



Original research article

## Symbolism, signs, and accounts of electric vehicles in California

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## ABSTRACT

Conceptual frameworks regarding the spread of new ideas and products through a relevant social group posit communication is necessary between those few group members who are first to act upon the new idea or product and the many more potential later actors. In the case of plug-in electric vehicles (PEVs), achieving potential social goals regarding human health, climate, air quality and energy requires many more households become PEV owners and users than have so far. Workshops were convened with PEV owners and owners of internal combustion engine and hybrid vehicles (collectively, non-PEVs) in three regions throughout California representing different levels of PEV sales and charging infrastructure deployment. Participants guided the creation of their workshop's agenda: non-PEV owners stated their questions about PEVs; PEV owners added more they wanted to tell about PEVs and about themselves becoming and being PEV owners. In the subsequent conversations, PEV owners constructed “accounts”—both in the sense of (informally) tallying the costs of buying a PEV and in the sense of telling a story of their lives with PEVs. Their storytelling conveyed the signs of PEVs: how PEVs, charging infrastructure, and incentives are (to PEV owners) an obvious suite of symbols and what those symbols mean (to PEV owners). In effect, the PEV owners teach the owners of non-PEVs a new symbol system and in doing so enhance the non-PEV owners' ability to see, hear, and interpret the signs of PEVs. Routinely, but not universally, among the non-PEV owners learning the symbol system of PEVs produces more positive evaluations of PEVs.

### 1. Introduction

The case for why a transition to electric power should be made in the transportation sector has been made for multiple reasons across many constituencies including global climate change (for example, [1]) and air quality (national, e.g., the US, [2], regional, e.g., cities in China, [3], and across sub-sets of populations within any such geo-political units, e.g., by income and ethnicity in the US [4]). Whether for climate, air quality, or any other social benefit, the light-duty vehicle sector is essential to meeting goals in highly motorized nations. For example, in the US the light-duty transport sector created approximately 17% of total CO<sub>2</sub> equivalent greenhouse gas emissions in 2015 [5]. In the US, approximately 120,000 plug-in electric vehicles ((PEVs), a category including both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs)) were registered new in 2014 [6], amounting to 0.7% of new light-duty vehicle sales that year. PEV sales rose to 194,000 in 2017 [6], or approximately 1.1% of new sales. Cumulative PEV sales from 2011 to 2017 in California amount to approximately 1.5% of the stock of on-road light-duty vehicles. As California is the US state with the highest PEV sales—it has routinely been estimated to account for half of US PEV sales—the PEV stock figures for the US for

2017 must be less than California's. It remains the case that many more PEVs will have to be sold than already have if electrifying light-duty transport is to succeed in securing social benefits.

In the US, households buy (or lease) most light-duty vehicles. Toward understanding whether and how more households would acquire PEVs, this article addresses communication between those who have already acquired PEVs and those who have not. Communication between PEV owners and between PEV and non-PEV owners—as told by PEV owners—has been previously reported. TyreeHageman et al. [7] describe the use of social media by and among early PEV owners. Encounters of people who are not PEV owners with both PEVs [8,9] and with the process of becoming PEV owners [10] have been reported. Burgess et al. [11] discuss encounters between PEV drivers and non-PEV owners with the distinction that the PEV drivers were not PEV owners, but drivers in a trial. Further, Burgess et al. [11] only report from the PEV drivers. While Axsen and Kurani [12–14] also study drivers in a PEV trial, they report from both sides of conversations between PEV drivers and members of their social networks (outside their immediate households). Axsen et al. [15] also report on conversations among PEV drivers (in an extended trial) and between drivers and their social networks.

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A series of reviews has summarized the growing literature on consumer response to PEVs and to some extent fuel cell electric vehicles (FCEVs). These reviews include (in reverse chronological order) [16–19]. Commonly, people who have already purchased PEVs are labeled “early adopters,” often intentionally invoking Rogers’ diffusion of innovations framework [20]; examples include studies in Germany [21] and Japan [22]. Changing the language but adhering to distinguishing between consumers who have purchased PEVs and those who have not, a study from Canada distinguishes between “pioneers” (PEV buyers) and a “potential early mainstream” [23]. Within the group of early buyers of PEVs in the US, Hardman et al. [24] divides them into “high-end” and “low-end” based on the wide gulf in price and performance between make-models of PEVs offered for sale circa 2011–2014. Rather than reserve “early adopter” for those who have already purchased a PEV, Morton et al. [25] apply this label to one of five clusters they propose form potential market segments in the UK.

### 1.1. Communication, symbols, and electric vehicles

One signal of the importance Rogers ascribed to communication between early and later actors is he changed the name of his seminal book *Diffusion of Innovations* [26] to *Communication of Innovations* [27] for its 2nd edition. (He changed it back for all three subsequent editions.) Different researchers hypothesize communication between early actors and as-yet-to-be-actors differently. In their review, Axsen and Kurani [12] explore four forms of communication and an overarching context that may spread information about PEVs: diffusion, conformity, dissemination, and translation, all potentially operating within a reflexive context. They find information flows between drivers of PEVs and owners of non-PEVs more likely entail translation (i.e., “the social negotiation of the meaning and benefits of a new technology or behavior) and reflexivity (i.e., “dynamic, continuous, self-aware process of defining and expressing oneself, guided by one’s efforts toward a sense of order, direction, and development”) [12]. In the preface to his fourth edition [20], Rogers presages this more complicated view: “...other types of diffusion are more accurately described by a convergence model, in which communication is defined as a process in which the participants create and share information...”

Mechanisms of communication—e.g., conformity, contagion, and threshold effects—have been modeled or simulated in the context of PEVs and hydrogen fuel cell electric vehicles (FCEVs). Mau et al. [28] claim mixed evidence for a “neighbor” effect through the estimation of a discrete choice model on data from a split-sample design in which the market share of PEVs and FCEVs is varied across respondents. However, as Mau et al. [28] specified no social or geographic distance as market share varied, the results seem more apropos to threshold effects, i.e., the aggregate number of PEV or FCEV owners. Eppstein et al. [29] use an agent-based model (ABM) that simulates homophily—a tendency to associate with others who are more like oneself and therefore reinforces conformity. Kangur et al. [30] also use an ABM that incorporates both an explicit spatial distance between agents as well as conformity by assigning agents to networks based on spatial distance, socio-economic, demographic, and psychological measures.

Germane to a discussion of communication is language, or more generally systems of symbols. Heffner et al. [31] studied symbolism in the early market for hybrid electric vehicles using Saussure’s model of signs [32]: dyads of signifier and signified, i.e., a symbol and its meanings. Adopting this approach here, many “things” of and about PEVs, including those that may also be seen as functional or instrumental, are symbols of PEVs in addition to any abstract symbol systems such as written texts or spoken words: PEVs themselves, charging infrastructure, incentives, policies, etc., distinguished by whether they are exhibited or spoken as a matter of public outreach or private marketing. The same signifier may convey multiple signified meanings depending on the messenger and the recipient. For example, a monetary rebate on the purchase of a PEV has an instrumental value in

whatever currency it is offered, but may also mean something different depending on whether it is offered by a government or an automobile manufacturer and whether the rebate is observed by someone inclined to perceive it as a positive sign of support or a negative sign of the relative weakness of a fledgling socio-technical system compared to the strength of the incumbent.

That the valence of the signified meaning of a signifier may be positive for some people and negative for others is an extension of Barthes’ [33] layers of interconnected meanings of signs reported in Heffner et al. [31]. Denotations are widely-shared meanings associated with a signifier; connotations are more subjective meanings that involve interpretation of a signifier and its signified denotations by individuals or smaller groups (than share the associated denotation). That different people assign different denotations to the same sign and derive different connotations from the same denotation reveals complex translation and reflexive reinterpretation, in the language used by Axsen and Kurani [12]. Differences in the valence of the signs of an innovation may be part of what distinguishes early from potential later actors.

Dittmar’s [34] typology of instrumental, symbolic, and affective motivations has been used to describe the purchase and use of automobiles generally [35,36] and PEVs’ specifically [37–39]. All three may be communicated symbolically with varying success; as they invoke embodied reactions, affective or emotional attributes may best be conveyed via direct experience. For example, while it may be communicated to someone via spoken or written words that PEVs have good acceleration such symbolic representations are unlikely to elicit the same response as the physical sensation of acceleration. Still, efforts to convey affective or emotional attributes via symbol systems is another example the “non-symbolic” being made symbolic.

The signified meanings of PEVs have been both assumed and explicitly studied, largely at the level of broadly shared denotations. Articles on PEVs and consumers, for example this one, routinely start by establishing some social, sustainability or environmental *bona fides*—associating PEVs with these ideas broadly, or clean air and reduced climate change more specifically. Analysis then proceeds to assess whether people who buy or are inclined to buy a PEV are likely to have, for examples, pro-environmental values [40], lifestyle practices [41], and identities [42]. While the meanings that Ivory and Genus [43] argue were applied to battery electric vehicles at the turn of the 19th–20th centuries may or may not apply today, their review of the “signification of objects” usefully furthers the argument here that automobiles and PEVs symbolize meanings and the reading of those meanings affects who will (or won’t) acquire them, and when.

Most denotations assigned to hybrid electric vehicles (HEVs) by their owner [31], e.g., preserve the environment, oppose war, manage personal finances, reduce support to oil producers, and embrace new technology, have been confirmed for PEVs by previous research. For example, Krupa et al. [44] concludes being “on the forefront of new technology” is a denotation of PEVs. White and Sintov [45] attempt to expand the denotations available to PEVs to include technological innovator and social responsibility—as the latter would include ideas included in “reduce support to oil producers.” Perhaps because of the wording of their survey statements, they find evidence to support an amalgam of these two. That PEVs might be a financially sound choice is less explored—hinting at a pervasive acceptance of a narrative that PEVs are expensive to buy and may not recoup the upfront expense through operating cost savings. In retrospect, the denotation “oppose war” ascribed to HEVs by some owners [31] may indicate the role of historical context; at that time, the US had re-entered into war in Iraq for the second time in not much more than ten years.

The possible meanings of PEVs have been further opened to the “self” in the correspondence between self-identity and the uptake (or not) of PEVs. Skippon et al. [46] assume these meanings are captured by the big five personality factors [47]: openness, conscientiousness, extraversion, agreeableness, and neuroticism. Along these lines,

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