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Consumers continue to be confused about electric vehicles: comparing awareness among Canadian new car buyers in 2013 and 2017

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Abstract

Despite policy support and technological progress, consumer adoption of electric vehicles remains limited globally. One important barrier to electric vehicle adoption may be limited consumer awareness. We investigate trends in consumer awareness, familiarity, and experience with electric vehicles by comparing cross-sectional survey responses from two representative samples of Canadian new vehicle-buyers collected in 2013 ($n = 2922$) and in 2017 ($n = 1808$). While a significantly higher proportion of 2017 respondents have 'heard of' key electric vehicle models, stated familiarity and experience are low for both samples. Further, about three-quarters of respondents in both samples are confused about the basic notion of how to refuel (or recharge) electric vehicles—and how these vehicles differ from hybrids. Conversely, over half of 2017 respondents report having seen at least one electric vehicle charger in public, which is more than double the proportion reported in the 2013 sample. These trends hold in analyses of three Canadian provinces, including two that have engaged in significant consumer outreach activities over this time frame. Overall, in contrast to expectations, our results suggest that consumer awareness remains low and stagnant, which may hinder market growth and inhibit the climate mitigation potential of electric vehicles.

Introduction

Although plug-in electric vehicles (PEVs) hold substantial potential to reduce tailpipe greenhouse gas emissions from passenger vehicles [1, 2], their market share remains limited globally [3]. Note that by PEV we include battery electric vehicles (BEVs) powered by electricity only and plug-in hybrid electric vehicles (PHEVs) which can use both gasoline and grid electricity. As of 2018, PEVs comprised 2%–4% of new passenger vehicle sales in many Western countries, including the UK [4], France [5], the USA [6], and our case region of Canada [6]. Thus, the ability of PEVs to serve as climate mitigation technologies is inhibited by their relatively low rates of diffusion. Commonly cited explanations for low PEV market share include lack of recharging infrastructure, high purchase prices, inadequate vehicle supply, short driving ranges, long recharging time, and limited consumer awareness [7–10].

Here we focus on consumer awareness of PEVs, given that widespread deployment of PEVs in the passenger vehicle market hinges (in part) on consumers' awareness of their existence and basic understanding of how they are operated [11]. Illustrating the importance of PEV awareness, an empirically-based modeling study of Canadian consumers finds that potential demand for PEVs in 2015 could have been as high as 12% of new market share, but lack of consumer awareness, among other constraints, limited actual sales to just under 1% [12]. Further, research finds that higher PEV awareness predicts greater interest in purchasing a PEV [13, 14].

Published consumer research on PEVs has tended to focus on consumer valuation of the technologies and their attributes, with little focus on consumer awareness or understanding (e.g. [15–17]). In fact, much of the stated preference research assumes or implies 'perfect information' among consumers—that car buyers have knowledge of all vehicle options and

defined valuation of their attributes. The few qualitative and quantitative studies that do explore consumer awareness find it to be quite limited. Qualitative interviews conducted in the US in 2008 [18] and Canada in 2013 [19] find that mainstream car buyers are confused about how PEVs are operated, and how BEVs compare to PHEVs, as well as how both compare to hybrid vehicles. Additional qualitative research conducted in California in 2014 observes that some car buyers are even unaware that PEVs are available for sale, and after learning about PEVs, participants state that lack of awareness is a 'main hurdle to PEV sales' [20].

On the quantitative side, a 2011 US survey finds that two-thirds of respondents misunderstand PEVs' basic features, such as their typical electric driving range [9], and a 2015 US survey finds that 65% of respondents cannot name a BEV that is available for sale in the US [13]. A 2016 survey of US consumers finds that while 96% of respondents are aware that PEVs exist, only half consider themselves 'familiar' with them [21]. Repeated surveys of US citizens implemented in 2015 [22], 2016 [23], and 2017 [24] find that a minority (though slightly increasing number) of consumers report having been a passenger in a PEV (16%–19% from 2015 to 2017) and having driven a PEV (5%–8% from 2015 to 2017). We note that [24] is the one study that we are aware of that compares awareness trends, though this study does not systematically compare samples, is of US citizens (rather than car buyers), and exists in the grey literature only (i.e. it is not peer-reviewed). Although not assessing awareness, a recent longitudinal study of US drivers finds that intention to adopt a PEV is increasing over time [25].

In short, published research has yet to characterize potential differences in consumer awareness of PEVs over time. While one might expect that consumer awareness of PEVs has been increasing as sales, model variety, policy, and overall market experience increase, it is not clear if such learning is actually occurring among mainstream consumers. In an attempt to fill this gap, this study compares results from two similar, in-depth online surveys conducted in 2013 ($n = 2922$) and 2017 ($n = 1808$). Both surveys were completed by representative samples of Canadian new vehicle-buyers (excluding French-speaking Canada), defined as those who plan to purchase (or have recently purchased) a new vehicle, but did not own a PEV at the time of the survey. We operationalize PEV awareness through four different measures: (1) self-reported familiarity with PEVs, (2) understanding of how to fuel PEVs, (3) experience with PEVs, and (4) awareness of public PEV chargers. Our starting hypothesis is that all measures of awareness will be higher among 2017 respondents, given the Canadian context of growth in PEV sales (from 0.2% to 1.1% of new vehicle sales during that time), increased model diversity (from eight to 34 models available for sale in different parts of the country), and increased implementation of PEV-supportive policies in some regions between 2013 and 2017. Further, as PEV adoption and policy varies by province in Canada, we compare awareness trends in three provinces that have had differing levels of PEV adoption and policy support during the study period. The purpose is to assess if the national trends we observe hold at the regional level (though we do not perform a sophisticated analysis on whether a given policy might cause differing levels of awareness).

Method

Survey design

In this article, we draw upon data from two surveys: the Canadian Plug-in Electric Vehicle Survey (CPEVS-2013), implemented in 2013, and the Canadian Zero-Emissions Vehicle Survey (CZEVS-2017), implemented in 2017. Both are in-depth, web-based surveys that consist of several components. Respondents were recruited by a market research company asking them to complete a survey related to their 'household vehicles and use, transportation needs and interest, and thoughts on new vehicle technology'. For detailed explanations of the survey designs, see [26], regarding CPEVS-2013, and [27], regarding CZEVS-2017.

We focus on four questions in each survey, each of which we consider to be a different measure of consumer PEV awareness. The questions are phrased similarly in the 2013 and 2017 versions, but in most cases include slight differences in the vehicle technologies or models considered, as well as the response options presented. For example, CZEVS-2017 asked respondents to consider hydrogen fuel cell vehicles in addition to hybrids, PHEVs, and BEVs in several questions whereas CPEVS-2013 did not. We only analyze responses that are directly comparable and as such, we do not believe the slight differences in survey questions confound the results. The questions we consider for each measure of PEV awareness are as follows:

(1) Self-reported familiarity with PEVs: 'How familiar are you with the following vehicles or technologies? For example, do you know how you would drive and refuel them?' Responses were recorded on a five-point scale ranging from 'Not at all familiar' to 'Very familiar'.

(2) Understanding of how to refuel common PEV models: 'Some of these vehicles only use gasoline, some only use electricity from an electrical outlet, and some can use both. How do you think that each of the following vehicles can be fueled?' Respondents were asked to select the correct fuel option for several vehicle technologies and models from a list of fuel options ('only gasoline,' 'only electricity from being plugged into an electrical outlet,' 'either

gasoline or electricity from being plugged into an electrical outlet,' or 'I don't know').

(3) Experience with PEV models: 'Please indicate your experience with each of the following vehicle models.' Respondents selected all the possible experiences ('I've seen one,' 'I've spoken with the owner of one,' 'I've driven or been a passenger in one', and 'I want to buy one') that applied to them for several vehicle models.

(4) Awareness of public chargers: 'Have you seen any electric vehicle recharge stations at parking spots or spaces that you use?' From a list of possible locations, respondents indicated all the locations they have seen a charger.

Data collection

Samples for both surveys were recruited using market research companies, who provided respondents with a financial incentive (approximately CAD$20) to participate. For CPEVS-2013, the sampling frame was consumers who had purchased a vehicle within five years prior to completing the survey and those who use a vehicle regularly, and the survey was implemented in most Canadian provinces (excluding French-speaking Canada, due to translation costs). The CZEVS-2017 sampling frame consisted of consumers who intend to purchase a new vehicle within 12 months of completing the survey, and was implemented in all Canadian provinces, including in French-speaking regions using a French translation of the survey. For this paper, we exclude French-speaking respondents from the CZEVS-2017 sample so that our national analysis compares only samples from the same regions.

Table 1 displays the characteristics of both samples and the Canadian Census. Compared to the Census, both samples are slightly older, and the CZEVS-2017 sample is older on average than the CPEVS-2013 sample. The CZEVS-2017 sample has a higher mean and median income than both the CPEVS-2013 sample and the Census, which is consistent with Canadian trends that observe an annual increase of 1%–2% in household income [28]. Both samples also have higher education levels than the Canadian population and higher rates of home ownership. It is typical of new vehicle-buying households to be slightly older and have higher levels of education, income, and home ownership than the general population (e.g. as found by [15, 29]).

Data analysis

All analyses were performed using IBM SPSS statistical software (Version 24). For each of the four survey questions, we depict the frequency of responses in the 2013 and 2017 samples and perform chi-square tests of association to evaluate potential significant differences in proportions between the samples. We also calculate 95% confidence intervals for each proportion, and note that proportions with overlapping confidence intervals can still be significantly different [30]. We perform the same analysis on the subsamples of respondents from Alberta, British Columbia, and Ontario in our exploration of regional variation. We also perform a one-way analysis of variance (ANOVA) to test for significant differences in awareness proportions between subsamples from the three provinces, including Tukey post-hoc tests to identify which provinces specifically differ from one another.

Both surveys included some regional oversamples (i.e. British Columbia and Alberta in CPEVS-2013, and British Columbia, Quebec, and Ontario in CZEVS-2017). To produce comparable national samples for each dataset, we calculated and applied regional weights to correct for these oversamples. We calculated weights by comparing the proportion of the sample from each province to the proportion of Canadian population in each province (in 2013 and 2017), and applied the corrective weights at the provincial level as needed.

Results

Consumer familiarity, understanding, and experience

Figures 1–3 summarize several measures of consumer awareness for the entire Canada samples (regionally weighted to represent all English-speaking new car buyers). Survey questions asked about several commonly sold PEV models, as well as the Toyota Prius (a hybrid) for comparison, and PEV technology more generically.

As summarized in figure 1, significantly more respondents in 2017 have 'heard of' the Toyota Prius (a hybrid), Chevrolet Volt (a PHEV), and Nissan Leaf (a BEV), compared to the 2013 sample. In 2017, almost all respondents have heard of these models (81%–96%, by model), including the Tesla Model S (a BEV), which was only asked about in the 2017 survey. However, respondent reports of familiarity with these models and technologies follow a much different pattern. For each model and technology in both samples, stated familiarity is low, ranging from 17% to 31% of respondents. Further, there is no evidence of higher familiarity among 2017 respondents; in fact, stated familiarity is significantly lower in the 2017 sample for the Toyota Prius, as well as for hybrid, PHEV, and BEV technologies more generally.

The survey instruments assessed consumer understanding of PEVs by asking respondents to identify the correct refueling methods for the same vehicle models as above—with options consisting of 'only gasoline,' 'only electricity from being plugged into an outlet,' 'either gasoline or from being plugged into an electrical outlet', and 'I don't know.' For each of the four vehicle models (in 2013 and 2017, respectively), only a

Table 1. Demographic characteristics of the CPEVS-2013 and CZEVS-2017 samples, and of the Canadian Census.

	CPEVS-2013 Sample	CZEVS-2017 Sample	Canadian Census[a]
Year	2013	2017	2016
Sample size	2922	1808	35 151 728
Age (of person filling out the survey)			
34 or younger	35%	25%	30%
35–44	19%	18%	16%
45–54	18%	21%	17%
55–64	16%	21%	17%
65+	11%	15%	20%
Mean age	43	47	41
Median age	43	48	41
Household income (pre-tax)			
<$40 000	16%	15%	26%
$40 000–$59 999	21%	17%	16%
$60 000–$89 999	27%	25%	20%
$90 000–$124 999	24%	22%	16%
$125 000+	12%	21%	22%
Mean income	$77 372	$83 808	$76 403
Median income	$74 444	$81 600	$70 336
Gender			
Female	55%	44%	51%
Male	45%	56%	49%
Highest level of education completed (of person filling out the survey)			
Other	20%	16%	45%
College, CEGEP, or other non-university diploma	44%	32%	42%
University degree (Bachelor)	24%	31%	16%
Graduate or professional degree	11%	21%	8%
Residence type			
Detached house	64%	65%	59%
Attached house (e.g. townhouse, duplex, etc)	16%	12%	12%
Apartment	16%	22%	28%
Mobile home	2%	1%	1%
Residence ownership			
Own	75%	78%	68%
Rent	25%	22%	32%
Number of people per household			
1	12%	19%	28%
2	37%	41%	34%
3	21%	20%	15%
4+	29%	20%	22%
Vehicle ownership[b]			
0	—	4%	12%
1	45%	50%	42%
2	44%	39%	34%
3+	10%	7%	11%

[a] Census data available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E.
[b] Vehicle ownership data obtained from Natural Resource Canada's 2007 Survey of Household Energy Use.

minority of respondents correctly identified the refueling method for the Toyota Prius (11% and 13%), Chevrolet Volt (33% and 25%), Nissan Leaf (24% and 23%), and Tesla Model S (41% for 2017 only) (figure 2). Again, there is no evidence of higher understanding in the 2017 sample—in fact, understanding is

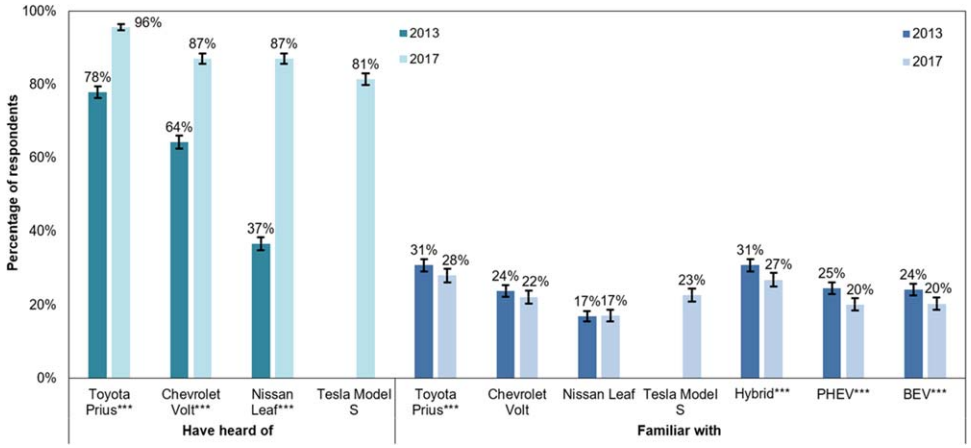

Figure 1. Self-reported familiarity with the Toyota Prius (hybrid), Chevrolet Volt (PHEV), Nissan Leaf (BEV), Tesla Model S (BEV) and general hybrid, PHEV, and BEV technologies. 2013 sample size: $n = 2922$; 2017 sample size: $n = 1808$. Error bars represent 95% confidence intervals, and asterisks represent proportions that are significantly different at the $p < 0.01$ (***), $p < 0.05$ (**), and $p < 0.1$ (*) level, as assessed by chi-square tests of association. (Note that overlap between confidence intervals does not negate the possibility for significant differences to exist between proportions [30]). For familiarity, we combine responses of 'moderately familiar' and 'very familiar.'

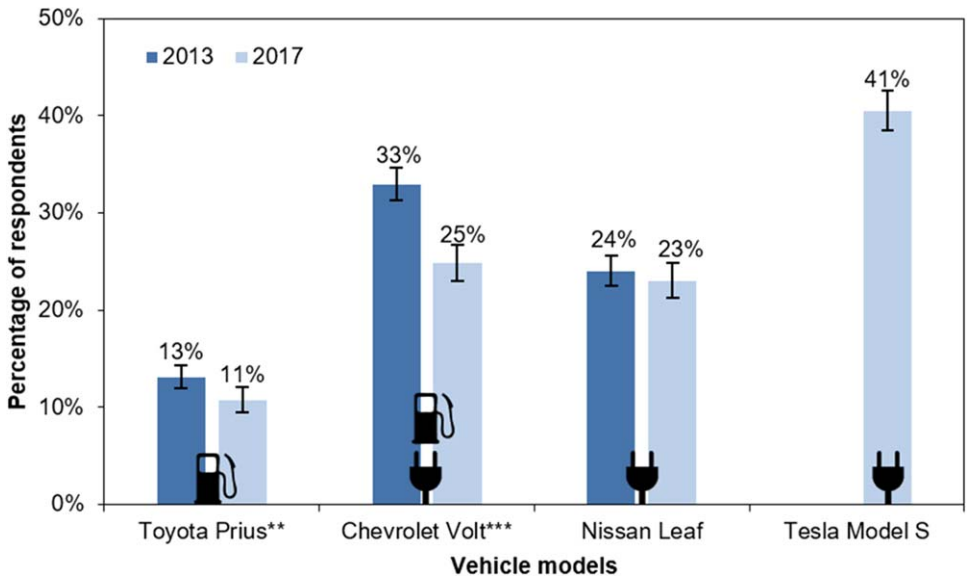

Figure 2. Correct refueling method identification for the Toyota Prius (hybrid), Chevrolet Volt (PHEV), Nissan Leaf (BEV), and Tesla Model S (BEV). The correct refueling method is shown using icons, with the Prius being fueled with gasoline only, the Volt with gasoline and by plugging into an electrical outlet, and the Leaf and Model S by plugging into an electrical outlet only. 2013 sample size: $n = 2922$; 2017 sample size: $n = 1808$. Error bars represent 95% confidence intervals, and asterisks represent proportions that are significantly different at the $p < 0.01$ (***), $p < 0.05$ (**), and $p < 0.1$ (*) level, as assessed by chi-square tests of association. (Note that overlap between confidence intervals does not negate the possibility for significant differences to exist between proportions [30]).

significantly lower for the Toyota Prius and Chevrolet Volt. The Toyota Prius (refueled with gasoline only) received the lowest frequency of correct responses in both samples, demonstrating a persistent confusion about how hybrid vehicles work. Notably, the Tesla Model S (refueled with electricity only, and assessed in 2017 only) had the highest proportion of correct responses.

Finally, respondent experience with these vehicle models was assessed with questions about speaking with a PEV owner, as well as driving or being a passenger in a PEV (figure 3). Overall, experiences with PEVs are rare in both samples, being reported by about 2%–6% of respondents. Comparing the two samples, the 2017 level of experience with the Chevrolet Volt is somewhat lower than 2013 experience, and somewhat higher for the Nissan Leaf. Experience with the Toyota Prius is comparatively higher than experiences with PEV models (10%–14%)—a finding that can be partially explained by the Prius being available for sale for almost a decade before the Volt and Leaf, and the resulting higher proportion of Priuses on the road in Canada. To illustrate, in 2013 and 2017 sales of the Toyota Prius alone accounted for 1% of new vehicle

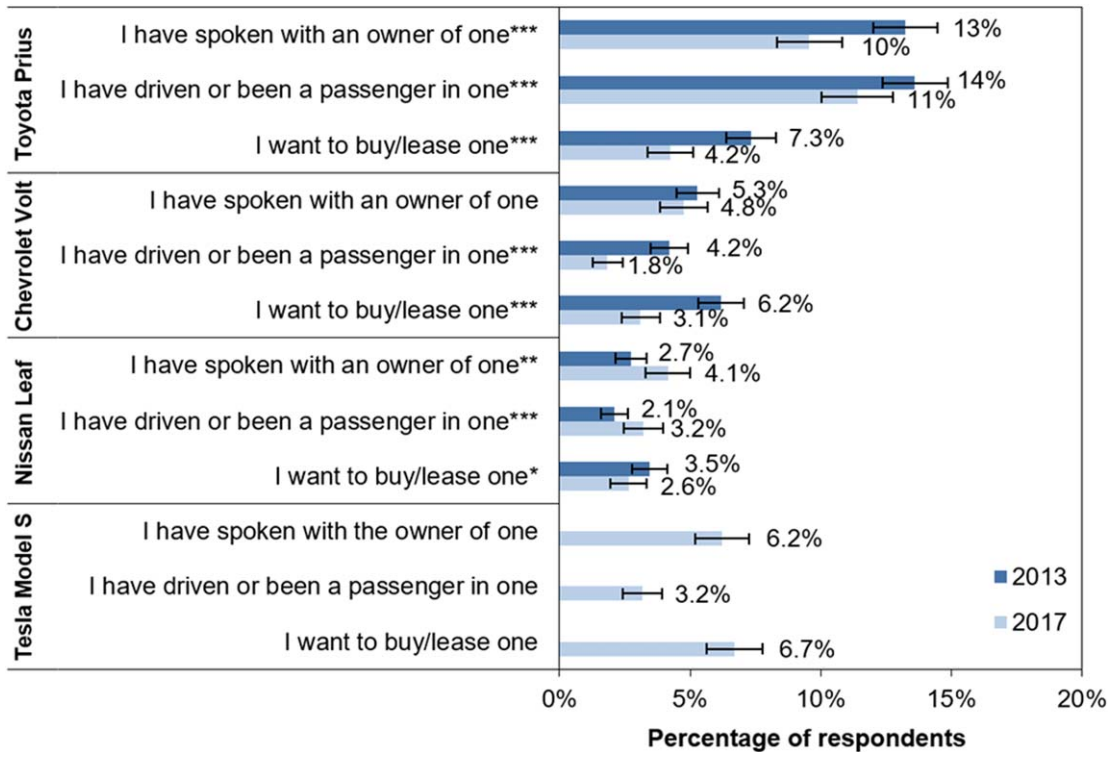

Figure 3. Experience with the Toyota Prius (hybrid), Chevrolet (Volt), Nissan Leaf (BEV), and Tesla Model S (BEV). 2013 sample size: $n = 2922$; 2017 sample size: $n = 1808$. Error bars represent 95% confidence intervals, and asterisks represent proportions that are significantly different at the $p < 0.01$ (***), $p < 0.05$ (**), and $p < 0.1$ (*) level, as assessed by chi-square tests of association. (Note that overlap between confidence intervals does not negate the possibility for significant differences to exist between proportions [30]).

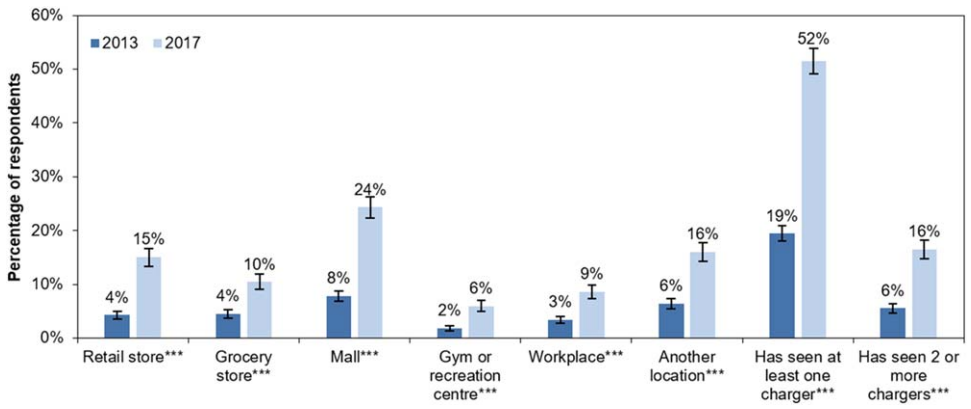

Figure 4. Awareness of public PEV chargers. 2013 sample size: $n = 2922$; 2017 sample size: $n = 1808$. Error bars represent 95% confidence intervals, and asterisks represent proportions that are significantly different at the $p < 0.01$ (***), $p < 0.05$ (**), and $p < 0.1$ (*) level, as assessed by chi-square tests of association.

market share (compared to 0.2% in 2013 and 1% in 2017, for all PEV models) [6].

Consumer awareness of public PEV chargers

Unlike the previously shown measures of PEV awareness, respondent awareness of public chargers is significantly (and consistently) higher in the 2017 sample than in the 2013 sample (figure 4). For each location surveyed, the proportion of 2017 respondents who have seen a PEV charger is at least double or triple the proportion reported in the 2013 sample. The proportion of 2017 respondents who have seen at least one charger (52%) is more than double that reported in the 2013 sample (19%). Similarly, significantly more 2017 respondents (16%) have seen two or more chargers compared to the 2013 sample (6%).

Regional variation

PEV adoption and policy in Canada varies substantially by province, which might suggest regional differences in

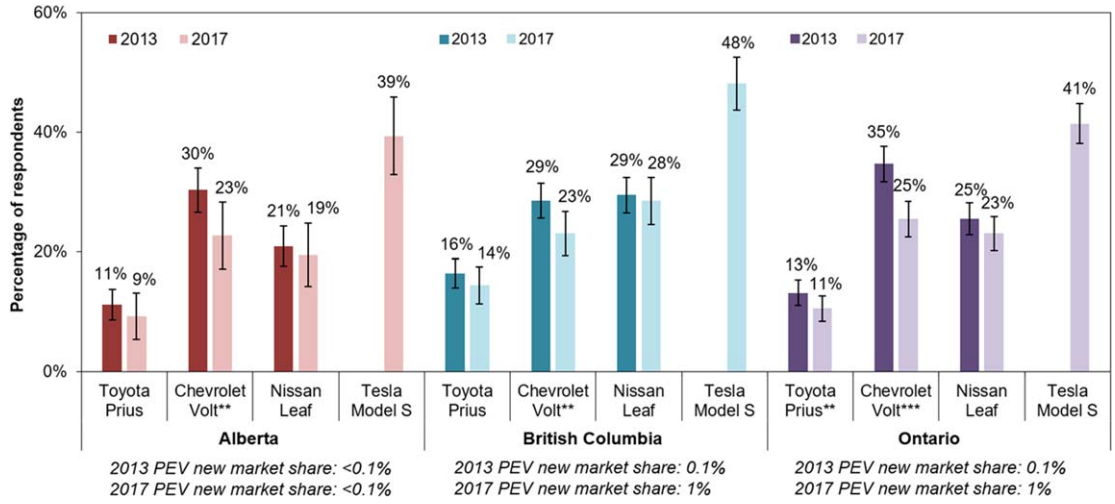

Figure 5. Percentage of respondents who identified the correct refueling method for the Toyota Prius (hybrid), Chevrolet Volt (PHEV), Nissan Leaf (BEV), and Tesla Model S (BEV, 2017 only), organized by province (Alberta: $n = 588$ in 2013, $n = 216$ in 2017; British Columbia: $n = 928$ in 2013, $n = 499$ in 2017; Ontario: $n = 1{,}010$ in 2013, $n = 826$ in 2017). Error bars represent 95% confidence intervals, and asterisks represent proportions that are significantly different at the $p < 0.01$ (***), $p < 0.05$ (**), and $p < 0.1$ (*) level, as assessed by chi-square tests of association. (Note that overlap between confidence intervals does not negate the possibility for significant differences to exist between proportions [30]).

PEV awareness that the previous nationwide analyses may have overlooked. To explore for any potential regional differences, we conducted separate analyses of respondents from three Canadian provinces: Alberta (2017 population = 4.3 million), British Columbia (2017 population = 4.8 million), and Ontario (2017 population = 14 million) [31]. During the study period, British Columbia and Ontario have experienced steady growth in PEV market share, which in both cases have grown from 0.1% of new vehicle sales to around 1% [32, 33]. Alberta has had comparatively lower PEV market share, remaining well under 0.1% throughout the study period [32, 33]. PEV policy support has also been stronger in British Columbia and Ontario, with both provinces introducing PEV purchase incentives before 2013, and both introducing numerous PEV-supportive policies between 2013 and 2017 (e.g. allowing PEV drivers to have unrestricted access to high-occupancy vehicle lanes, and investing in public and home charging infrastructure). Notably, both provinces have also had information campaigns (e.g. British Columbia's Emotive program and Ontario's Plug'n Drive program), which promote PEV use through public outreach. In contrast, Alberta has had no direct PEV-supportive policies at the provincial level to date. Given these provincial adoption and policy contexts, we expect that there might be differences in awareness among regions, where British Columbia and Ontario might have overall higher awareness of PEVs compared to Alberta—though we do not analyze causality between any specific policies and awareness. We focus this comparison on respondent understanding of PEVs, which we operationalize as identifying the correct refueling method for PEV models (as shown in figure 2). We consider this to be our most robust—and objectively verifiable—measure of awareness. We do not consider this analysis to be a test of policy effectiveness or impact but rather as an exploration of whether patterns of awareness hold or differ across regions with contextual differences.

Table 2. Proportion of respondents identifying the correct refueling type for the Toyota Prius (hybrid), Chevrolet Volt (PHEV), and Nissan Leaf (BEV) in Alberta, British Columbia, and Ontario. Asterisks indicate proportions that significantly differ at the $p < 0.01$ level (***), $p < 0.05$ level (**), and $p < 0.1$ level (*) (p-value thresholds are Bonferroni adjusted). Matching letters denote which proportions are significantly different from one another, as determined by one-way ANOVA Tukey post-hoc testing.

		Alberta	British Columbia	Ontario
2013	Toyota prius**	11%[a]	16%[a]	13%
	Chevrolet volt**	30%	29%[b]	35%[b]
	Nissan leaf***	21%[c]	29%[c]	25%
2017	Toyota prius	9%	14%	11%
	Chevrolet volt	23%	23%	25%
	Nissan leaf**	19%[d]	28%[d]	23%

Contrary to expectations, patterns of understanding in all three provinces are similar to what we observe among the national samples. That is, in the 2017 provincial subsamples, the proportions of respondents who correctly identify how to refuel each vehicle model are similar to or less than the proportions observed in the 2013 subsamples (figure 5). We examined regional variation in the other three awareness measures (not shown), finding similar patterns to what is observed among the full samples. In short, we find no evidence of higher PEV awareness among 2017 respondents in any of the three provinces (or in Canada overall).

Comparing the provinces within a given year, we find slight differences in understanding between respondents in each provincial subsample. Table 2 compares the proportions of correct responses from

each province in each sample year. We do not observe any particularly strong or consistent patterns, although in some cases PEV understanding is lower in the Alberta subsample compared to British Columbia and Ontario. For example, compared to Alberta respondents, a significantly higher proportion of British Columbia respondents correctly answer how the Nissan Leaf is refueled in both the 2013 and 2017 samples. Overall, we find that PEV awareness trends in these three regions are consistent with observations from the national analysis.

Discussion

Arguably, consumers' valuation and adoption of PEVs will depend on their awareness of PEVs' existence and understanding of basic PEV features, such as whether they use gasoline, electricity, or both [11]. While some stakeholders and researchers may assume that consumer awareness has been increasing as PEVs are introduced to the market, our results suggest that Canadian new vehicle-buyers have overall low PEV awareness, and that this awareness is relatively unchanged from 2013 to 2017.

Two measures of awareness have increased during the study period. First, in 2017, almost all respondents (87%) have 'heard of' the Chevrolet Volt and Nissan Leaf, and these levels are significantly higher than the 2013 sample. These observations are comparable to those from a 2016 survey of US consumers that found 96% of respondents are aware of the existence of PEVs [21]. Second, awareness of public PEV chargers has more than doubled in 2017 compared to 2013, consistent with the six-fold increase in charging stations from around 1000 to almost 6000 during the study period [3].

However, our measures of PEV familiarity, understanding, and experience have remained stagnant or decreased between our 2013 and 2017 samples—trends that hold in separate analyses conducted on provinces with (British Columbia and Ontario) and without (Alberta) PEV-supportive policies, including public information campaigns. Less than one-quarter of respondents consider themselves familiar with the Chevrolet Volt and Nissan Leaf (or with PHEVs and BEVs, in general), with 2017 familiarity being significantly lower than or similar to the 2013 sample. Notably, these observations are comparatively lower than a 2016 survey of US citizens, which found that half of respondents are familiar with PEVs [21].

In terms of understanding, most respondents in the 2017 sample are still confused about the basic differences between a PHEV and a BEV, where only a minority demonstrate correct understanding of how the Chevrolet Volt (PHEV) and Nissan Leaf (BEV) are refueled. Even fewer understand how the Toyota Prius (hybrid) is refueled. Perhaps explaining some of this confusion, the Prius has at times been available as a PHEV version (the Prius Prime) in Canada from 2012 to 2015, and again beginning in late 2017 (after data collection for the 2017 survey). Further, the Chevrolet Bolt (a BEV), which began sales in 2017, has a similar name to the Volt. Confusion between PHEVs, BEVs, and hybrids has been consistently observed in qualitative research and survey studies in North America [13, 18, 19]. Reported experience with PEVs is also very limited and relatively unchanged, where only a fraction of respondents has driven or been passengers in a Volt or Leaf, or even spoken with the owner of one.

Limitations and future research

Before discussing potential reasons for these findings, we acknowledge several limitations of this study. The primary limitation is the comparability between samples. The sampling frames are slightly different, where the 2013 sample consists of respondents who have recently bought a new vehicle and the 2017 sample consists of those who intend to buy a new vehicle. While we consider both of the samples to be accessing the target population of 'new vehicle-buyers,' we acknowledge the differences in sample frames could impact results. For example, we include respondents who do not own any vehicles in the 2017 sample (though the 2013 sample does not include any such respondents). However, we performed the analyses omitting non-vehicle owning respondents in the 2017 sample and observed that the results did not meaningfully change.

In relation, we observe some slight differences in demographic distributions between the samples (as explained in our Method section), which might reflect differences in the sampling frames—although some demographic distributions should legitimately change in that time frame (notably, mean Canadian income has increased by about 1%–2% per year [28]). Slight differences in age and gender could potentially impact observed awareness levels, though past Canada-based research shows a convoluted relationship—being younger and being female can be associated with both lower PEV ownership but higher PEV purchase intention [31]. We acknowledge that an alternate approach would be to apply corrective weights to one of our samples to make one or more demographic distributions more similar. However, we prefer to keep the samples unweighted (aside from the regional corrective weights noted above), and to inform the reader of the slightly different sampling frames and demographic distributions. Further, we believe that many of our results are intuitive and do indicate a comparability between samples, including consistent increases in having heard of PEV models and awareness of chargers, and consistent understanding of how to fuel the Nissan Leaf. Further, we suggest cautious interpretations for any observation of lower levels of awareness in the 2017 sample, which we see more as lack of

evidence for a strong increase in awareness over time, rather than strong evidence of an actual decrease.

In addition, we analyze results from two cross-sectional surveys, not from the same respondents over time in a longitudinal manner, hence we cannot conclude if any learning (or lack thereof) has occurred among respondents. Some of the questions in this analysis had slight differences in response options as well (see Method section), which might explain some of the observed differences in results—although our analysis focuses on directly-comparable responses. Future research on this topic would benefit from using a longitudinal approach, or at least using an identical sampling frame and survey instrument. We also acknowledge that this paper presents a fairly simplistic analysis. Future research could examine potentially demographic and attitudinal characteristics associated with higher and lower PEV awareness to better understand the reasons underlying overall PEV awareness. The relationship between higher awareness of PEV chargers and the growing number of PEV chargers could also be more precisely examined, for example by collecting awareness and charger data for a larger number of regions (to permit multivariate analysis). Additionally, the causal impact of PEV policies on awareness could be tested in future studies.

Last, any survey results are potentially vulnerable to bias. For example, acquiescence bias refers to a tendency by respondents to agree with or respond positively to survey statements framed around agreement. Our survey instruments aimed to minimize such bias, especially in the case of these awareness questions by specifically stating in the prompt that it is 'okay if you are not familiar with any of these vehicle models or technologies'. Although there is a chance that the survey could have biased respondents towards answering that they had 'heard of' certain PEV models or PEV charging stations, for instance, we would expect the levels of bias to be similar in both samples. That there is still such a large increase in positive responses for both questions suggests that familiarity and awareness of chargers has increased.

Implications and conclusions

Even with those limitations in mind, we believe our analysis provides reasonable insight into Canadian consumer awareness of PEVs, and of potential changes between the two time periods. Most reductively, we find no evidence that overall consumer PEV awareness has increased over time. We suggest three reasons that might explain this lack of consumer learning. One explanation could be that PEVs comprised less than 1% of total vehicles on the road in Canada in 2017, and the increase from 0.2% to 1.1% PEV new market share simply is not enough to attract the attention of mainstream consumers. Second, our few observations of (slight) decreases in awareness (lower PEV familiarity, and decreased understanding of how to refuel the Chevrolet Volt) could be in part explained by the increase in diversity of PEV models available during this time (from eight models in 2013 to 34 models in 2017). The addition of models to the market might further confuse consumers about the defining differences between a PHEV [32] or BEV—or a hybrid, flex-fuel, or hydrogen fuel cell vehicle, for that matter. Third, studies indicate that consumers have poor dealership experiences when shopping for PEVs in Canada [32], the US [33], and in Europe [34], which is unlikely to have helped the spread of positive or accurate information about the technologies. In fact, a recent survey of 308 US auto dealerships found that around 50% or less of surveyed dealerships provide any consumer education about PEVs, such as how to operate a PEV or how PEVs compare to conventional vehicles [35]. Suggesting the importance of this interaction, the same study found that three-quarters of prospective PEV buyers indicated that the dealership has a strong influence on their PEV purchase decision [35].

In short, there is a widespread and seemingly persistent lack of consumer awareness of PEVs in Canada, as has been found in the US (e.g. [9, 13, 20, 24]). Notably, our findings indicate that assumptions about perfect (and increasing) consumer awareness of PEVs would be inaccurate at present, which has implications for researchers who model and forecast the PEV market. Quantitative models of PEV adoption and usage ought to explicitly represent consumer awareness (or lack thereof) as a potential barrier to adoption, which may lead to more pessimistic forecasts of technology adoption. In addition, the apparent confusion among most consumers indicates that any consumer research on this topic ought to be carefully designed and interpreted, where consumers cannot reliably express preferences for a product they do not have a basic understanding of [36].

Further, despite national and regional increases in PEV sales, model diversity, and policy support, our results suggest that consumer awareness remains low and stagnant. Given that there is a positive relationship between awareness and interest in purchasing a PEV [13, 14], policymakers ought to recognize that lack of awareness is likely an important barrier to adoption, which may in turn hinder the realization of various PEV adoption and climate mitigation goals. While some may interpret these findings as evidence of the importance of PEV information and awareness campaigns, recall that we found little difference in awareness between regions that had such campaigns in place during the study period and a region that did not. It is possible that awareness campaigns were too small to have had an observable impact, where larger or more effectively designed information or outreach campaigns (beyond what has been attempted thus far) might have more positive impact. Future research could explore the effectiveness of larger outreach campaigns.

In addition, policymakers should consider other levers that might indirectly increase consumer PEV awareness. For example, another hypothesis for future research is that policies that incentivize or require the sale of PEVs might put the onus on automakers and dealerships to more effectively market and spread awareness about PEVs. A more stringent version of California's zero-emissions vehicle mandate might have such an effect, in that it requires automakers to sell (and thus market) zero-emissions vehicles. As another example, a program that provides incentives (or PEV education programs) to auto dealerships for the sale of PEVs might also help to prompt key stakeholders to improve consumer awareness and understanding of PEVs. Further, more effective collaboration between automakers, policymakers, and key industry stakeholders could lead to larger impacts on PEV awareness, perhaps through experiential marketing (e.g. ride and drive events) given our finding that consumers have almost no experience with PEVs. However, such policies and strategies can only be verified with more trials and research—all we know for now is that in recent years, efforts in Canada have had little impact.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available for legal and/or ethical reasons.

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