



## Original research article

# Confusion of innovations: Mainstream consumer perceptions and misperceptions of electric-drive vehicles and charging programs in Canada



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## ABSTRACT

Consumer demand is an important aspect of a successful transition to low-carbon technology—where consumers must have basic awareness and understanding of a technology in order to purchase and use it. In this study we explore consumer knowledge, confusion and perceptions for two related technology cases: plug-in electric vehicles (PEVs) and a program that allows the electric utility to control the timing of PEV charging to support renewable electricity. We focus on “Mainstream” vehicle buyers, who differ from the first PEVs buyers. We conducted semi-structured interviews with 22 new-vehicle buying households in the greater Vancouver area of British Columbia, Canada. Overall, participant awareness was very low for both technologies; most participants were confused about hybrid and plug-in hybrid technology and did not understand the sources of electricity that PEVs might consume. Once the case technologies were explained, most participants expressed a wide range of positive and negative perceptions of both, which we categorize into a framework of perceived functional (e.g. cost and performance), symbolic (e.g. “strangeness” and loss of control), or societal (e.g. pollution reduction) attributes. We conclude with suggestions of how research and policy can consider and further examine the roles of knowledge and perceptions in markets for low-carbon technologies.

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## 1. Introduction

*“What’s the deal here? You don’t plug this in, the hybrid?” – Clair (interviewee)*

*“That gets pretty complicated, when you start talking about [balancing the grid].” – Andreas (interviewee)*

Integrating the adoption of plug-in electric vehicles (PEVs) with the deployment of renewable electricity would improve the environmental potential of each and may in fact be necessary to achieve greenhouse gas (GHG) emissions reductions at a large scale [1–3]. What individuals and households know and perceive about PEVs and renewable electricity could have a significant influence on the extent to which these technologies are purchased or utilized. However, many studies that model or simulate the potential environmental benefits of vehicle-grid integration tend to assume that most or all consumers will willingly purchase PEVs and take part in controlled charging programs—without empirically-informed

representation of consumer behavior and motivation [4–6]. This paper explores the potential role of consumer knowledge and perceptions in such a technological transition. Specifically, we use semi-structured interviews to explore “Mainstream” consumer knowledge and perceptions regarding the uptake of two case technologies: PEVs and utility controlled charging programs which are framed as a means to support renewable electricity deployment.

We define a PEV as any vehicle that has the ability to be propelled by electricity and is recharged from an external power source. In North America, PEVs can be charged using either a regular outlet (110 V) or specialized electric vehicle supply equipment (240 V–480 V). PEVs include electric-only vehicles (sometimes called battery electric vehicles or BEVs) and plug-in hybrid electric vehicles (PHEVs). Conventional hybrid-electric vehicles (HEVs), such as the conventional Toyota Prius hybrid, are not considered to be PEVs—but we include them in our study because we find that consumers’ understanding of PEVs often relates to their understanding (or misunderstanding) of HEVs.

We define utility controlled charging (UCC) as a program in which the electric utility has some degree of control over the charging of a PEV’s battery, controlling either the timing of charging or direction of electricity flow to a PEV’s battery. While a UCC pro-

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gram could offer multiple benefits such as cost savings due to more efficient management of electricity load, we focus on the potential to facilitate the integration of intermittent sources of renewable electricity, *e.g.* such a system might defer PEV charging to occur when there is a surplus of wind energy being provided to the grid [7–9]. In this study we intentionally use the term UCC to refer to a broad range of technological protocols, including unidirectional “smart charging systems” (sometimes called “V1G”), as well as bidirectional vehicle-to-grid (V2G) systems [10]. UCC is an emerging technology that is currently limited to smaller demonstration projects, and has not yet been implemented on a commercial scale anywhere in North America. Although we did not expect most “Mainstream” consumers to have previous experience with a UCC system, we explore consumer awareness and understanding of related concepts, such as the sources of electricity as well as the idea that the “timing” of charging a PEV might have different environmental or financial impacts. Presumably, such insights could inform future UCC program development. In our definition of renewable electricity, we focus on intermittent utility-scale wind, solar photovoltaic (not rooftop solar panels), and small-scale hydro; we do not include large-scale hydroelectric dams.

We define “Mainstream” consumers as the general population of new vehicle buying households that have not purchased a PEV. Empirical research demonstrates that such Mainstream buyers are likely to have less awareness and understanding relative to the early buyers of PEVs (or “Pioneers”) that tend to have high enthusiasm for pro-environmental technology [11,12]. It seems important to better understand Mainstream buyers’ perceptions (and misperceptions), as these would be the “next” buyers of PEVs if the technology achieves further market penetration—and even more important if PEV adoption is to reach the kind of sales trajectory identified by the International Energy Agency as necessary to keep global GHG emissions within a 2 °C target, *i.e.* reaching 40% of new passenger vehicle market share by 2040 [13].

To elicit Mainstream consumers’ perceptions in their own words, we follow a qualitative research approach. Specifically, we conducted 22 semi-structured interviews with Mainstream new vehicle buying households in British Columbia, Canada. These interviews were part of the larger Canadian Plug-in Electric Vehicles Study (CPEVS) described in Axsen et al. [11], which included interviews and surveys with Mainstream and Pioneer (PEV-owning) participants. Our goal is to better understand how these Mainstream consumers think about these case technologies, including their confusions and misperceptions, without judging or deriding participants. In short, our research objectives are to:

1. Assess participant knowledge (awareness, familiarity, and understanding) of the case technologies, and
2. Identify participants’ perceptions of functional attributes (what it does), symbolic attributes (what message it conveys), and societal attributes (what it means for society) of the case technologies.

## 2. Literature review and conceptual framework

In this study we explore Mainstream buyers’ knowledge and perceptions of plug-in electric vehicles (PEVs) and utility controlled charging (UCC) programs (combined with renewable electricity). Knowledge is defined here as what a consumer knows about the technology, including: i) awareness as the extent to which they are conscious that a technology or an attribute exists, ii) familiarity as how well acquainted they are with the details of a technology, and iii) understanding as their comprehension of a technology’s implications and how it operates. We define perceptions as what a consumer thinks about a technology – including the attributes

they perceive and how these are evaluated. Perceptions can be functional, symbolic, or societal as described below, following a framework established by Axsen and Kurani [14] and since applied by others to categorize consumer perceptions of low-carbon technology, including PEVs and renewable energy systems [15–17]. We do not presently address consumer preferences or the construction of preferences, but note that when consumers come into contact with a novel technology, they tend to construct their preferences as they learn about it and its attributes [18,19]. The notion of constructed preference suggests that consumer awareness, familiarity, and understanding of a novel technology will shape their learning and valuation of the technology.

For emerging technologies such as PEVs and renewable electricity, knowledge is likely to be imperfect or non-existent among Mainstream buyers for several years after its introduction to the market, and perhaps even longer. Axsen et al. [11] found that the majority of Mainstream survey respondents in Canada were unclear about what a PEV was and how it was operated, such as understanding how a PHEV differs from a BEV or conventional hybrid. Note that regular hybrid vehicles had been available for sale in North America for over 10 years at the time of data collection (2013), indicating that confusion and lack of awareness can persist long after commercial introduction of low-carbon technology. Similarly, Krause et al. [20] found that US consumers were confused about the basic features of PEVs such as their appearance, range, and costs. For renewable electricity, Ozaki [21] found that some UK study participants were not aware that their utility offered the option of paying voluntary tariffs to support renewable electricity (when indeed their utility did provide that option), and Salmela and Varho [22] found that Finnish interview participants identified a lack of knowledge about the environmental impacts of electricity production as a reason for not purchasing renewable electricity. In sum, consumers’ knowledge may be mistaken or uncertain, and consumers may not be aware that technologies exist or have certain attributes.

As a consumer becomes aware of the technology, they can form perceptions about a number of attributes. We use the framework noted above to categorize perceptions of pro-environmental technology attributes as functional, symbolic, or societal [23]. Functional attributes, defined as perception of what the technology does for the individual, are undoubtedly important in influencing consumer decision-making. These attributes tend to be the primary focus of many analyses; PEV market studies commonly assess consumer perceptions and valuation of the functional attributes of PEVs such as operating cost, driving (battery) range, and recharge time (*e.g.* [20,24–26]). However, PEV interest (and interest in passenger vehicles more generally) is typically driven by other factors as well.

The second category is symbolic attributes, defined as perception of what message or messages the technology conveys, which can also influence consumer choices [27]. Schuitema et al. [28] found that UK consumers’ intentions to adopt PEVs can be positively influenced by an expectation of feeling proud to own one, or inversely, negatively influenced by an expectation of feeling embarrassed to drive one. Heffner [29] showed that US consumer purchases of HEVs could be viewed as actions that communicated a self-image of intelligence, caring about others, or supporting national energy security. On the electricity side, Ozaki [21] found that demonstrating the importance of environmental issues to peers was an important factor in the decisions of some UK consumers to adopt voluntary renewable electricity tariffs. In one study directly assessing Canadian consumers’ response to UCC, Bailey and Axsen [30] found that some consumers were concerned about privacy and loss of control—relating to trust in their electric utility and their motivation to preserve a sense of control. Although symbolism can be a very powerful driver of consumer behavior, note

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