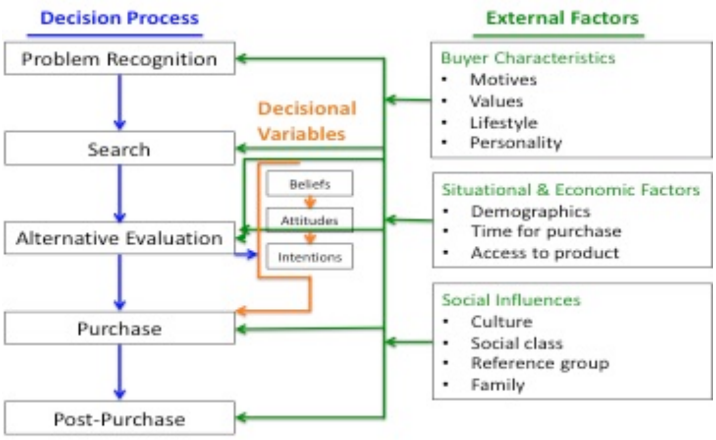

Figure 1. Modified EKB Model of the Consumer Decision Process, with External Factors.

override an ugly colour). A non-compensatory decision rule involves a non-negotiable attribute (e.g., only all-wheel drive vehicles will suffice). The results of the alternative evaluation step can be defined as follows: an "evoked set" (i.e., potential purchases); an "inept set" (i.e., products with no chance of purchase); and an "inert set" (i.e., consumer has no strong opinion). Many of the relevant studies in the transportation literature focus on consumer alternative evaluation by employing surveys, focus groups, and/or interviews. A significant number of studies in the literature are formal preference studies (e.g., stated, revealed, etc.), which can be modelled using discrete choice techniques (e.g., multinomial logit, probit, etc.).

The actual *purchase* is the fourth step in the purchase process. In it, the consumer decides whether or not to buy a product from the evoked set. The translation from alternative evaluation to purchase actualization is influenced by consumer beliefs, attitudes, and intentions, as well as by such factors as the quality of the retail experience, the availability of promotions, and the offered terms and conditions for sale or lease. 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 behaviour is the fifth step of the purchase process. In it, the consumer uses the product and evaluates, over time, his/her feelings about the purchase and whether the product met pre-purchase expectations. Post-purchase product satisfaction shapes consumer heuristics regarding products, helping to simplify future product information search and alternative evaluation (e.g., around a brand). Post-purchase product dissatisfaction can create a negative heuristic for future purchases that will reduce information search by associating the unsatisfactory product or brand with the inept set; this is especially likely to occur when there is a large difference between expectation and experience. Because consumer satisfaction with a purchase plays a major role in future buying behaviour, companies make significant investments to improve the post-purchase experience, including offering product guarantees and providing customer service (Cho, Im et al. 2002).

All steps of the decision process are affected by a combination of factors, including consumer characteristics (e.g., lifestyle, values, personality, etc.), situational and economic variables (e.g., income, life events, etc.), and social influences (e.g., social class, cultural identification, influence of family and friends, etc.). In addition, there is potential for feedback between decision process steps (e.g., while comparing alternatives, a consumer may redefine the problem and alter his/her search criteria).

Application to PEV literature

We now turn to the state of knowledge regarding PEV adoption and utilization to date, as presented in existing journal articles, government agency reports, and trade publications and tied to the modified EKB model of consumer decision-making.

PROBLEM RECOGNITION

As framed by Punj and Srinivasan (1992), differences in consumer motivations to undertake the purchase process can be used to divide the car buyer population into four distinct segments: new need; product depletion; higher expected satisfaction; current dissatisfaction. "New need" consumers may have been previously satisfied with their current vehicle (or their non-vehicle status), but a life event may reveal the need or desire for a vehicle to serve a different purpose. In the context of vehicle purchase, "product depletion" consumers either need to replace a broken car or prefer not to drive an aged vehicle. Consumers entering the purchase process in the "higher expected satisfaction" segment are largely satisfied with their current vehicle and either want to add to their household fleet or expect to gain some additional benefit by upgrading to a new car. Consumers experiencing "current dissatisfaction" recognize the need to begin the vehicle purchase process due to unreliability or excessive cost of an existing vehicle. This group is distinct from "product depletion" in that the previous vehicle generally still meets the consumer's needs, but the consumer recognizes that it soon may not. Punj and Srinivasan (1992) found "new need" and "product depletion" groups to differ significantly from the others in terms of several pre-search, search, alternative evaluation and post-purchase satisfaction variables, demonstrating the role of problem recognition in shaping later stages of the purchase decision.

In Figure 2, we apply Punj and Srinivasan's categories of motivations to the results of an internet survey on reasons for new vehicle purchase conducted by Mintel Group in 2014. The survey responses cover all four categories, although most appear to be related to "higher expected satisfaction."

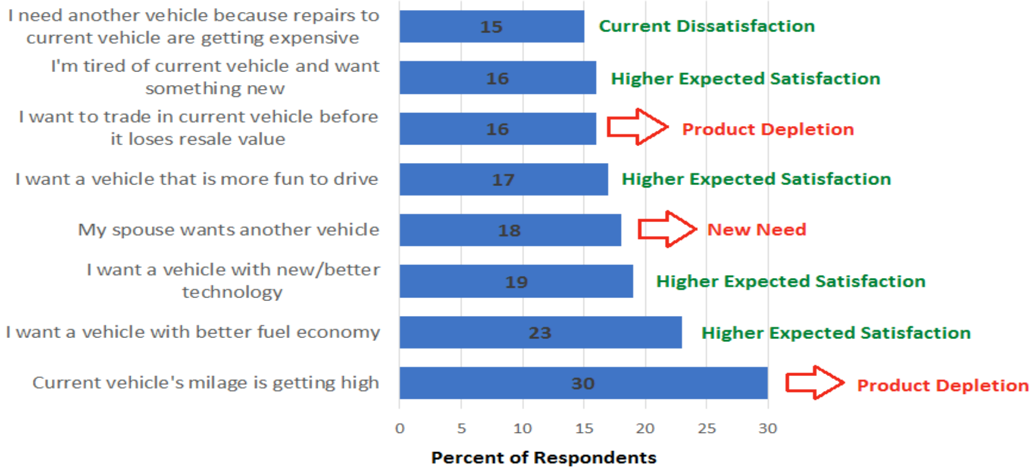

Figure 2. Reasons for Purchasing a Vehicle (Mintel Group, Ltd, 2015).

We suggest that future studies of consumer reasons for choosing PEVs could benefit from expanding questions and/or answer sets to align with this useful framing. In attempting to apply this framing to the results of a study regarding PEV acquisition in California (Santulli 2015), we found that none of the reported survey responses fall into the categories of "product depletion" or "new need." It is unclear whether these motivations were grouped into a small category of "other reasons" in the study, if the study did not capture these motivations, or if consumers with such motivations do not buy PEVs.

SEARCH

As mentioned above, consumers consult both internal and external information sources in the search step.

While it is difficult to concretely describe the internal search process, it is possible to explore consumer familiarity with PEV availability and functionality, and to infer how this knowledge base contributes to PEV purchase decisions. For example, Singer (2015), finds that approximately half of survey respondents can name a specific PEV make and model or report having seen PEVs in parking lots. However, over 40 % of respondents believe they have never been in or near a PEV, while very few are aware of charging stations locations. Only 20–24 % of respondents state that they are likely to consider a BEV or PHEV for their next vehicle acquisition, suggesting that PEVs are unlikely to fare well in the internal search process (i.e., most consumers may not realize a PEV could meet their needs and thus will not search for additional information on PEVs). Similarly, Kurani et al. (2015) find limited consumer awareness of electric drive range, charging infrastructure, and incentives.

Given the variety of brands, models, and options available, external search for any vehicle purchase has the potential to be extensive, taking significant amounts of time and involving online research as well as dealership visits (National Academy of Sciences 2015). The costs involved in researching a PEV purchase are even greater due to consumer unfamiliarity with the technology.

Here we consider the treatment of PEVs in the major external information sources for vehicle purchase: test drives, third-party ratings, recommendations from family and friends, and online research. First, test drives are of limited utility for the PEV purchase if a car dealership has few, if any, PEVs available for test drive (true of most U.S. car dealerships – see Cahill 2015) or if the consumer is unable to experience the charging process. PEV manufacturers have attempted several approaches to overcome such problems. In one example, General Motors (GM) and the Department of Energy (DOE) collaborated to place Chevy Volts in the fleets of public utilities for months-long trial periods (Francfort, Bennett et al. 2015). In another example, Chevy Volts were offered for 3-day test drives (National Academy of Sciences 2015). The GM-DOE trial of Volts in public utility fleets showed that using PEVs in an organization's fleet provides not only lower fleet energy costs to the organization, but also gives employees an opportunity to gain fluency with the charging process, which is often a barrier for potential consumers. A stated choice experiment by Jensen et al. (2014) suggests that direct experience with EVs, implemented in the form of a three-month trial, significantly increases consumer preference for the vehicles. Corporate, rental, government, and point-to-point car-sharing fleets could all potentially be leveraged to increase PEV exposure in the general population. Second, independent ratings agencies (e.g., Consumer Reports, Ward's Automotive) tend to list traditional vehicles by size with PEVs at the end, perpetuating the illusion that PEVs are an entirely isolated category of vehicle, rather than a subtype of vehicles within existing size classes. The extent to which this is a problem is easily discerned through A/B testing of web page click-throughs, although we are unaware of such testing, to date. Third, recommendations from friends and family are less useful in the PEV purchase than in the traditionally-fueled vehicle purchase due to inconsistent deployment of PEV across the U.S. Still, neighbourhood effects and the influence of social networks are important features of PEV diffusion (e.g., Zhu and Liu 2013) and could probably be strengthened. Fourth, although a plethora of websites provide information that could aid consumers in the PEV purchase process, it is unclear to what extent consumers are aware of, make use of, or are confused by these internet sources (National Academy of Sciences 2015). According to the National Academy of Sciences (2015), some of the information available online includes: make and model availability, prices, technical specifications, reviews, and comparisons between PEV models and similarlysized traditionally-fueled vehicles; locations of public charging stations; lists of PEV incentives by state or zip code; estimates of total cost of PEV ownership; interactive cost calculators; and insights into the everyday reality of PEV ownership and operation. The plethora of online sources of information on PEVs include websites hosted by: PEV manufacturers; PEV dealers; PEV enthusiasts; general car-buying organizations, such as Kelley Blue Book and Edmunds; electric utilities; non-profit environmental organizations; and federal and state agencies.

ALTERNATIVE EVALUATION

Consumers evaluate available vehicle options on objective and subjective characteristics. As noted by Sovacool and Hirsch (2009), within the consumer's evaluation of alternatives, PEVs may face a combination of technical barriers as well as "more subtle impediments relating to social and cultural values, business practices, and political interests." While the evaluation methodology will vary by consumer, there are several useful generalizations that can be used to systematically describe the process of alternative evaluation.

Many studies on transportation choices in the academic and other literatures aim to reveal the consumer alternative evaluation process and consumer values by employing surveys, focus groups, and/or interviews. A significant number of these studies are formal preference studies (e.g., stated, revealed, etc.), which can be modelled using discrete choice techniques (e.g., multinomial logit, latent class utility). Consumers display many strategies in choosing from available product portfolios. A *compensatory* decision rule involves the consumer "trading off" good and bad attributes of a product (e.g., low price might override an ugly colour), while a *non-compensatory* decision rule involves a non-negotiable attribute (e.g., consumer requires six passenger seats). A vehicle that fails to satisfy consumer needs in respect to a non-compensatory decision rule is likely to be removed from further consideration.

Table 1 provides a summary of some of the ways the PEV literature considers the consumer evaluation of PEVs.

It is interesting to contrast the pros, cons, and consumer bottom line regarding PEVs in Table 1 against the evaluative criteria used for the general LDV purchase process. In a recent new owner survey (Strategic Vision 2013, N=300,000), the top reasons for LDV purchase overall were found to be: reliability, durability, quality of workmanship, value for the money, and manufacturer's reputation, with perceived vehicle reliability a non-negotiable attribute for many consumers (this is potentially very important when considering the prevalence of distrust of new technologies in the PEV literature). Although a substantial share of consumers claimed that fuel economy was an important factor in the vehicle purchase, it was generally ranked lower than such considerations as dependability, comfort, and safety. This was true even in periods of high gasoline prices. With gas prices around $4 per gallon, reliability was a primary consideration for 68 % of potential buyers, while fuel economy was a primary consideration for only 45 %; even seating comfort was more important to new vehicle purchasers (Strategic Vision 2013). In addition, only 5 % of consumers who purchased a vehicle stated they were willing to pay a higher price for an environmentally-friendly vehicle.

Data from "rejecters" (who considered PEV, but did not buy) suggests they applied traditional reliability and durability criteria to the decision and expressed concerns about the technology and batteries (National Academy of Sciences 2015). These findings resonate with those of Singer (2016), who finds PEVs are primarily eliminated from consideration due to high purchase price (i.e., perceived to be a poor value).

Returning to Table 1, we note that studies on consumer evaluation of PEVs do not tend to touch on issues of quality of workmanship, value for the money, and manufacturer's reputation. It is unclear whether these are not significant issues for consumers in reference to PEVs or if researchers have simply failed to frame their questions to capture this information.

PURCHASE

The vehicle purchase decision is influenced by the characteristics of the evoked set of vehicles, as well as other factors such as the quality of the retail experience and the specific terms of sale or lease.

Regarding the quality of the retail experience, we note that it can be very influential in a consumer's product choice, which can change at the time of purchase for several reasons, including: vehicle availability, incentive for a competing product, lack of necessary funds, negative critique of proposed purchase by

Table 1. Research on Consumer Evaluation of PEV Pros and Cons.

PEV Pros	PEV Cons
– "Peppy" drive, smooth acceleration, quiet – Less/no oil changes (Voelcker 2013, Voelcker 2014) – Electric motors are more efficient than gasoline engines – Cost savings and reduced maintenance costs (Ingram 2013) – Incentives (Sierzchula, Bakker et al. 2014) – "Green" (Krupa, Rizzo et al. 2014) – Plug-in hybrid SUVs can maintain good towing capacity	– Range (e.g., Daziano 2013, Lin 2014) – Resale value unknown (Zhou, Santini et al. 2016) – Uncertainty about PEV "greenness" (NAS 2015) – Distrust of new technology (Egbue and Long 2012) – High battery cost (Hidrue, Parsons et al. 2011) – Consumer discounting of future fuel cost savings (Hidrue, Parsons et al. 2011)
Research on Consumer Bottom Line Evaluation	
– "Favorable" or "very favorable" impressions declined between 2009 (62 %) and 2012 (55 %) (Pike Research 2012) – Interest in PEV is predominantly shaped by consumers' perceptions of PEV cons (Carley, Krause et al. 2013) – Probability of PEV purchase can be increased by providing total cost of ownership comparison to consumers (Eppstein, Grover et al. 2011, Dumortier, Siddiki et al. 2015) – Recent literature suggests a wide range in consumer valuation of fuel economy (Greene 2010) – Limited availability and unfamiliarity prevent many from trying and purchasing PEV (Stephens 2013, Voelcker 2014) – Some view fuel economy in terms of cost savings and as a signal of conservation values (Turrentine and Kurani 2007)	

peers, etc. Vehicle availability and other aspects of the dealership experience can significantly affect whether or not a consumer follows through on the purchase of a PEV. Evarts (2014) finds many dealers had fewer than ten PEVs on their lots, while (U.C. Davis 2014) finds that 65 % of California's dealerships had zero PEVs for sale. The problem of low PEV availability is compounded by the fact that PEV sales are more complex for dealers than traditionally-fueled LDV sales. PEV sales require specialized sales force knowledge, as demonstrated by Evarts' finding that PEV knowledge levels are generally low, with typically one or two "gurus" in high-volume dealerships serving as customer points-of-contact for PEV-related questions. The complexity of PEV sales for dealers can be proxied by the amount of time required for each sale: 56 % of PEV buyers make three or more visits to dealerships, twice the average of buyers of conventional vehicles (Cahill, Davies-Shawhyde et al. 2014). Findings suggest that the purchase process is not leaving customers satisfied, even if they are satisfied with the vehicle they purchase; Cahill et al. (2014) finds that 45 % of consumers report that they are "very dissatisfied" and 38 % "dissatisfied" with the purchase experience. 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.

Regarding the terms of sale or lease, we note that leasing is used comparatively more often in PEV acquisition than in LDV acquisition overall, although this varies by type of PEV, with Tesla a notable exception (Strategic Vision 2013). There is also considerable variation in the prevalence of leasing across geographic regions; for example, California PEV acquisition involves leasing at a higher rate (28.8 %) than in the overall U.S. new-vehicle market (20–24 %) (see, e.g., Rai and Nath 2014). One reason for the high rate of PEV leasing may be that leasing agencies are able to incorporate federal income tax incentives more rapidly compared to a consumer navigating tax deductions after purchase (National Academy of Sciences 2015). Importantly, leasing provides an opportunity to test PEV technology in everyday conditions at a substantially reduced level of risk compared to outright purchase.

Sales tracking data provided through DOE's Alternative Fuels Data Center suggest that the market for PEVs has expanded over the past five years in terms of annual number of vehicles purchased and diversity of PEV models offered for sale. In 2011, the Nissan Leaf and Chevy Volt were the only PEV models widely available in the U.S., with approximately 20,000 units sold annually. By 2015, the PEV sales volumes had more than quadrupled, and a plethora of new PEV models are now available from a wide cross section of major vehicle manufacturers, with the Leaf, Volt, and Tesla Model S accounting for about half of all PEV sales.

As PEVs are a relatively new technology, many consumers may be adopting a "wait-and-see" attitude toward it. The generalized decision science topics of decision avoidance and choice deferral apply to PEV purchases, given the prevalence of consumers "waiting for the technology to advance" (National Academy of Sciences 2015). These tactics include relying on the default option (Johnson and Goldstein 2004, Baron and Ritov 2009, Heidenreich and Kraemer 2015), anchoring (Ben-Elia and Avineri 2015), and engaging in inaction inertia (Tykocinski, Pittman et al. 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. Of these five factors, difficulty of selection and time pressure were the most important causes of consumer delay.

Exploring the demographics of current PEV adopters (as compared to buyers of all LDVs) reveals opportunities for increases in near-term adoption (Liu, Cooke et al. 2011). As Kurani et al. (2007) suggest, while current PEV adopters may not perfectly represent today's mainstream consumers, their behaviour and viewpoints provide insights into the future valuation and use of PEVs by other consumers. In terms of buyer attributes, for example, Caperello et al. (2014) find 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. There are significant differences in buyer demographics across common PEV models. Female buyers make up a larger share of buyers of the plug-in Toyota Prius, which represents only a slight deviation from a mainstream HEV in terms of technology and operation, while buyers of EVs are predominantly male (Strategic Vision 2013). Existing studies of PEV buyer demographics reveal intersections between PEV purchase and gender, as well as PEV purchase and household income; the majority of PEV buyers so far are wealthy, highly educated, married males (de Haan, Peters et al. 2006). 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. Graham-Rowe et al. (2012) identify numerous barriers to PEV adoption by mainstream consumers, including prioritization of personal mobility over environmental benefits, concerns over the social desirability of PEVs, and the expectation that imminent technological innovation will render current models obsolete.

POST-PURCHASE

In evaluating consumer satisfaction with a PEV purchase, including whether it has met *ex ante* expectations, the following post-purchase factors are considered to be potentially important: charging experience, appreciation/status associated with vehicle characteristics, newly formed practices around driving and charging, range anxiety, perceived reliability, and resale value. Reducing consumer uncertainty or enhancing consumer satisfaction along any of these dimensions may increase the probability of repeat PEV purchases by any given consumer and may increase the likelihood of positive PEV exposure in that consumer's social circles (e.g., through neighbourhood effects, social marketing, etc.).

Given the newness of the technology, PEV charging currently carries more practical and social complications than refuelling a traditionally-fueled vehicle, although this gap is closing as the number of PEVs on the road increases. The consumer experience with PEV charging is influenced by: availability of charging locations, cost to charge, network effects, and perceptions of charging etiquette (Caperello, Kurani et al. 2013). Numerous studies find that increasing public charging infrastructure accessibility can promote PEV use (Dong, Liu et al. 2014). Smart

(2014) finds that PEV drivers with access to home charging and workplace charging have considerably higher annual electric vehicle miles travelled (eVMT) than average for all PEVs, and their eVMT exceeded the national average annual total vehicle miles travelled (VMT), suggesting that workplace charging encourages and enables the use of PEV for commute purposes. An estimated 46 % of new PEV buyers are without convenient home-charging access because they park on the street or live in multi-unit housing, however (Axsen and Kurani 2012). Total average costs of home-charging infrastructure vary by region and by configuration of existing residential electricity systems, but are in the range of $1,000–$2,000 (Smart 2014).

Charging stations are also available to PEV drivers at a variety of locations, including public parking lots and garages, retailer parking lots, transportation hubs, hotels, and educational facilities (Smart 2014). Public charging stations may be free to use or charge a nominal fee based on the period of time a vehicle is plugged in. Beyond any fees for plugging in, public charging facilities present a range of complications, including limited hours of operation, parking fees, and restricted access. Parking spaces in front of charging units may be inaccessible due to construction, non-PEV vehicles occupying the parking spot, or other PEVs occupying the spot but not charging. Driver uncertainty regarding the etiquette of interactions with other PEV drivers, the acceptable length of time to occupy spaces, and the unplugging of another's PEV further complicate public charging (Caparello et al. 2013). Charging unit maintenance and reliability is also a major factor impacting the PEV driving experience.

Research on typical travel behaviour using LDVs suggests that the current ranges typical of PEVs are more than sufficient for the majority of trips; 71 % of trips are 10 miles or less in length and only one percent of trips cover greater than 100 miles (Federal Highway Administration 2011, Smart 2014). A sizable 2009 investigation of trip lengths by travel purpose arrives at similar results, finding an overall mean trip distance of slightly less than 10 miles, and mean trip lengths for a variety of purposes (e.g., work commute, shopping or errands, travel to/from school, etc.) in the range of 5 to 25 miles, well within the capabilities of most PEV models (Federal Highway Administration 2011). Of relevance to range anxiety, Turrentine et al. (2011) found that PEV instrumentation indicating the remaining electricity stored is imprecise. Accuracy of "miles-to-empty" indication is also complicated by the impact of speed, driving style, and ambient temperature on battery capacity and rate of discharge. Based on the typical trip lengths revealed by travel logs and other studies, it appears that range is primarily a psychological barrier. Franke et al. (2012) found that people base their anticipated range needs on their most recent long trip, rather than everyday driving behaviors. Numerous studies suggest that range anxiety decreases with exposure to PEVs. Golob and Gould (1998) found that after only two weeks of EV use, households did not change their desire for additional range, but Franke et al. (2012) found that range anxiety decreased as drivers adjusted to driving EVs over a 6-month period. Rauh et al. (2014) found that experienced EV drivers had a lower threat appraisal, higher self-confidence, and less range stress. Similarly, Shaheen et al. (2008) report that high levels of PEV exposure led to more realistic range expectations. Also, networks of charging infrastructure have recently substantially expanded in many urban centers; higher density and visibility of charging will allay lingering range anxiety, as drivers gain confidence that they will not be stranded.

Little research on PEV resale value is available so far, but some is beginning to emerge. The Consumer Reports Annual Auto Survey (2016) provides some insights into the market for used PEVs. Consumer Reports currently lists 16 used hybrids as "Good Bets," only one of which includes the plug-in 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. Hybrid vehicles (non-plug-in) provide a useful proxy for the performance of PEVs in the used car market. HEVs have historically depreciated at lower rates than most types of LDVs, particularly during periods of high gas prices. EVs are simpler from a mechanical perspective, with fewer moving parts (e.g., combustion engine components) to potentially fail. Of greatest concern is the longevity of PEV batteries, which can cost $6,000 to $10,000 to replace, although costs are falling.

Conclusion

PEVs are gaining traction among some consumers as a viable alternative to traditionally-fueled LDVs. However, PEV purchasers to date tend to be early adopters living in urban, affluent neighborhoods, primarily in States that follow California's Zero Emissions Vehicle mandate, while many mainstream mass-market consumers remain uncertain about the suitability of PEVs for their driving needs. We have reviewed the various literatures addressing the PEV purchase process through the lens of a consumer behaviour/decision science framework by applying a modified version of the EKB Model to frame major themes in findings and reveal knowledge gaps. We now present some concluding thoughts with respect to potential opportunities to increase PEV uptake, continuing to use the EKB Model structure.

Problem recognition: When a consumer recognizes that he or she needs to purchase a new vehicle, it is unlikely that he or she will do so because of expected satisfaction with a PEV versus any LDV. PEVs are not widely advertised outside of certain niche locations and customer segments. In addition, in external information sources PEVs are often treated as a discrete class, rather than as simply another option in the realm of available small- to mid-size vehicles. Treating PEVs as something "other" likely exacerbates a barrier to increased adoption by reinforcing consumer notions that PEVs cannot readily replace traditionally-fueled vehicles.

Recommendation: i) Identify new market segments of consumers who would have a particularly high preference for some of the positive aspects of PEVs that may not be widely known (e.g., would value the convenience of home-charging, would appreciate ease, low cost of maintenance). *ii)* Test consumer response to the format of PEV information presentation.

Search: Internal search is relatively understudied with respect to the PEV purchase process, but is likely to be particularly important to those who buy with little time to research a purchase, those who default to heuristics regarding brand, etc. External search is important but many questions remain about which websites, types of information, etc., are most effective in encouraging PEV purchase.

Recommendations: i) Initiate a new research effort focused on how internal search plays a role in blocking and/or facilitating PEV diffusion; *ii)* Conduct systematic analyses regarding the various online external information sources that are available to consumers. *iii*) Develop and evaluate new ways to provide consumers with direct driving and charging experience.

Alternative evaluation: Researchers are already making use of survey, interview, focus group, and related methods to explore consumer preferences and perceptions regarding PEVs. However, there appear to be some gaps in the range of questions asked, and in some cases, the framing of PEV purchases in some information sources may unintentionally focus attention on the "otherness" of PEVs.

Recommendations: i) Fill in the gaps by including questions related to: existing experience in gas stations (compare/contrast with charging); existence of "new need" or "product depletion" motivations for PEV purchase, etc. *ii)* Consider creating guidelines for future PEV surveys to improve coordination with previous analyses; *iii)* Make better use of existing survey data via meta-analysis techniques.

Purchase: PEV purchasers so far have tended to be early adopters in affluent urban areas, with limited charging infrastructure (public and private) deterring many mainstream consumers.

Recommendations: i) A network analysis could determine how closed-off the various niches of the U.S. are from one another, which could reveal pathways through which PEV diffusion can be encouraged; *ii)* PEV marketing and consumer preference studies have so far focused heavily on factors related to EV range and environmental benefit. A better understanding of consumer appreciation of non-energy and range aspects of PEVs (e.g., acceleration, performance, ability to forego gas station trips, lack of engine noise, safe handling, etc.) could help to more comprehensively frame the value proposition to consumers; *iii)* Further investigate consumer procrastination around the PEV purchase process; *iv)* Investigate strategies to better facilitate home charging at the time of sale to reduce costs and reassure potential buyers.

Post-purchase: Public and workplace charging can crucially expand daily PEV driving range (and reduce range anxiety), compared to at-home charging alone. However, consumers can be intimidated by away-from-home charging, in terms of finding and using unfamiliar charging facilities and the social etiquette of doing so.

Recommendation: Further study of public PEV charging behaviour, particularly in terms of community-developed systems of etiquette and instances of under- or mis-utilization of public charging. Findings from studies of this type can guide the development of best practices in terms of recommended etiquette guides to provide to prospective PEV buyers and recommendations for charging site managers to streamline the process of public charging.

Finally, PEV resale is relatively new and understudied, both in terms of disposition of previously-leased vehicles, and of the purchase of used PEVs by inexperienced consumers.

Recommendations: i) Focus research attention on the market for used PEVs. Encouraging a strong market for used PEVs has the benefit of encouraging repeat purchasers and can expose a broader range of consumers to PEVs (note that most vehicle purchases in the U.S. go through the secondary market); *ii)* Focus research on the PEV post-lease experience, including off-lease purchase and factors influencing repeat PEV leasing.

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