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The Plug-in Electric Vehicle Policy Report Card

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Abstract

Amidst the current “hype” surrounding plug-in electric vehicles (PEVs), many countries and regions are enacting various PEV-supportive policies in an ad-hoc manner, without clear goals or evaluation metrics. In this paper, we develop an evaluation framework based on the likely ability of a package of these policies to achieve one goal: PEVs capturing at least 40% of new passenger vehicle market share by 2040 (in line with deep GHG abatement goals). We develop simple methods to translate different policy types, including incentives, infrastructure deployment, and supply mandates into market share “points” based on policy stringency and duration. We then assign an overall letter grade (A, B, C, D or F) to a given region based on the suite of policies in place. We apply our framework to Canada’s 10 provinces. Seven provinces have enacted little or no effective policies and are assigned “F” and “D” grades. Three provinces demonstrate greater policy effort (British Columbia, Ontario and Québec), though only one is on track to achieve a “B-” grade (Québec). Our framework provides an accessible tool for policymakers to assess the effectiveness of different PEV-supportive policy packages, and our application identifies uncertainties that can be better understood through further research.

Keywords: Plug-in electric vehicles, policy analysis, climate policy, policy evaluation, climate change mitigation, Canada

1 Introduction

To support objectives related to climate change mitigation, local air pollution and energy security, governments are implementing a range of policies to encourage the adoption of plug-in electric vehicles (PEVs) [1]. Recent research describes varied PEV efforts in over a dozen countries [2,3], while other studies describe differences in PEV-related policies at sub-national levels such as cities and U.S. states [4–6]. Given that PEVs remain an emerging technology, it is challenging to assess how different policies may translate to long-term PEV sales. In this paper, we draw from available literature to develop an evaluation framework that estimates the likely effect of a package of policies on PEV new market share in the long-term.

Given the various market failures, institutional failures, and "transitional" failures that favour conventional fossil-fuel powered vehicles over PEVs, a strong set of climate policies will likely be needed to induce a substantial transition to electric mobility [7,8]. PEV policies can broadly be categorized as demand-focused or supply-focused [9]. Demand-focused policies aim to encourage consumers to purchase PEVs (either battery electric or plug-in hybrid electric) by for example offering financial incentives or developing refuelling infrastructure. By contrast, supply-focused policies encourage or require suppliers to develop and sell PEVs, for example by specifying that a certain share of vehicles sold in a jurisdiction have zero emissions as measured at the tailpipe (i.e., California's Zero Emission Vehicle (ZEV) mandate).

Although PEVs provide several societal benefits, our policy framework focuses on the goal of significant decarbonization by 2050 that is in line with federal and most provincial GHG reduction targets in Canada. Such targets inevitably require a substantial shift to alternative fuels such as electricity, hydrogen or biofuels for road transport. For example, the International Energy Agency suggests that to stabilize CO_2 concentrations at 450ppm, 40% of new passenger vehicle sales must be PEV by 2040 (with most remaining vehicles fuelled by biofuels) [10]. Acknowledging that such a technology target is simplistic, we use this "40% by 2040" benchmark as an approximate quantification of PEV "success". Note that our focus on one goal ignores other policy evaluation criteria, such as economic efficiency, administrative feasibility, equity and political acceptability [11,12]. This framework means to leave those concerns to the policymaker in a given region.

In short, this paper has two objectives. First, we develop an evaluation framework that can be used to compare the level of PEV policy effort among jurisdictions. Second, we apply this framework to evaluate the progress of Canadian provinces toward decarbonizing light duty vehicles in the long-term. We assume an implicit 2040 sales target of 40% PEVs, although analyses for Canada suggests that the required market share to meet federal and provincial targets for GHG emissions may be higher [13,14]. We select Canada because few studies have evaluated PEV policies in this country. Canada is a federation with 10 provinces three territories that assigns distinct powers to different levels of government. Although Canada has signed the COP21 Paris Agreement, climate policy implementation in general, and support for PEVs in particular, is varied across the country.

3. Method

3.1. Policy evaluation: New market share "points" and the "PEV Policy Report Card"

We first identified PEV-related policies in Canada and categorized them according to several characteristics we deemed important based on our review of PEV policy studies across different jurisdictions. We then evaluate PEV-related policies in each province according to their ability to drive PEV adoption, with the presumed goal of 40% new vehicle sales in 2040 based on the IEA [10]. Our framework considers eight categories of PEV policies (Table 1), including demand-focused policies (financial and non-financial incentives, public (non-home) charging infrastructure deployment, EV-ready building codes, and policies that increase the cost of fossil fuels relative to electricity) and supply-focused policies relating to auto manufacturers and fuel providers (ZEV mandate, fuel economy standards and a low-carbon fuel standard).

For each policy type, we identify a "benchmark" stringency and duration based on a judgmental estimate of what might be the maximum politically acceptable level in North America. In some cases, policies of this stringency have already been implemented while in other cases policies are more stringent reflecting prices or targets indicated in the literature. Based on the available literature, we then estimate the effect of that benchmark stringency on the 2040 PEV sales target we have assumed, in terms of new market share "points". That is, our evaluation framework translates a given policy (as currently implemented or announced) into new market share "points" in 2040. We represent uncertainty in these estimates by providing a range of potential impacts. Ideally this range is provided by the literature, but where it is not available we provide a range of plus or minus 50%.

Table 1: Summary of policy evaluation framework

Policy	Description	Benchmark effect of policy (i.e., stringency and duration required to achieve substantial market share impact, while likely being politically acceptable in North America)	Equivalent in purchase subsidy ($CDN 2016 monetary value)	Benchmark new market share impact in 2040 (percentage point increase in sales)
Demand-focused policies				
Financial incentives	What is the value and likely duration of financial incentives (e.g. vehicle purchase, home charger installation, waived user fees)?	$12,000 per vehicle for 15 years.	$12,000	10% (5%-15%)*
Non-financial incentives	What is the value and likely duration of non-financial incentives, such as HOV lane access?	HOV lane access of equivalent value to that in California for 15 years.	$1,200	1.0% (0.5%-1.5%)
Public (non-home) charging	What is the value of public charger availability?	Sufficient public charger density required to fully alleviate range anxiety for BEV owners.	$3,800	3.2% (1.6%-4.8%)
Building codes	Is there an EV-ready building code?	100% of population has level 2 home charging access (i.e., total building stock).	$9,600	8% (4%-12%)
Fuel cost environment	Is there a policy that increases the cost of carbon-intensive fuels relative to electricity?	Carbon price or electricity subsidy on track to meet $150/tonne CO_2e by 2030.	$18,000	15% (7.5%-22.5%)
Supply-focused policies				
ZEV mandate	Are automotive manufacturers required to produce PEVs?	California's ZEV mandate (requiring 2025 ZEV credits equivalent to 9 to 21% PEV sales).	$18,000	15% (9%-21%)
Fuel economy standards	Do automotive manufacturers receive credits to produce PEVs?	Fuel economy standards with PEV credits reaching 98g CO_2e/100 km by 2025.	$2,400	2% (1%-3%)
Fuel standards	Do electric utilities receive credits for electricity sold to PEVs?	Low carbon fuel standard requiring a 10% reduction in carbon intensity by 2020, with PEV credits.	$300	0.3% (0.1%-0.4%)

*Benchmark market share range with uncertainty.

For each policy identified in a region, we linearly scale its new market share points based on the magnitude (e.g. the size of the incentive) and the duration (e.g. how long the incentive is available). For example, an incentive of $5,000 per vehicle for 10 years would be estimated to have the same impact as an incentive of $10,000 per vehicle for 5 years—a simplistic assumption that can be improved in future versions of this framework. For each policy identified that applies only to a subset of the region's population (e.g. to just one city in a province), we likewise linearly scale the policy impacts based on that proportion. For example, an EV-ready building code applying to half a province's population is calculated as having half the potential market share impact compared to an equivalent policy applied to the entire population.

To estimate the total effect of a given region's portfolio of PEV-related policies on 2040 market share, we sum up our estimated market share impacts for each individual policy. This summation is simplistic and does not account for potential interactions among policies. Such interactions might be particularly important between demand- and supply-focused policies, e.g. where a PEV purchase incentive might help a region to achieve the requirements of its ZEV mandate (rather than the incentive being wholly additive to the ZEV mandate).

For each region, we assign a letter grade based on the sum of the market share percentage points a province receives across the full suite of policies in place. The purpose of this grading scheme is to assign jurisdictions into one of five "letter grade" categories (analagous to grades commonly assigned to students in North America) reflecting policy effort: i) likely to boost PEV adoption enough to meet or exceed 2040 targets ("A"), ii) likely to boost PEV adoption, but not enough to achieve targets ("B"), iii) likely to achieve relatively limited adoption of PEVs ("C" and "D"), and iv) likely to induce only marginal adoption of PEVs ("F"). The following subsections explain our methods of translating a given policy's stringency and duration into estimated contribution towards 2040 market share points.

Financial incentives: High levels of incentives are correlated with higher levels of PEV market share among countries and US states [5,6,15]. For example, Norway reached PEV new market share levels of 22% in 2016 due to financial and non-financial incentives equal to up to half of average vehicle costs over 10 years [6]. Axsen et al. [9] find that the financial component of Norway's incentives applied to a Canadian context (totalling about $12,000 CAD per vehicle) might achieve a market share of roughly 10% within 15 years. Such a purchase incentive is comparable to that recently announced by the province of Ontario. Several factors explain the lower level of impact as modeled in Canada relative to the experience of Norway, including a preference for larger vehicles that are more expensive to electrify [9].

For financial incentives, we set the benchmark at this level, i.e., $12,000 for 15 years yielding a market share impact of 10% as determined through analysis with the REPAC model ,which is based on Axsen et al.'s [9] discrete choice model. This cited model also produces an uncertainty range of plus or minus five percentage points, ranging from 5% to 15% 2040 market share points. This range aligns with several other PEV market share modeling studies (e.g. [16,17]), but is significantly lower than studies that have greater sensitivity to demand-focused policies (e.g. [18,19]). Although financial incentives could be used to achieve greater levels of adoption, their financial sustainability over longer periods may be problematic. Even the assumed 15 year benchmark may be unrealistically optimistic. For example, 10 out of 14 previously-implemented financial incentive programs for PEVs in Canada have lasted less than five years.

Non-financial incentives: Value of HOV lane access We focus on HOV lane access because this is the only non-financial incentive identified in Canada. Jin et al [15] estimate the value of HOV lane access for a given city based on a formula, which we used for our calculations here Following [15], we use Google maps to examine traffic at 8am on a weekday for Canadian cities that provide HOV lane access to PEV owners. Major roads with orange or red markings are considered as important roads. We visually estimate the share of these roads that have HOV lanes, which we assume is representative of the percentage of traffic alleviated. We use values for congestion cost (C_c) based on Transport Canada data described in UTTF [20]. Finally, we assume a value of 50% for P_r based on Jin et al [15]. The resulting value of V_{HOV} for each city is weighted by proportion of the population that is likely influenced by the HOV lane access to determine a monetized value for the entire province. We translate this monetary value into a 2040 market share impact assuming the same relationship as between financial incentives and market share (i.e., $12,000 over 15 years yields 10%). We set $1,200 (1%) as the benchmark (Table 1) because this is the revealed value of HOV lane access in California, the US state with the highest HOV lane benefit made available to PEVs [15].

Public charger rollout We assign a monetary value to public charger availability based on a method established by Lin & Greene [21], estimating the cost a BEV owner would have to pay to rent a second vehicle for trips that exceed the range of his or her BEV. This cost would decrease given greater availability of public chargers, thereby creating a value of the charger network given by the formula:

$$B_{rc} = B_{med}\ x\ (N_{pc}\ x\ N_g) \quad (1)$$

Where B_{rc} is the monetized benefit of range confidence for BEV owners, B_{med} is the benefit for the median driver under ideal charger availability, N_{pc} is the number of public chargers and N_g is the number of gasoline stations. We determine a value of \$3,800 for B_{med} based on an average daily rate of \$22 across Canada (assuming a period of 10 years and a 7% discount rate) [22]. The number of charging stations by province (N_{pc}) is estimated by reviewing information from ChargeHub (2016), while the number of gasoline stations (N_g) is based on Statistics Canada [23]. We select a monetary value of \$3,800 as the benchmark for this policy, because this is the value of a charging network that (from the simplified perspective of this method) alleviates range anxiety. This value is translated into a market share impact in a similar fashion as for financial incentives.

Building codes Empirical research suggests that home charging could be considerably more important than public charging access [24]. Lin et al. [21] find that providing all U.S. households with Level 2 charging by 2025 increases demand for PEVs by between 5 and 10 percentage points of new market share. Axsen et al. [9] estimate discrete choice models with Canadian consumer data, finding that home access to Level 2 charging increases mainstream consumer willingness-to-pay for PHEVs by \$1300, and for BEVs by \$3300. In line with these findings, analysis with the REPAC model, based on Axsen et al.'s [9] discrete choice model, found that that lack of access to home charging in two Canadian provinces reduces unconstrained demand for PEVs by eight percentage points of new market share in 2030. We therefore set the benchmark for this policy as an EV-ready building code applying to an entire province, with a potential 2040 impact of eight new market share points. The ratio of the monetized value of the "benchmark" levels of home-charging and public-charging policies in Table 1 (with home charging being about 2.5 times higher) is also similar to the those empirically estimated by Bailey et al. [24]. If a policy only applies to new buildings, we scale the market share impact by the proportion of average building age for which the policy is active, assuming an average building life span of 100 years.

Fuel cost environment: A region's fuel cost environment can favour PEV adoption through several means, including taxation of fossil fuels, taxation of carbon, or subsidization of electricity rates. We base our benchmark on modeling of carbon pricing, and translate other fuel cost policies based on their equivalence in carbon price. In other words, if a region implements a subsidy for PEV electricity rates, we translate it to an equivalent carbon tax by dividing the annual estimated charging savings by the PEV's annual carbon emissions reduction. Analysis for Canada suggests that a carbon price in excess of \$100/tonne CO_2e is likely necessary to achieve federal targets for greenhouse gas abatement in 2030 [25]. More recent calculations by the authors based on the same modelling framework–the CIMS technology simulation model as described by [26,27]– suggest that a carbon price of between \$100 and \$200 could increase demand for PEVs by 15 percentage points of new market share in 2040. Therefore, our benchmark for fuel cost environment is an implicit or explicit carbon price that is on a trajectory to meet at least \$150/t by 2030.

Zero-Emissions Vehicle (ZEV) mandate: The most direct supply-focused policy is a ZEV mandate, which incentivizes auto manufacturers to invest in the innovation of PEVs (and HFCVs), and to produce and actively market such vehicles in the regulated region. California's ZEV mandate requires automakers to earn a minimum number of ZEV credits annually based on the number of vehicles they sell [13,28]. Lutsey et al. [5] find that five of the seven U.S. cities with the highest PEV sales in 2015 are in states that have adopted California's ZEV program. The authors also find that the six U.S. cities with the highest level of PEV model availability in 2015 were in ZEV States—a factor that the authors found to be statistically associated with PEV sales, controlling for the presence of other policies. The ultimate PEV market share resulting from a ZEV mandate is dependent on the types of vehicles automotive firms develop, which could be some mix of PHEVs, BEVs and HCFVs. In the case of California's ZEV mandate (our benchmark policy), PEV market shares could plausibly range from 9% to 21% of new vehicles sold in 2025 and be in compliance with the policy, assuming HFCVs are not developed in significant quantity. Although the impact of this policy could increase after 2025 due to declining capital costs (i.e., technology learning) such impacts are uncertain. Therefore, we take the conservative view and assume 2040 market share impacts are the same as projected impacts in 2025.

Fuel economy standards: The U.S. and Canada currently have Corporate Average Fuel Economy (CAFE) standards in place, requiring that new passenger and light commercial vehicles sold in Canada must meet fleet-wide GHG emission standards through the year 2025. Fleet requirements for passenger cars sold in 2025 are 97 g CO_2e/km, which is reduction of 35% from 2015 requirements [29]. As part of the current CAFE standards, BEV models are considered not to have any emissions, and only gasoline-based emissions are counted for PHEV models. Both vehicle models count as more than one conventional vehicle when calculating the weighted average fuel economy of a manufacturer (e.g. one BEV sold in 2017 counts as 2.5 cars, and one PHEV as 2.1 cars).The U.S. Environmental Protection Agency projects that electric vehicles need to make up about 2% of new vehicle market share in 2025 for fleet-wide CAFE compliance [30], which we take as the benchmark stringency for this policy. Adjusting this value for uncertainty of plus or minus 50% leads to a range of between 1% and 3%.

Low carbon fuel standards: A low-carbon fuel standard (LCFS) was first implemented in California in 2007 and similar policies have since been adopted by several other jurisdictions including the European Union and the Canadian Province of British Columbia [31]. The LCFS requires fuel suppliers to reduce the carbon intensity of fuels sold in a jurisdiction. One option for compliance in some jurisdictions (e.g. California and British Columbia) is for fuel suppliers to purchase credits from suppliers of electricity for PEVs. Yang [32] estimates the monetary value of such credits (as implemented in California) to be in the range of one to several hundred dollars per year per BEV, which in theory would be passed along to PEV buyers as equivalent financial or non-financial incentives. Using the relationship between monetary value and market share points determined for financial incentives, we estimate the impact of this policy to be between 0.1% and 0.4%, with a mid-point of 0.3% ($300).

4. Results and discussion

4.1. Policy scan and evaluation

Our scan identified 99 policies that directly or indirectly aim to increase the adoption of PEVs in Canada. The majority of policies (80%) are implemented by provincial governments. Municipalities account for a further 10% of policies, with the remaining 10% roughly split between utilities and the federal government. The largest number of regional policies were identified in Québec, Ontario and British Columbia, the three most populous provinces. The remaining provinces each implemented fewer than six policies. No policies were identified in Saskatchewan or Prince Edward Island.

Demand-focused policies outnumber supply-focused policies by over six to one. The most common demand-focused policies are financial incentives (24), investment in public charging (13) and building codes and planning efforts focused on increasing the availability of home charging (10). Financial incentives include subsidies for vehicle purchase (13), subsidies for home charger installation (10) and waiving user fees (1).

Supply-focused policies include the federal vehicle emissions standard (which applies equally to all provinces), British Columbia's low carbon fuel standard and Québec’s proposed ZEV mandate. Other supply-focused policies primarily include research and development programs (10), which were identified as part of the policy scan, but their potential impacts on PEV market share are not estimated as part of the policy evaluation.

We use the evaluation framework described in Section 3.2 to estimate the projected PEV market share impact of active policies in each province as shown in Figure 1. All provinces affected by the presence of federal fuel economy standards, which ensures a minimum market share "point" impact of 2% for each province. The evaluation also assigns a positive impact to public charger availability in all provinces. In many provinces (Alberta, Saskatchewan, Manitoba, New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland and Labrador), these two initiatives (federal fuel economy standards and the public charger network) are the only policies contributing to the PEV market share impacts. As a result, these provinces are assigned a market share impact of between 2.3% and 3.5%.

Due to a variety of additional policies in British Columbia, Ontario and Québec, these provinces are likely to boost PEV adoption further, and are assigned a market share impact of between 8.8% and 10.2%. Nevertheless, the gap between estimated market share impacts and the presumed target of 40% is large for all provinces, even after accounting for a potentially significant range of uncertainty. Financial incentives in Ontario (which work out to an average of $6,400 per vehicle over a period of 10 years) have the largest market share impact of any single policy (5.3%). The impact of incentives is slightly lower in Québec (3.7%) and British Columbia (1.9%) due to lower incentive values and shorter announced durations. British Columbia's Carbon Tax is projected to have a market share impact of 3.0%, while Québec's cap-and-trade policy is anticipated to have a lower impact (around 1.6%) due to its lower projected carbon price ($30/t in British Columbia compared to $16/t in Québec). The projected impact of HOV lane access in British Columbia, Ontario and Québec (included in the non-financial incentives category) is less than 0.03%, resulting from the fact that only a small share of total traffic congestion in a province that is alleviated by access to a relatively small number of HOV lanes.

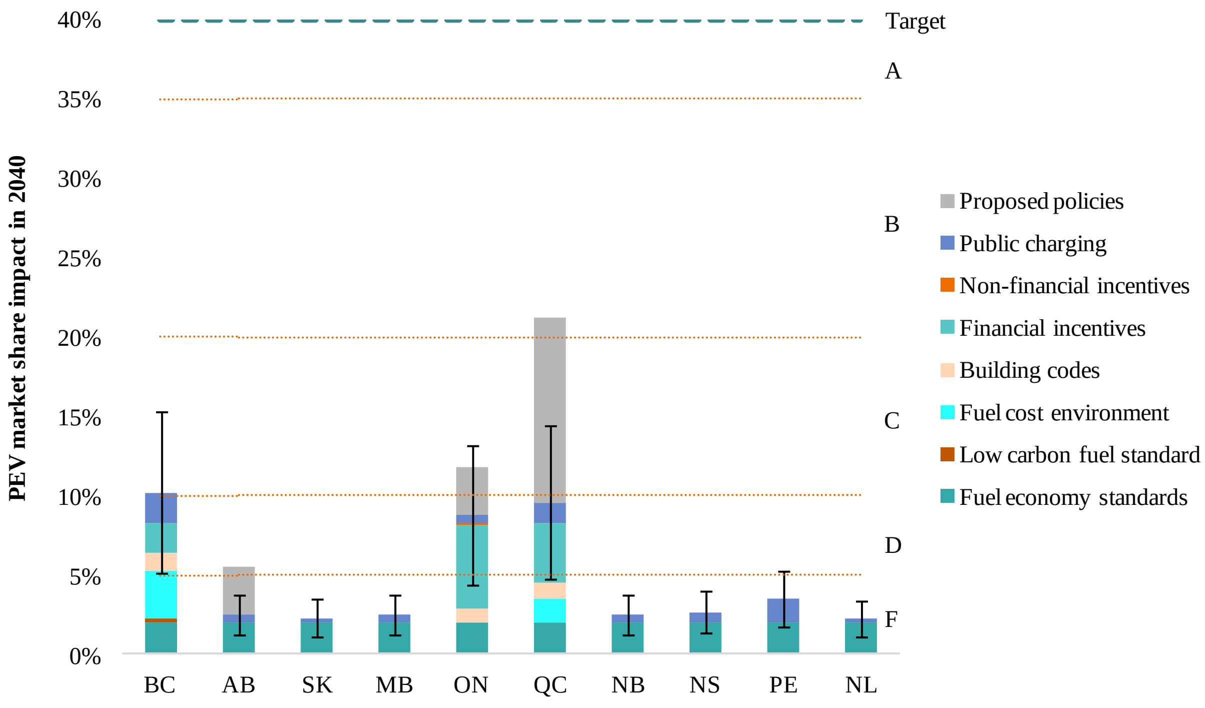

Figure 1: PEV initiative evaluation by province

Note: FED = Federal, BC= British Columbia, AB=Alberta, SK= Saskatchewan, MB= Manitoba, ON= Ontario, QC= Québec, NB= New Brunswick, NS= Nova Scotia, PE= Prince Edward Island, NL= Newfoundland and Labrador

PEV market share impacts are translated into letter grades as shown in Table 2. Based on active policies, most provinces receive an “F” because PEV policies implemented in their respective jurisdiction are likely to induce less than 5% new market share “points” by 2040. British Columbia receives a “C-” because its policies are likely to result in greater but still limited adoption of PEVs (between 10% and 20%). Ontario and Québec's efforts are rated at just below 10% (a “D”). However, both Ontario and Québec have announced policies that if adopted may increase projected market share impacts. Of these proposed policies, most substantive is Québec's ZEV mandate. If adopted, this policy would boost the province's market share points by 15% and it would be rated a “B-”. Ontario has also proposed a number of policies in its recent climate action plan, including financial subsidies, free overnight charging and EV-ready building codes. If these policies were implemented, Ontario’s grade would improve to a “C-”.

This evaluation highlights at least two key policy approaches for each province to receive an “A” grade. On the supply-side, the most significant option is to implement a ZEV mandate of sufficient stringency. For example, if Québec's policy is implemented it could be increased in stringency over time, from 15% PEV sales by 2025 to 40% by 2040. Although the ultimate outcome of this supply-focused policy is uncertain, its potential impact on PEV adoption is quite large. On the demand side, financial incentives combined with changes to the fuel cost environment (e.g., through a carbon price) would also be sufficient for any jurisdiction to receive an “A” grade. Alternatively, all of these policy options could be combined in a policy package that focuses equally on both demand and supply. Although a broad array of policies may be more complex to implement, it has the benefit of not overly relying on a single policy with uncertain impacts.

Table 2 PEV initiative evaluation showing market share points and grading by province

	BC	AB	SK	MB	ON	QC	NB	NS	PE	NL
Grade based on current policies	**C-**	**F**	**F**	**F**	**D**	**D**	**F**	**F**	**F**	**F**
Grade based on current policies **plus** those being considered as of mid-July, 2016	C-	D	F	F	C-	B-	F	F	F	F

Note: FED = Federal, BC= British Columbia, AB=Alberta, SK= Saskatchewan, MB= Manitoba, ON= Ontario, QC= Québec, NB= New Brunswick, NS= Nova Scotia, PE= Prince Edward Island, NL= Newfoundland and Labrador

5. Discussion and conclusions

Our policy evaluation framework provides an accessible tool for policymakers to assess the effectiveness of different PEV-related policy packages. The framework can be adapted to various targets (i.e., other than our assumed goal of 40% PEV sales by 2040) and is flexible in terms of providing credit for different policy approaches (e.g. demand-focused relative to supply-focused). We think that a simplified summary of policy impacts is helpful for policy makers seeking to understand which PEV policies to pursue and at what level of stringency in order to achieve their objectives.

Like many regions, jurisdictions across Canada have implemented a large number of PEV-related policies in recent years. This study reveals the extent to which PEV policy implementation has been uneven across Canada. The majority of provinces have undertaken little or no substantive efforts to boost PEV adoption, while some (British Columbia, Québec and Ontario) have implemented and are proposing more substantive policies. Nevertheless, despite greater levels of policy effort in these jurisdictions, no province in Canada is likely to meet PEV targets required to decarbonize transport given present policies. This finding implies that the strength of existing policies will need to be increased, or new policies developed, if targets are to be achieved.

This analysis has a number of important limitations. In particular, it treats policy impacts simplistically and fails to account for interactions among them. Some of these interactions may be quite significant. For example, a carbon pricing policy may have no incremental impact if an existing fuel economy standard is in place. Likewise, the impact of financial incentives could overlap significantly or even completely with supply-focused policies. A further limitation is that the impact of all policies is uncertain, especially when considering impacts out to 2040. We have attempted to incorporate a reasonable measure of uncertainty into the analysis, but it is possible that the bands we drew are not large enough.

These limitations point to an opportunity for further research. The evaluation framework could be greatly improved by replacing our simplistic calculations for each individual policy type with a more sophisticated approach that considers both interactive effects and uncertainty. In particular, we note that the REPAC model developed by Axsen et al [9] could be adapted to provide insight into the market share impacts of various types of demand and supply-focused policies for a given jurisdiction.

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