

How policy can build the plug-in electric vehicle market: Insights from the respondent-based preference and constraints (REPAC) model

Jonn Axsen^{1*} and Michael Wolinetz²

¹*School of Resource and Environmental Management, Simon Fraser University, 8888 University Drive, Burnaby, B.C. Canada V5A 1S6.*

²*Navius Research, PO Box 48300 Bentall Vancouver BC Canada, V7X 1A1*

** Corresponding author. , Tel: +1 778 782 9365 Fax: +1 778 782 4968, E-mail: jaxsen@sfu.ca*

Short Abstract

To forecast electric vehicle sales, we develop the REspondent-based Preference and Constraint (REPAC) model. We elicit consumer preferences based on data collected from 531 new vehicle-buying households in Canada. REPAC adds real-world constraints based on awareness and charging access data, and adds supply constraints representing limited PEV variety and availability. REPAC's baseline ("no-policy") forecast for annual PEV sales is 1% new market share up to 2030. Forecasts for 2030 range from 1-10% with demand-focused PEV policies in place (e.g. purchase subsidies), while strong supply-focused policy is also required to achieve 2030 market shares over 30% (i.e. a Zero-Emissions Vehicle mandate).

Publication note: While we wish to present this material at EVS29, we would like to omit our paper from publication as findings have already been submitted to another journal.

1 Introduction

Some models indicate that in a country like Canada, the majority of all passenger vehicles will need to be plug-in electric vehicles by 2050 to meet regional climate change mitigation goals, with PEV sales growing rapidly from 2025 onward [1]. A given region needs to understand how to forecast and influence PEV sales in order to inform the design of effective climate policy, to anticipate recharge infrastructure needs, and to plan an electricity grid that can evolve with the transportation sector (e.g. to facilitate controlled charging or vehicle-to-grid regimes). Thus, we see two primary goals for a PEV market share forecast model: 1) to anticipate the size and composition of the PEV market, and 2) to understand how to influence that market through policy.

However, forecasts of alternative-fuel vehicle sales are inherently uncertain and often unduly optimistic. A scan of PEV market literature yields a wide range of forecasts, where in "no policy" scenarios, PEVs make up as little as 1% of new vehicle market share out to 2030, or up to 5% of new market share as early as 2020 [2, 3]. Studies in the grey literature can be even more optimistic, forecasting PEV sales of 17-28% in 2020 and 30-70% in 2030, primarily driven by sustained reductions in PEV battery costs [4, 5]. Clearly, policymakers and decision-makers need to be cautious when forecasting PEV sales as well as planning how to influence their adoption. To improve understanding of PEV forecast models, Al-Alawi and Bradley [6] summarize and compare dozens of modeling studies including those using agent-

based models [e.g., 2] and discrete choice models [e.g., 7]. The authors conclude that most models provide a poor representation of consumer behaviour, fail to represent the supply of vehicles (i.e. automaker decisions) and neglect to fully represent the effects of national and regional policy.

Given our stated objective of policy relevance, it is especially important for a PEV forecast model to represent the full spectrum of policy options. However, of those models that explicitly represent policy, the vast majority only include demand-focused policies that seek to increase consumer interest in PEVs, notably purchase subsidies and increased recharging infrastructure. However, supply-focused policies can also be very powerful, as they instead put direct pressure on vehicle or fuel suppliers to develop, market and sell PEVs. Examples include California's Zero-Emissions Vehicle (ZEV) mandate and low-carbon fuel standard. Policymakers ought to be informed about the relative effects of demand-focused and supply-focused policies.

In this paper we present a PEV market share model that seeks to address the limitations of past models noted by Al-Alawi and Bradley [6]. We call this the REspondent-based Preference And Constraint (REPAC) model, which is based on a rich set of survey data we collected from a sample of 531 new vehicle buying households in British Columbia, Canada, as part of the Canadian Plug-in Electric Vehicle Study [8]. The REPAC model is "respondent-based" because it is informed by these survey data and represents each individual survey respondent. REPAC's market share forecasts are based on elicited measures of respondent preference for vehicle class and PEV type (via a latent-class discrete choice model), then applying real-world constraints including PEV familiarity and supply constraints (including PEV model variety and dealership availability).

In the remainder of this paper we provide a more detailed literature review, and then further explain the REPAC model including survey data collection and its three sub-models. We then demonstrate how the model can be used to simulate PEV market share under various policy scenarios and discuss the implications of these findings on policy development and future research in PEV forecasting.

2 The model

The REPAC model seeks to combine the strengths of three modelling approaches (constraints models, choice models, and agent-based models), while addressing the recommendations provided by Al-Alawi and Bradley [6] to produce policy-relevant PEV adoption forecasts. REPAC consists of three sub-models. The discrete choice model estimates the probability that each respondent will choose each vehicle drive train type (i.e., conventional, hybrid, PHEV or BEV) in the absence of constraints on the choice. The output of this sub-model should be thought of as unconstrained demand or "latent" demand—preferences that are not actually realized as PEV demand due to constraints. The vehicle model describes the cost and performance of the archetypal vehicles (one for each drivetrain) that we use to set up the choice model attributes. Finally, the constraints model represents the factors that prevent the unconstrained demand of each respondent being realized as sales, including lack of familiarity with PEVs, lack of home recharge access, and lack of PEV supply (e.g. that none or few PEVs in a given vehicle class are available from a local auto dealership).

3 Results and Discussion

In the "no-policy" baseline scenario, the total unconstrained demand for PEVs is 23% of new market share in 2020. However, the constrained demand for PEVs is less than 0.5% in 2015, rising to roughly 1% in 2020. Figure 1 illustrates the individual and combined effect of each constraint in the REPAC model in 2020. Constraining demand to the 54% of respondents with reliable home charge access reduces PEV demand to 14% of sales. Limiting PEV sales to those 22% of respondents that are currently familiar with PEVs reduces the PEV new market share to 6%. Applying the PEV availability constraint results in a 6.5% new market share. Applying all three constraints in the baseline "no-policy" scenario results in a PEV new market share of roughly 1% in 2020, with little change in that market share through to 2030.

Figure 1 Impact of REPAC constraints on PEV new vehicle market share, 2020

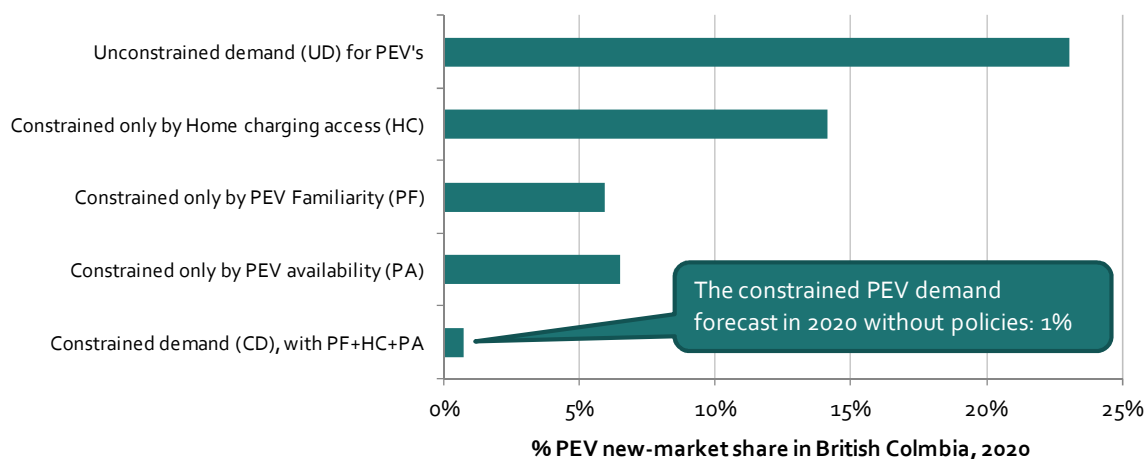
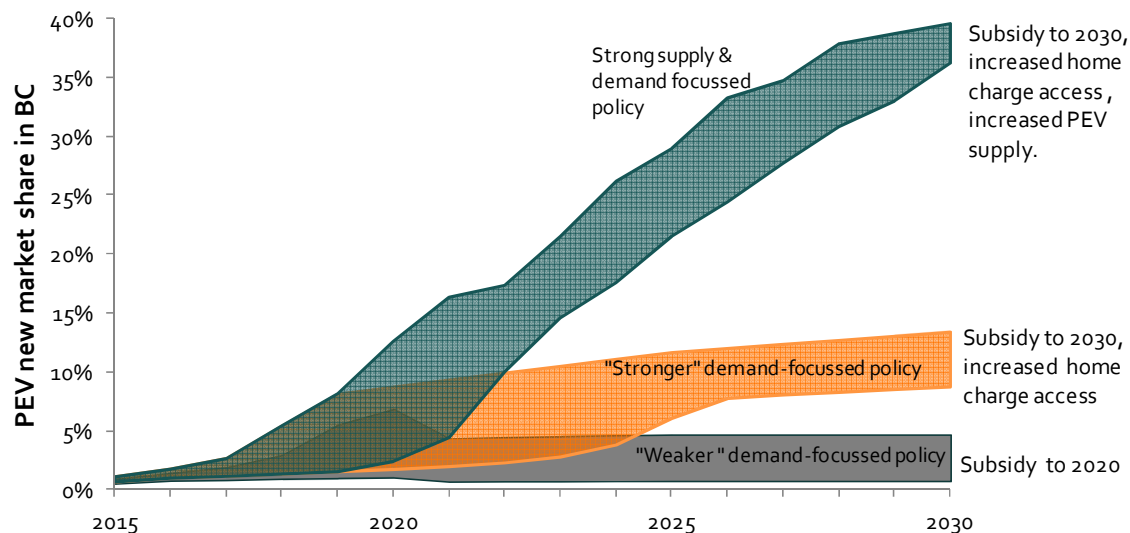


Figure 2 depicts the PEV new market share forecast in each of the three policy scenarios for 2015 to 2030. The shaded areas represent the uncertainty in the forecast resulting from variation in two uncertain parameters. In the “weaker” demand-focused policy scenario, the short-term PEV subsidy (2015-2020) results in a PEV new market share between 1-5% by 2020 and 2030, showing only a slight increase from the baseline “no-policy” scenario. The “stronger” demand-focused policy scenario (maintaining the subsidy to 2030 and increasing home charging access) increases PEV new market share to 2-8% in 2020 and 8-14% by 2030. When we add the supply-focused policy that approximates the effects of a ZEV mandate (which increases the variety of PEV models from 20 to 50), the PEV new market share forecast reaches 36-40% by 2030.

Figure 2 PEV new market share under policy scenarios (with shading representing uncertainty in the rate at which PEV familiarity changes and the extent to which PEV availability constrain sales)



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Authors

Dr. Jonn Axsen is an Assistant Professor at Simon Fraser University. He explores transitions to sustainable energy systems. He draws from disciplines of economics, psychology, sociology and engineering to investigate the nexus of technology, environmental policy, and consumer behaviour. Jonn's study of consumers' social valuation of plug-in electric vehicles has earned him recognition as "Young Researcher of the Year" at the OECD's 2011 International Transportation Forum. His specific research interests include: adoption of pro-environmental technology; electric mobility and alternative fuel vehicles; consumer attitudes, values, lifestyle and social influence; citizen acceptance of energy and policy; energy system simulation modelling; and climate policy design and impacts



Michael Wolinetz is a senior partner with Navius Research, specializing in energy modeling in Vancouver, British Columbia. He completed his Master's in Resource Management at Simon Fraser University. He enjoys applying quantitative methods to better understand the interaction between policy, economics, technology and the environment.

