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A BLUEPRINT FOR CLEAN AND AFFORDABLE ELECTRIC CARS IN BRITISH COLUMBIA

Recommendations to the Government of British Columbia on design of the zero-emission vehicle standard

February 19, 2019

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Climate Solution Series

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EXECUTIVE SUMMARY

PHOTO Vlad Tchompalov, Unsplash

In December 2018, the Government of British Columbia announced North America's most progressive zero-emission vehicle standard, as part of the CleanBC climate plan. The David Suzuki Foundation and Sustainable Transportation Action Research Team provide recommendations to the government on how the zero-emission vehicle standard could be designed for maximum impact.

California and Quebec provide similar examples of a ZEV mandate, which is effective in encouraging ZEV sales, but has many provisions that weaken the overall sales goal and are more complex than necessary.

B.C. should consider a simplified ZEV mandate, which we illustrate with the example of a One-to-One credit system that sets a minimum requirement for ZEV electric driving range, but otherwise treats all battery electric vehicles and hydrogen fuel-cell vehicles the same. Such a design should focus its credit and compliance system on the singular goal of increasing ZEV sales for the light-duty vehicle sector.

We support B.C.'s adoption of a ZEV mandate as a uniquely effective policy instrument. It drives innovation, provides more choice for consumers, increases zero emission vehicle sales, abates GHG emissions and can be designed to be cost effective. We note that the stated goals for ZEV sales are consistent with what research shows is needed to achieve 2030 and 2050 GHG reduction targets.

INTRODUCTION

PHOTO Thomas Kolnowski, Unsplash

In December 2018, the Government of British Columbia announced North America's most progressive zero-emission vehicle standard, as part of the CleanBC climate plan. The objective of this law is to ramp up sales of non-polluting cars in the province to 10 per cent by 2025, 30 per cent by 2030 and 100 per cent by 2040. The legislation will be complemented by additional measures to make ZEVs more affordable and convenient to refuel.

British Columbia's transportation system represents nearly 40 per cent of the province's emissions and needs to evolve rapidly if we are going to meet our legislated, long-term climate targets (for 2030, 2040 and 2050). In addition to active transportation, lower-carbon fuels, smarter growth and enhanced public transit, increasing the supply and affordability of electric and other zero-emission vehicles is a critical solution for jurisdictions that aim to modernize their transportation systems.

In the global context, the goal of reaching 30 per cent ZEV sales by 2030, which is stated by the Clean Energy Ministerial, is consistent with research by the International Energy Agency demonstrating the trajectory needed to achieve 2 C warming scenarios.[1] For British Columbia,

1 IEA (2017). New CEM campaign aims for goal of 30 per cent new electric vehicle sales by 2030. https://www.iea.org/newsroom/news/2017/june/new-cem-campaign-aims-for-goal-of-30-new-electric-vehicle-sales-by-2030.html.
IEA (2017). World Energy Outlook 2017. OECD: Paris, France.

it is clear that uptake and usage of plug-in hybrid vehicles, hydrogen vehicles and battery electric vehicles will drastically reduce GHG emissions compared to conventional vehicles, from both tailpipe and well-to-wheel perspectives, in the short- and long-term.[2]

The David Suzuki Foundation has been at the forefront of advocating for smart transportation policy in Canada for more than two decades, including the B.C. publication of the ground-breaking research paper, ***Breaking Gridlock: B.C.'s Transit Investment Deficit and What Can Be Done to Fix It***, that proposed a framework to solve the funding crisis. It was adopted by the B.C. and federal governments for Metro Vancouver's historic $7.3 billion transit funding agreement in 2018). In 2015, the Foundation brought leading electric vehicle policy-makers from California to B.C. to learn from the state's experience with ZEV requirements and the benefits it has delivered.[3]

The SFU Sustainable Transportation Research Team (SFU-START) is a research collaborative within the Faculty of Environment at Simon Fraser University led by Dr. Jonn Axsen that focuses on the transition to lower impact transportation systems. SFU-START takes a unique interdisciplinary approach to its research, combining elements of economics, engineering, marketing, policy and psychology into the analysis of sustainable transportation solutions.

For consumers, electric vehicles have substantial benefits over the average internal combustion engine vehicles including:

- Higher performance and less noise
- More energy-efficient; e.g., about four times more energy efficient than a conventional car[4]
- Lower maintenance and fuel costs (about one quarter of the operating costs of an internal combustion vehicle)[5]
- Substantially lower carbon and air pollution

This policy blueprint is divided into three sections. The first provides evidence in support of a ZEV mandate as an effective policy instrument for B.C. The second briefly summarizes the Quebec and California mandates, and the third outlines and recommends pertinent design features for B.C.'s zero-emission vehicle standard.

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2 Kamiya, G., J. Axsen, et al. (2019). "Modeling the GHG emissions intensity of plug-in electric vehicles using short-term and long-term perspectives." Transportation Research Part D: Transport and Environment 69: 209-223.

3 Wade Crowfoot, Lois Corbett and Greg Moore (2015), Against the Odds: How Democracies Can Solve Climate Change, https://pics.uvic.ca/events/against-odds-how-democracies-can-solve-climate-change

4 David Suzuki Foundation and Canadian Academy of Engineering (2016), Canada's Challenge and Opportunity: Transformations for Major Reductions in GHG Emissions, Trottier Energy Futures Project https://davidsuzuki.org/science-learning-centre-article/report-canadas-challenge-opportunity-transformations-major-reductions-ghg-emissions/

5 BC Hydro (2018) Unplugged: Myths block road to the electric car dream https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/news-and-features/Report-unplugged-myths-block-road-to-EV-dream_April%202018.pdf

SECTION 1

SUPPORT FOR THE ZEV MANDATE AS A POLICY INSTRUMENT

PHOTO Derek Bruff (CC BY-NC 2.0)

We support B.C.'s adoption of a ZEV mandate as a uniquely effective policy instrument, for a number of reasons recently summarized by the UC Davis International EV Policy Council's report on ZEV mandates.[6] Positive attributes of the ZEV mandate include:

#1: A ZEV MANDATE SUCCESSFULLY DRIVES INNOVATION

Several studies find that California's ZEV mandate has effectively positively influenced ZEV-related innovation activities, including increased patent activity, development of vehicle prototypes, private companies forming partnerships, and increased employment and investment in companies in California.[7] Because changes in such activities must be observed over several years, both China and Quebec's ZEV mandates are too new to demonstrate the effects. While B.C. is a smaller market than California, the adoption of a particularly long-term and stringent ZEV mandate (requiring 100 per cent sales by 2040) can help to inspire other regions to adopt a similar policy, further sending a signal for long-term investment in ZEV research and development.

6 Hardman, S., A. Jenn, et al. (2018). Driving the Market for Plug-in Vehicles: Understanding ZEV Mandates. Davis, California, USA, University of California, Davis.

7 Vergis, S. and V. Mehta (2010). Technology innovation and policy: a case study of the California ZEV mandate. Paving the Road to Sustainable Transport: Governance and innovation in low-carbon vehicles. T. F. Group.
Melton, N., J. Axsen, et al. (2016). "Moving beyond alternative fuel hype to decarbonize transportation." Nature Energy 1(3): 1-10.
Dyerson, R. and A. Pilkington (2005). "Gales of creative destruction and the opportunistic incumbent: The case of electric vehicles in California." Technology Analysis and Strategic Management 17(4): 391-408.
Burke, A., K. S. Kurani, et al. (2000). Study of the Secondary Benefi ts of the ZEV Mandate, UCD-ITS-RR-00-07 University of California, Davis, Institute of Transportation Studies.

#2: A ZEV MANDATE INCREASES ELECTRIC VEHICLE AVAILABILITY (PROVIDING MORE CHOICE FOR CONSUMERS)

Several studies based in B.C. and Canada demonstrate that there is a limited supply of ZEVs relative to conventional vehicles, including limited model variety and availability in a given jurisdiction, and limited inventory and knowledge at dealerships.[8] Regions in the U.S. that are under the jurisdiction of the ZEV mandate have higher ZEV availability than other regions.[9] The logic of the relationship is fairly clear: with a stringent ZEV mandate in place, automakers are incentivized to develop more ZEVs in general over the long term, and to supply and market these vehicles in regions where the policy is in place (compared to a non-regulated region).

#3: A ZEV MANDATE INCREASES ZERO EMISSION VEHICLE SALES

Several studies demonstrate that these ZEV supply constraints can substantially reduce ZEV sales. For example, statistical analysis of 200 metropolitan areas in the U.S. finds that ZEV availability is an important driver of ZEV sales.[10] B.C.- and Canada-based modelling studies show that without increased ZEV supply, ZEV new market share by 2030 is not likely to exceed five to 10 per cent.[11] Another B.C.-based study shows that the Province of B.C. cannot effectively "free-ride" off of the innovation effects of a ZEV mandate enacted in other jurisdictions. Rather, a B.C.-based ZEV mandate would also be needed to drive sales to achieve long-term GHG reduction targets in B.C.[12]

8 Wolinetz, M. and J. Axsen (2017). "How policy can build the plug-in electric vehicle market: Insights from the respondent-based preference and constraints (REPAC) model." Technological Forecasting and Social Change 117: 238-250.
Axsen, J. and M. Wolinetz (2018). "Reaching 30 per cent plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada." Transportation Research Part D: Transport and Environment 65: 596-617.
Matthews, L., J. Lynes, et al. (2017). "Do we have a car for you? Encouraging the uptake of electric vehicles at point of sale." Energy Policy 100: 79-88.
Clean Energy Canada (2018). Batteries Not Included. Vancouver, Canada, Simon Fraser University.

9 Lutsey, N., S. Searle, et al. (2015). Assessment of Leading Electric Vehicle Promotion Activities in United States Cities. . San Francisco, CA, The International Council on Clean Transportation.

10 Lutsey, N. and S. Slowik (2018). The Continued Transition to Electric Vehicles in U.S. Cities. San Francisco, USA, The International Council on Clean Transportation (ICCT).

11 Wolinetz and Axsen 2017; Axsen and Wolinetz 2018

12 Sykes, M. and J. Axsen (2017). "No free ride to zero-emissions: Simulating a region's need to implement its own zero-emissions vehicle (ZEV) mandate to achieve 2050 GHG targets." Energy Policy 110: 447-460.

#4: A ZEV MANDATE CAN PLAY A STRONG ROLE IN CARBON ABATEMENT

Several modelling studies have demonstrated the importance of this policy in achieving long-term GHG reductions in the U.S.[13] Similarly, published research on B.C. confirms the importance of this goal of 30 per cent ZEV sales by 2030, and more ambitious goals by 2040 as part of a trajectory to meet 80 per cent GHG reduction targets by 2050.[14] A ZEV mandate could be a particularly important driver of emissions reduction in the light-duty vehicle sector, potentially more powerful than even a stringent low-carbon fuel standard.[15]

#5: A ZEV MANDATE CAN BE DESIGNED TO BE RELATIVELY COST-EFFECTIVE

There is considerable uncertainty involved in estimating the various costs of a policy, including direct government costs and broader social welfare costs. One modelling study shows that the (social welfare) efficiency of a ZEV mandate depends on design, and such a policy can be more efficient if it sends a strong and clear signal to more quickly reduce adoption costs for electric vehicles.[16] Considering only direct government expenditure costs, a recent study demonstrates that a ZEV mandate-based strategy would be a considerably lower-cost pathway to achieve the 30 per cent by 2030 sales goal compared to a strategy focused on long-term purchase incentives.[17]

13 Greene, D. L., S. Park, et al. (2014). "Analyzing the transition to electric drive vehicles in the U.S." Futures 58: 34-52.
Greene, D. L., S. Park, et al. (2014). "Public policy and the transition to electric drive vehicles in the U.S.: The role of the zero emission vehicles mandates." Energy Strategy Reviews 5: 66-77.
Greenblatt, J. B. (2015). "Modeling California policy impacts on greenhouse gas emissions." Energy Policy 78: 158-172.

14 Sykes and Axsen (2017)

15 Lepitzki, J. and J. Axsen (2018). "The role of a low carbon fuel standard in achieving long-term GHG reduction targets." Energy Policy 119: 423-440.

16 Fox, J., J. Axsen, et al. (2017). "Picking Winners: Modelling the Costs of Technology-specific Climate Policy in the U.S. Passenger Vehicle Sector." Ecological Economics 137: 133-147.

17 Axsen and Wolinetz 2018

SECTION 2

KEY DETAILS OF THE CALIFORNIA AND QUEBEC ZEV MANDATES

A woman fuels her FCEV fuel cell vehicle at a hydrogen fueling station. PHOTO Dennis Schroeder, National Renewable Energy Lab (CC BY-NC-ND 2.0)

THE CALIFORNIA SYSTEM

The current design of the California ZEV mandate is highly complex. Much of this complexity is a result of the long and varied history of this policy since its inception in 1990, which has included very important changes in:

- Policy goals: starting with an air pollution focus, and later transitioning to GHG emissions and innovation goals.
- Technology: starting with simple battery electric vehicle, then later including hybrid vehicles, hydrogen fuel cells and plug-in hybrid electric vehicles, and more recently incentivizing advanced (long-range) battery electric vehicles.
- Automaker opposition and negotiation: some companies strongly fought the policy in the mid-1990s and have since asked for a number of provisions to ease compliance. In particular, some of the current provisions were initially enacted when technology was perceived as too limited for automakers to comply with the policies. Some of these provisions only serve to weaken the effectiveness of the mandate.

As a result, the current California ZEV mandate is complicated, and some of its specific details are not necessary or even desirable for a B.C. ZEV standard. The full details of the California

ZEV mandate are reported elsewhere, and here we provide only a brief summary of this complexity, where the policy includes:

- Four different vehicle categories (see Appendix 1 for definitions)

    1. Zero-emissions vehicles, which includes most battery electric vehicles and hydrogen fuel-cell vehicles.
    2. Battery-electric vehicle with extended range.
    3. Transitional zero-emission vehicles, which includes most plug-in hybrid electric vehicles on the market.
    4. Neighbourhood electric vehicles.

    There are rules about how many of each category can count for each company's overall compliance requirement.
- There is a unique credit formula for each vehicle type (summarized in Appendix 1), where credits assigned to a given vehicle range from 0 to 4, mostly based on electric driving range. A number of current battery electric vehicle models earn more than 1 credit. As examples: a 2018 Nissan Leaf earns 2.01 credits, while a 2018 Tesla Model S earns 3.85 credits. The most commonly sold plug-in hybrid electric vehicles in Canada earn around 1 credit.
- Extra credits are granted for "transportation emission reduction activities," which are not directly related to the sale of compliant light-duty ZEVs, including sales of medium-duty ZEVs, the use of ZEV demonstration vehicles, and the linkage of ZEVs to transit systems.
- There are three different automaker categories, defined based on annual sales per year. Small automakers (selling less than 4,500 vehicles/year) are not regulated, intermediate automakers (selling 4,500 to 20,000 vehicles/year) are given some flexibility in which vehicle categories they can use for compliance, and large automakers (selling over 20,000 vehicles/year) are the most constrained in which vehicle categories they use for compliance (e.g., there is a minimum for compliance from the ZEV category).
- If an automaker earns extra credits, these credits can be sold to other automakers.
- For non-compliance, an automaker is fined up to $5,000 per credit. For example, if automaker X is required to submit 3,500 credits in 2022 but only submits 3,250 credits, then automaker X is required to pay the California government up to (3,500 – 3,250) x $5,000 = $1,250,000 for failing to comply.

THE QUEBEC SYSTEM

As passed in 2016, the Quebec ZEV mandate is similar to the California policy in stringency, timeline, detail and complexity. Appendix 2 provides a full list of policy differences.

Most differences are minor, including:

- Different names (but the same definitions) for the four vehicle categories, though the neighbourhood electric vehicles category is also defined slightly differently in Quebec (focused on three-wheelers).
- Oddly, Quebec uses the same definitions for automaker size as does California (despite being one-fifth the size), meaning that more automakers could be defined as "small" or "intermediate" and thus have more relaxed requirements.
- Quebec grants credits for "reconditioned" ZEVs, or conventional vehicles that are retrofitted to be a ZEV.
- Quebec does not grant credits for "transportation emission reduction activities."
- California limits the amount of neighbourhood electric vehicles–derived credits that intermediate vehicle manufacturers can use to meet their requirements, whereas neighbourhood electric vehicles credits can meet up to 100 per cent of Quebec's IVM requirements.
- Quebec's policy is more lenient during the first two years of introduction (3.5 per cent and 6.5 per cent in Quebec versus 4.5 per cent and seven per cent in California, in 2018 and 2019, respectively).
- Quebec allows manufacturers to indefinitely bank their credits for future use (it does limit the use of such credits to 25 per cent of total compliance every year).

SECTION 3

DESIGNING AN EFFECTIVE ZEV MANDATE FOR B.C.

An electric hybrid heavy duty truck is plugged in to charge. PHOTO Dennis Schroeder, National Renewable Energy Lab (CC BY-NC-ND 2.0)

In short, and as noted by the *International EV Policy Council*, a stringent and well-designed ZEV mandate can play an important role in achieving deep decarbonization goals for the light-duty vehicle sector.[18] In this section, we discuss design considerations for the ZEV mandate, focusing on the features that are most likely to help achieve the primary goals of GHG abatement and increased light-duty ZEV sales in B.C.

To illustrate the potential for different policy designs, we compare the California style of (relatively complex) ZEV mandate with a greatly simplified sales credit system that we call "One-to-One" — that is, one ZEV sale equals one ZEV credit. Rather than four vehicle categories and a range-based formula, a One-to-One system could be simplified to two or perhaps even one category:

- ZEV: a light-duty battery electric vehicle or hydrogen fuel cell vehicles of a minimum driving range (e.g., 100 km) that can operate in urban and freeway conditions. Each ZEV sale earns one credit.
- Plug-in hybrid electric vehicle: a plug-in hybrid of a minimum electric driving range (e.g., 30 km). This would earn either one credit (and could thus be lumped with the ZEV category above) or be given a partial credit based on the likely relative GHG reduction effectiveness of the plug-in hybrid electric vehicle compared to a battery electric vehicle (e.g., a 0.75 credit). Notably, recent analysis of real-world driving data show that actual usage of plug-in hybrid electric vehicles with 60 kilometres of range can electrify as many annual vehicle kilometres as a battery electric vehicle.[19]

18 Hardman, S., A. Jenn, et al. (2018). Driving the Market for Plug-in Vehicles: Understanding ZEV Mandates. Davis, California, USA, University of California, Davis.

19 Plötz, P., S. A. Funke, et al. (2017). "CO2 Mitigation Potential of Plug-in Hybrid Electric Vehicles larger than expected." Scientific Reports 7(1): 16493.

Further, such a simplified system could remove any provisions (or "secondary compliance mechanisms") that divert attention away from the direct goal of increasing ZEV sales. For example, the simpler system could exclude the provision for "transportation emission reduction activities" (as Quebec has done).

Here we summarize several important considerations for ZEV mandate policy design, which we illustrate by comparing the California design with a One-to-One system (summarized in Table 1).

Consideration #1: Policy goal effectiveness. The California ZEV mandate is concerned with GHG emissions and with stimulation of innovation. Perhaps in line with this latter goal, its credit system strongly favours long-range battery electric vehicles. In fact, the nature of California credit system implies that the primary policy goal is to increase the availability of long-range battery electric vehicles rather than to necessarily increase the total new market share of ZEVs. Further, the California system leads to a large disparity between the credit requirements and the sales goal — as one long-range battery electric vehicle can effectively "count" for up to four ZEV credits. In practice, the actual 2025 ZEV market share in California will be lower than the overall ZEV sales target, leading to uncertainty in both realized ZEV sales and GHG emissions impacts.

According to the province, in slight contrast, the B.C. ZEV mandate is driven by the primary goal of long-term GHG emissions reduction (for 2030 and 2050 goals) and the more specific goal of increasing ZEV sales as a percentage of light-duty vehicle sales (new market share in 2025, 2030 and 2040). We thus suggest that the B.C. policy be designed so that the requirements and credit system closely (or directly) match these goals. As noted, a One-to-One system would align its credit compliance system with the actual stated sales goals. Further, automakers would be free to identify which electric driving ranges would be most appealing to consumers at a given price point so that they, too, can focus on the ZEV sale goal rather than trying to "game" the system to maximize their achievement credits per dollar invested (which might result in more sales of long-range battery electric vehicles, but fewer ZEV sales overall, and fewer GHG reductions).

Consideration #2: Administrative simplicity. Policy-makers must also consider how complicated a policy is, and what kind of institutional capacity they need to set up, implement, monitor and update the policy. There can be large advantage to "harmonizing" policy across jurisdictions, or in this case, to use most or all of the same ZEV mandate design details as used in California or Quebec. It may be particularly attractive to "free-ride" off of California, given that the California Air Resource Board will continue to manage and update its policy (which B.C. could continue to copy). In this sense, following California may have some advantages, which is probably why Quebec's policy is so similar to that of California. That said, while the One-to-One system described above might take some extra thinking to set up initially, it could come with the reduced need for detailed future updates of the policy (given that the policy would be simply more technology neutral). Another option is to start with a California-like system for the initial years (to 2025), and then transition to the One-to-One system for compliance years that extend beyond the California mandate (2026 to 2040).

Consideration #3: Cost-effectiveness. A good policy design will avoid unnecessary costs or losses in social welfare. There has been no published research exploring how different ZEV mandate credit systems might compare in cost-effectiveness. We expect that the costs of the different systems noted here would be similar, though there is potential for the One-to-One system to be more efficient, in that automakers and consumers have more freedom to choose which ZEV design (and range) they prefer to manufacture and purchase, respectively. Such a simple system could avoid the need for recurring negotiation of specific provisions and credit mechanisms with automakers.

Table 1: Illustrative comparison of two credit systems for B.C.'s ZEV mandate

	"California-like" system	"One-to-One" simplified system
Policy goal-effectiveness	Lower: ZEV sales are uncertain, as longer range battery electric vehicles are heavily favoured (and count for more ZEVs). Additional compliance mechanisms also reduces uncertainty.	Higher: credit system is more closely aligned to the stated goal of ZEV new market share.
Administrative simplicity	Similar: can "free-ride" off of existing policy and institutions (e.g., CARB).	Similar: requires new policy design, but should be simpler to administer in the long-run.
Cost-effectiveness	Uncertain, probably similar.	Probably similar — though might be more cost-effective to focus on ZEVs rather than specific ZEV range.

Consideration #4: Policy interactions. A final consideration is that to achieve long-term GHG mitigation goals, policy-makers must consider the full "mix" of policies in place, including carbon pricing, vehicle efficiency standards, the low-carbon fuel standard, ZEV purchase incentives, HOV lane access, road pricing, transit investment, ridehailing regulation and recharging-infrastructure deployment. Among the supply-focused policies, there can be considerable interaction between a ZEV mandate, the national vehicle emissions standard, and the low-carbon fuel standard. In particular, if B.C.'s stated ZEV mandate sales goals are achieved, the increased adoption of ZEVs will also help automakers to comply with national vehicle emissions standards, and the usage of these ZEVs will help fuel suppliers comply with the provincial LCFS and national Clean Fuel Standards. Such overlap between policies might be reasonable, provided that policy-makers have effectively planned their policy mix over the long-term, to ensure that, even with such policy overlap, 2030 and 2050 climate targets are still achieved. A number of published modelling studies have considered such interactions for Canada's light-duty vehicle sector.[20]

In summary, we offer the following insights for B.C.'s planned ZEV mandate:

- The stated goals for ZEV sales are consistent with what research shows is needed to achieve 2030 and 2050 GHG reduction targets.
- The ZEV mandate has been shown to be an effective policy instrument, stimulating innovation in ZEV technology, increasing the availability of ZEV for sale, increasing ZEV sales, and reducing GHG emissions.
- California and Quebec provide similar examples of a ZEV mandate, which is effective in encouraging ZEV sales, but has many provisions that weaken the overall sales goal and are more complex than necessary.
- B.C. may differ from California in that it has set GHG reductions and ZEV sales as the primary policy goals (not innovation itself), and in that it has set stringent sales targets out to 2030 and 2040.
- Accordingly, B.C. should consider a simplified ZEV mandate, which we illustrate with the example of a One-to-One credit system that sets a minimum requirement for ZEV electric driving range, but otherwise treats all battery electric vehicles and hydrogen fuel-cell vehicles the same. Such a design should focus its credit and compliance system on the singular goal of increasing ZEV sales for the light-duty vehicle sector. Accordingly, other ZEV development activities, (e.g., for neighbourhood electric vehicles, or medium-duty or heavy-duty vehicles) should be addressed through separate regulation.
- We recommend that the B.C. government continue to prioritize GHG emissions goals and ZEV sales goals.
- Regarding GHG emissions goals, policy-makers must consider how the ZEV mandate will interact with other policies, notably in easing compliance with national vehicle-emissions standards, and national and provincial low-carbon fuel standard requirements.

20 Sykes and Axsen 2017; Lepitzki and Axsen 2018

- B.C. ought to consider the $5,000/credit penalty, to assure that it is sufficient to be binding for the long-term duration of the planned B.C. ZEV mandate. At the very least, the penalty should be inflation-adjusted.
- As for reporting/verification/enforcement, we are not aware of any reasons to deviate from the systems used in Quebec or California.
- While a ZEV mandate should be regularly updated and reviewed, learnings from the California experience warn that an overly "open" review may lead to continued attempts to weaken and "game" the policy. We thus recommend that the B.C. ZEV mandate stick to consistent overall goals (i.e., the stated ZEV sales targets), where reviews only focus on compliance, updates in regards to GHG emissions and related climate policies, and any drastic changes in technology or the market.

KEY RECOMMENDATIONS

1. Continue to prioritize deep emissions reductions and ZEV sales goals
2. Implement a simplified one-to-one credit system: one ZEV sale equals one ZEV credit
3. Include a binding, inflation-adjusted per credit penalty for non-compliance
4. Classify automakers according to sales volume on a proportional basis to the size of B.C.'s automotive market
5. Carefully consider how the ZEV mandate will interact with other climate policies
6. Do not provide early action credits for ZEV sales prior to the regulations coming into effect
7. Allow manufacturers to bank their credits for future use, but limit the time frame to two to three years and limit the use of such credits to 25 per cent of total compliance every year
8. Allow for separate regulations for medium- and heavy-duty vehicles

REFERENCES

Axsen, J. and M. Wolinetz (2018). "Reaching 30 per cent plug-in vehicle sales by 2030: Modeling incentive and sales mandate strategies in Canada." Transportation Research Part D: Transport and Environment 65: 596-617.

Azar, C. and B. A. Sandén (2011). "The elusive quest for technology-neutral policies." Environmental Innovation and Societal Transitions 1(1): 135-139.

Burke, A., K. S. Kurani, et al. (2000). Study of the Secondary Benefi ts of the ZEV Mandate, UCD-ITS-RR-00-07 University of California, Davis, Institute of Transportation Studies.

Clean Energy Canada (2018). Batteries Not Included. Vancouver, Canada, Simon Fraser University.

Dyerson, R. and A. Pilkington (2005). "Gales of creative destruction and the opportunistic incumbent: The case of electric vehicles in California." Technology Analysis and Strategic Management 17(4): 391-408.

Fox, J., J. Axsen, et al. (2017). "Picking Winners: Modelling the Costs of Technology-specific Climate Policy in the U.S. Passenger Vehicle Sector." Ecological Economics 137: 133-147.

Greenblatt, J. B. (2015). "Modeling California policy impacts on greenhouse gas emissions." Energy Policy 78: 158-172.

Greene, D. L., S. Park, et al. (2014). "Analyzing the transition to electric drive vehicles in the U.S." Futures 58: 34-52.

Greene, D. L., S. Park, et al. (2014). "Public policy and the transition to electric drive vehicles in the U.S.: The role of the zero emission vehicles mandates." Energy Strategy Reviews 5: 66-77.

Hanley, N., J. Shogren, et al. (2013). Introduction to Environmental Economics: Second Edition. New York, NY, Oxford University Press.

Hardman, S., A. Jenn, et al. (2018). Driving the Market for Plug-in Vehicles: Understanding ZEV Mandates. Davis, California, USA, University of California, Davis.

IEA (2017). New CEM campaign aims for goal of 30 per cent new electric vehicle sales by 2030. https://www.iea.org/newsroom/news/2017/june/new-cem-campaign-aims-for-goal-of-30-new-electric-vehicle-sales-by-2030.html.

IEA (2017). World Energy Outlook 2017. OECD: Paris, France.

Kamiya, G., J. Axsen, et al. (2019). "Modeling the GHG emissions intensity of plug-in electric vehicles using short-term and long-term perspectives." Transportation Research Part D: Transport and Environment 69: 209-223.

Lepitzki, J. and J. Axsen (2018). "The role of a low carbon fuel standard in achieving long-term GHG reduction targets." Energy Policy 119: 423-440.

Lutsey, N., S. Searle, et al. (2015). Assessment of Leading Electric Vehicle Promotion Activities in United States Cities. . San Francisco, CA, The International Council on Clean Transportation.

Lutsey, N. and S. Slowik (2018). The Continued Transition to Electric Vehicles in U.S. Cities. San Francisco, USA, The International Council on Clean Transportation (ICCT).

Matthews, L., J. Lynes, et al. (2017). "Do we have a car for you? Encouraging the uptake of electric vehicles at point of sale." Energy Policy 100: 79-88.

Melton, N., J. Axsen, et al. (2016). "Moving beyond alternative fuel hype to decarbonize transportation." Nature Energy 1(3): 1-10.

Plötz, P., S. A. Funke, et al. (2017). "CO2 Mitigation Potential of Plug-in Hybrid Electric Vehicles larger than expected." Scientific Reports 7(1): 16493.

Rhodes, E., J. Axsen, et al. (2017). "Exploring Citizen Support for Different Types of Climate Policy." Ecological Economics 137: 56-69.

Sykes, M. and J. Axsen (2017). "No free ride to zero-emissions: Simulating a region's need to implement its own zero-emissions vehicle (ZEV) mandate to achieve 2050 GHG targets." Energy Policy 110: 447-460.

Vergis, S. and V. Mehta (2010). Technology innovation and policy: a case study of the California ZEV mandate. Paving the Road to Sustainable Transport: Governance and innovation in low-carbon vehicles. T. F. Group.

Wolinetz, M. and J. Axsen (2017). "How policy can build the plug-in electric vehicle market: Insights from the respondent-based preference and constraints (REPAC) model." Technological Forecasting and Social Change 117: 238-250.

APPENDIX 1

CALIFORNIA ZEV MANDATE VEHICLE TYPES AND CREDIT FORMULAE

Vehicle Type	Definition	Credit formula	Example
Zero-emission vehicles or ZEV	Vehicles that do not produce emissions during their operation. They include battery electric vehicles (e.g., Tesla Model 3, Nissan Leaf, BMW i3 battery electric vehicle) and hydrogen fuel cell vehicles (e.g., Toyota Murai, Honda Clarity HFCV, Hyundai Tucson FCV).	$C_{ZEV} = (0.01 \times R) + 0.50$ where R is the range of the vehicle in mi based on both the UDDS and CARB method of estimating range. Maximum credits granted are 4.00 for new vehicles. A vehicle with a range less than 50 mi (80 km) does not qualify for credits.	Nissan Leaf 2018 has a range of 151 mi (243 km): $C_{Leaf} = (0.01 \times 151) + 0.50 = 2.01$ *credits* Tesla Model S 2018 has a range of 335 mi (539 km): $C_{Model\ S} = (0.01 \times 335) + 0.50 = 3.85$ *credits*
Battery electric vehicles with extended range or BEVx	Vehicles that have a minimum externally charged electric range of 75 mi (121 km), and an internal combustion engine with the sole purpose of extending the range. They include certain plug-in hybrid vehicles (e.g., BMW i3 REx 94 Ah).	$C_{BEVx} = (0.01 \times R) + 0.50$ where R is the range of the motor vehicle in mi based on both the UDDS and CARB method of estimating range, and its minimum value is 75 mi (121 km). Maximum credits granted are 4.00 for new vehicles.	BMW i3 REx 94 Ah 2018 has an electric-only range of 114 mi (183 km): $C_{i3\ REx\ 94\ Ah} = (0.01 \times 114) + 0.50 = 1.64$ *credits*

Vehicle Type	Definition	Credit formula	Example
Transitional zero emission vehicles or TZEV	Vehicles that produce low emissions during their operation. They include most plug-in hybrid electric vehicles (e.g., BMW i3 REx 60 Ah, Mitsubishi Outlander PHEV, BMW 530e) and hydrogen combustion vehicles.	TZEV credit formulae vary with electric-only range R capability given to new vehicles as follows: • 0 < R < 10 mi $C_{TZEV} = 0$ • 16 < R < 80 mi $C_{TZEV} = (0.01 \times R) + 0.3$ • R > 80 mi $C_{TZEV} = 1.10$ where R is the electric-only range of the motor vehicle in mi based on both the UDDS and CARB method of estimating range. An extra 0.2 credits are granted for vehicles with a minimum electric-only range of 10 mi that meet emission requirements specified by the U.S. Environmental Protection Agency.	BMW i3 REx 60 Ah 2018 has an electric-only range of 73 mi: $C_{i3\ REx\ 94\ Ah} = (0.01 \times 73) + 0.30 = 1.03$ *plus 0.2 credits assuming it complies with U.S. EPA requirements for a total of 1.23 credits* McLaren P1 2015 has an electric-only range of 6.8 mi: $C_{P1} = 0$ *receives no credits because the range is less than 10 mi*
Neighbourhood electric vehicles or NEV	Zero-emission motor vehicles with speeds not exceeding 25 miles per hour (40 km per hour), with 0 to 20 miles per hour (0 to 32 km per hour) acceleration in six seconds or less, and a minimum range of 25 miles (40 km). These include golf carts and neighbourhood electric vehicles (e.g., CanEV Might-E Truck)	New low-speed motor vehicles are granted 0.15 credits each: $C_{NEV} = 0.15$	CanEV Might-E Truck 2018 has a range of 56 mi: $C_{Might\text{-}E\ Truck} = 0.15$ *credits*

APPENDIX 2

COMPARING CALIFORNIA AND QUEBEC ZEV MANDATES

The Quebec policy is almost identical to the California version. Both policies place heavy emphasis on compliance with longer-range ZEVs (i.e., not shorter-range plug-in hybrid electric vehicles), though it is not clear that the credit generation that scales with range necessarily scales with the environmental benefit provided by the longer-range vehicles.

Despite the similarities, it is difficult to say that the policies have the same stringency, for a few reasons. Of note, Quebec's policy applies the same definitions for vehicle manufacturer size, even though its auto market is a fifth the size of California's. In other words, more automakers would qualify as SVMs and IVMs in Quebec. On the other hand, California's policy has some added flexibility with manufacturers' ability for cross-jurisdictional credit trade with the 10 other states that have adopted California's policy.

Other variations between the two policies can generally be explained by the different contexts under which they are implemented: California has had the policy for over 15 years, while Quebec has just introduced it. Quebec could also be mimicking the California policy for ease of compliance. We list the following major differences between the policies:

- While the names of complying vehicles differ, their definitions are almost identical. Zero-emission vehicles are called as such in both policies. California's battery electric vehicle with extended range becomes "motor vehicle with extended range" in Quebec. Transitional zero-emission vehicles are called low-emission vehicles in Quebec. Finally, neighbourhood electric vehicles do not only have a different name under the Quebec policy but also differ in their definition: in Quebec low-speed vehicles, as they are called, specifically include three-wheeled vehicles (they must reach a maximum speed of 32 to 40 kilometres per hour within 1.6 kilometres)
- The Quebec policy grants credits for "reconditioned" vehicles, with a maximum mileage of 40,000 kilometres; i.e., those that are retrofitted with zero- or low-emission vehicle technologies.
- Quebec does not grant credits for transportation emission-reduction activities, as is the case with California.
- California limits amount of neighbourhood electric vehicles-derived credits that intermediate vehicle manufacturers can use to meet their requirements, whereas that same type of credit (LSV credits) can meet up to 100 per cent of Quebec's IVM requirements.

- The credit requirements differ from 2018 to 2020, after which they align almost perfectly. Quebec's policy is more lenient during the first two years of introduction (3.5 per cent and 6.5 per cent in Quebec versus 4.5 per cent and seven per cent in California, in 2018 and 2019, respectively).
- The constraints on which credits LVMs use to comply begin in 2020 under the Quebec version of the policy, but are in place starting in 2018 in California.
- Quebec allows manufacturers to indefinitely bank their credits for future use (it does limit the use of such credits to 25 per cent of total compliance every year). We could not find any information on manufacturer's ability to bank credits generated after MY 2018 in California.
- Manufacturers are reclassified based on their average sales in the previous three consecutive years in Quebec. In California, the average manufacturer sales must change for five consecutive years for it to be reclassified. Furthermore, California features a minimum global revenue of US $40 billion requirement for an IVM to become an LVM even if the manufacturer exceeded the 20,000-vehicle sales threshold for five consecutive years.
- California explicitly considers the sale of passenger cars and light duty trucks when calculating sales, while Quebec considers the sale of vehicles with gross-weight below 4,500 kilograms. However, these are effectively the same thing. The California policy also grants credits for the sale of electric medium duty vehicles (e.g., these could be more than 4,500 kilograms).
- California provides a flexibility mechanism that is not available in Quebec for IVMs that fall short of compliance. The state lets manufacturers meet credits within three consecutive years of non-compliance if they can demonstrate how they plan to generate the excess credit required to close the deficit.

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