Canada's ZEV Policy Handbook

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December 2017

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Acknowledgements

We would like to acknowledge research contributions from **Jerold Brito**.
We would also like to thank **Studio Jaywall** for their contributions to graphic design.

Our research would not have been possible without the generous support of our funders. We would like to thank and acknowledge the following organizations for their contributions:

METCALF FOUNDATION

Pacific Institute for Climate Solutions
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About START

The Sustainable Transportation Action Research Team (START), in the Faculty of Environment at Simon Fraser University, focuses on supporting sustainable shifts in our transportation systems by conducting interdisciplinary research and engaging governments, industry, and communities. Our research approach integrates the best methods and perspectives regarding technology assessment, market acceptance, business strategy, and public policy.

START produces policy- and industry-relevant sustainable transportation research in three key aspects of transportation: vehicles and drivetrains, fuels and infrastructure, and mobility and travel demand. For each aspect, we aim to produce comprehensive research to assess different transportation technologies, practices, and solutions according to technological, feasibility, consumer and citizen acceptance, business and innovation strategy, and public policy.

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Executive Summary

Achieving Canada's long-term greenhouse gas (GHG) reduction targets likely requires the adoption of **zero-emission vehicles (ZEVs)**. While some ZEVs are already available in Canada, strong climate policies are needed to induce a substantial transition to low-carbon mobility [1]. Consequently, various levels of government in Canada have begun implementing a variety of policies to support ZEV sales in the short and long term.

The Government of Canada, along with 9 other countries, has committed to a target of 30% of new vehicle sales being electric by 2030 as part of the Clean Energy Ministerial 30@30 campaign [2]. Federal, provincial and territorial governments have also committed to developing a strategy for ZEVs in 2018 [3]. The strategy will outline Canada's goals for ZEV adoption as well as the policies and programs that will be put in place to support those goals.

Objectives of the *ZEV Policy Handbook*

The purpose of this *Handbook* is to help a variety of stakeholders understand what ZEV policies are available, and to evaluate these policies according to several criteria. We build on our 2016 *Electric Vehicle Policy Report Card* [4], which evaluated the electric-vehicle supportive policies in place in each Canadian province—finding that Canada as a whole is not on track to meet long-term adoption targets. Now that the Canadian Government is developing a ZEV strategy, this *Handbook* evaluates the suite of policy options that are available to the government to inform that strategy.

Specifically, this document:

1. **Identifies policy options** to support ZEV adoption in Canada.
2. **Evaluates policies** against five criteria: effectiveness, cost effectiveness, public support, simplicity, and transformational signal.
3. **Demonstrates effective policy packages** that could achieve a 2040 ZEV sales goal consistent with Canada's GHG reduction targets, using different approaches to reflect the diversity of policymaker considerations.

We frame our evaluation around the level of ZEV adoption likely needed to meet deep greenhouse gas reductions, using the goal of 40% new vehicle sales or "market share" by 2040 [5]—a goal that is consistent with the Clean Energy Ministerial's "30% by 2030" target [2]. We focus on passenger light-duty vehicles although we note that ZEVs for medium and heavy-duty applications will also be important for decarbonizing transport.

Defining zero-emissions vehicles

Zero-emission vehicles (ZEVs) are vehicles with a propulsion system that can operate without producing GHGs or other air pollutants at the tailpipe, unlike vehicles powered solely by fossil fuels. Following the Canadian federal government's definition [6], ZEVs include vehicles powered by electricity (battery-electric and plug-in hybrid vehicles) and hydrogen (hydrogen fuel cell vehicles). Of course, GHG emissions can be created when producing electricity or hydrogen. To effectively reduce emissions, ZEVs must be complemented by the development of low-GHG electricity and hydrogen supply [7].

Policies that can increase ZEV adoption

A range of policies are available to encourage or require the adoption of ZEVs. These policies can be broadly categorized as demand-focused or supply-focused:

- **Demand-focused policies** encourage consumers to purchase ZEVs. Examples include offering financial or non-financial incentives to consumers, making ZEVs more attractive through carbon pricing and improving charging or fueling availability.

- **Supply-focused policies** encourage or require suppliers such as automakers to make ZEVs available to consumers. Examples include specifying a minimum share of vehicles sold to be ZEVs or requiring that vehicles sold in a region meet a fleet average emissions intensity. Supply-focused policies can also target fuel suppliers, requiring them to reduce the carbon intensity of the fuels they sell in a region, which has the potential to indirectly encourage ZEV adoption.

This *Handbook* evaluates the eight policy categories summarized in Table 1.

Policies are summarized and then evaluated based on their current implementation in Canada as well as a Strong version. The Strong version reflects the strength of policy that is consistent with long-term GHG and ZEV goals. Note that none of these Strong version policies currently exist anywhere in Canada—nor has the federal government explicitly proposed such Strong levels. Other policies exist that may also support the impacts of the demand and supply-focused policies described on the previous page, such as education campaigns, codes and standards, and funding for research and development. However, these policies are not considered in this *Handbook* because they are unlikely to drive a transition to ZEVs on their own—we consider these to be "supportive" policies that could potentially support a package of strong, binding policies.

Table 1: Evaluated ZEV policies

Policy	Description	Strong specification
Demand-focused		
Financial incentives	Reduce cost of ZEVs and infrastructure (subsidies, rebates, waived user fees or tax exemptions)	$6,000 incentive per ZEV for 20 years in all provinces
HOV lane access	Unrestricted access to high-occupancy vehicle (HOV) lanes for ZEVs	HOV lane access for ZEVs in all provinces that have HOV lanes
Public charging	Provide access to charging away from home	Increase public chargers to one for every two gas stations in all provinces
Building codes	Require charging access in new buildings	Electric vehicle-ready building codes for new residential buildings introduced in all provinces
Carbon pricing	Increase price of fuels that generate carbon emissions through carbon tax or cap-and-trade	Carbon price reaches and maintains \$150/t CO_2e by 2030
Supply-focused		
ZEV mandate	Require automakers to sell minimum share of light-duty ZEVs	National ZEV mandate results in 40% new market share by 2040
Vehicle emission standard	Specify a required maximum level of tailpipe emissions for light-duty vehicles	Federal standard requires fleet average emissions for light-duty vehicles of about 71 g CO_2e by 2040
Clean fuel standard	Require fuel suppliers to reduce the carbon intensity of fuels they sell, with credits for alternative fuel consumption (e.g. electricity, hydrogen)	National standard requires reduction in the carbon intensity of transport energy of 25% by 2030 and 45% by 2040, relative to 2010

Our Approach

We evaluate each of the eight policies listed in Table 1 against five criteria:

- **Effectiveness:** How does a given policy impact ZEV new market share (of new vehicles sales) in the long term (2040)?

- **Cost effectiveness:** What is the direct government expenditure for each ZEV adopted?

- **Public support:** Is there public support for this policy?

- **Policy simplicity:** How straightforward is the policy to implement and administer?

- **Transformational signal:** Does a policy provide a durable signal to stimulate investment in ZEVs now and in the decades to come?

We evaluate each criterion using a 5-point scale, where a score of 5/5 reflects excellent performance and a score of 1/5 reflects poor performance.

Our approach relies on a thorough literature review and builds on previous assessments of ZEV policy by START. We also employ the Canadian **REspondent-based Preference and Constraint (REPAC)** model, which simulates electric vehicle new market share by representing key components of electric vehicle demand, electric vehicle supply and relevant policy. The report provides more detail about how each policy was assessed.

Not all criteria are likely equally important to all policymakers. We thus leave ranking the relative importance of criteria to the reader. However, we strongly suggest that "effectiveness" be considered as one of the most important criteria.

Evaluating current ZEV policies in Canada

Current policies are insufficient for achieving 2040 ZEV targets. Current policies could result in a new ZEV market share of between 9% and 17% in 2040 [8]. The projections include the impact of all currently implemented ZEV-supportive policies in Canada initiated by federal, provincial and major municipal governments, as well as electric utilities. The implication of these results is that additional policies need to be implemented or existing policies strengthened to give ZEVs a 40% market share by 2040—which is why we evaluate the impact of the Strong ZEV-supportive policies as described next.

Evaluating Strong ZEV policies

ZEV policies have different strengths and weaknesses, yielding trade-offs for policymakers seeking to encourage ZEV adoption. Here we only summarize our evaluations of "Strong" policy levels—all of which are stronger than versions of the policies that may be in place currently within Canada. We describe policy effectiveness in terms of the resulting ZEV market share (% of sales) in 2040, or the change in "percentage points" of that market share relative to a scenario without policy (e.g. If ZEVs have a 10% market share without policy, an increase in 2 percentage points means the market share grows from 10% to 12%). Table 2 shows how each policy performs against the five criteria. We find that:

1. **Strong financial incentives can be effective, but are costly to government.** For example, Strong incentives of $6,000 per vehicle for 20 years could increase ZEV market share by 15–20 percentage points in 2040, resulting in a score of 3/5 for effectiveness. However, financial incentives require the most direct government expenditure of any ZEV policy, resulting in a score of 1/5 for cost effectiveness.

2. **HOV lane access is a simple and publicly acceptable policy, but with limited effectiveness in Canada.** A Strong version of this policy increases ZEV market share by at most 0.2 percentage points in 2040, relative to a scenario without policy, resulting in an effectiveness score of 1/5. Its effectiveness is low because Canada has a limited number of roads with HOV lanes, which only benefit drivers when there is traffic congestion.

3. **Deploying public chargers is relatively simple and publicly acceptable, but is unlikely to be effective on its own.** Public charging scores poorly in terms of effectiveness because charging infrastructure at home and at work tends to be of greater concern for electric-vehicle users [9]. This policy increases ZEV market share by 2 percentage points in 2040, for a score of 1/5.

4. **Electric vehicle-ready building codes are publicly acceptable, simple and cost effective for government to implement, but require time to impact ZEV adoption due to the life span of existing buildings.** Strong Building codes may increase ZEV market share by 1.5 to 4.5 percentage points in 2040, resulting in an effectiveness score of 2/5.

5. **Strengthened carbon pricing is typically a cost effective policy that can increase ZEV adoption, but is the least publicly acceptable policy.** A Strong carbon tax or cap-and-trade rising to $150/t CO_2e could increase ZEV market share by 3.5 to 15 percentage points in 2040, scoring a 3/5 for effectiveness. However, public support for carbon pricing is the lowest among all policies examined (2/5).

6. **A strong ZEV mandate would be the most effective, low-cost and transformative policy, though it would be relatively complex to set up and administer.** A Strong version of this policy could increase ZEV market share to 40% in 2040. It is the only policy examined to receive an effectiveness score of 5/5.

7. **Strengthened vehicle emissions standards are a relatively politically acceptable policy that have the potential to be effective at a low cost to government.** A Strong version of this policy could increase ZEV market share to 40% of new vehicle sales in 2040. **While it seems likely that compliance would occur by selling a mix of conventional, hybrid and zero-emissions vehicles, this outcome is not guaranteed. Ongoing improvements to the energy efficiency of hybrid vehicles could allow compliance to be achieved by selling mostly very efficient hybrids and few ZEVs.** Because of this uncertainty, this policy is rated as a 4/5 in terms of effectiveness.

8. **A clean fuel standard is a cost effective and generally publicly acceptable policy that, depending on its design, could increase ZEV uptake.** It is unclear how the market for compliance credits under this policy would incentivize automakers to develop and sell ZEVs. A Strong version of this policy therefore receives a 3/5 in terms of effectiveness.

Table 2: Evaluation of Strong ZEV policies

	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Demand-focused					
Financial incentives	3	1	3	4	2
HOV lane access	1	5	3	5	3
Public charging	1	4	3	3	4
Building codes	2	5	5	5	4
Carbon tax	3	5	2	4	3
Cap-and-trade	3	5	2	1	3
Supply-focused					
ZEV mandate	5	5	4	2	5
Vehicle emissions standard	4	5	4	3	4
Clean fuel standard	3	5	4	1	3

Three policy packages that could achieve Canada's ZEV targets

There are multiple policy pathways that can be effective in the long term, as demonstrated among regions that lead global ZEV sales, notably Norway and California.

Each policy type offers different scores and trade-offs across evaluation criteria, so regions may have different notions of what makes an "ideal" policy package. To help inform this process, we used the REPAC model to identify and characterize three policy packages that could achieve the levels of ZEV uptake needed to achieve longer-term climate targets (i.e., 40% of ZEV sales by 2040, which is consistent with the Clean Energy Ministerial's 30@30 targets):

1. A demand-focused policy package that includes national **long-term incentives** of $6,000 per ZEV for 20 years. This package is like Norway's approach to ZEV policy.

2. A supply-focused policy package that includes a **national ZEV mandate** of 40% by 2040, coupled with short term incentives ($6,000 per ZEV for 2 years). This approach is a Stronger version of California's approach to ZEV policy.

3. An alternative supply-focused policy package that includes a **strengthened national vehicle emissions standard** of about 71 g CO_2e by 2040 (combined average for light-trucks and cars), coupled with short term incentives ($6,000 per ZEV for 2 years) [10]. For context, the Strong emissions requirement is roughly 60% below the current fleet average. This emissions-based approach is like a stronger version of the European Union's approach to ZEV policy.

All three packages also include support for home and public charging infrastructure.

The impact of these policy packages on new ZEV market share is shown in Figure 1. Additionally, the packages are evaluated against our five criteria in Table 3. The evaluation of policy packages reveal that policymakers have options for achieving their ZEV targets:

- A demand-focused approach is simple to implement but comes at a high (direct) cost to government. Additionally, this approach will only send a strong transformational signal if government can provide certainty that the incentives will be sustained over the long term (decades, rather than several years). Further, the impact on long-term ZEV sales is uncertain as it depends on future ZEV costs and consumer preferences.
- A supply-focused approach relying on a ZEV mandate provides a strong transformational signal at little (direct) cost to government, with high certainty of effectiveness. Careful implementation of this policy is important due to its complexity.
- A supply-focused approach relying on a vehicle emissions standard could achieve potentially similar market share outcomes as a ZEV mandate. To be equally effective at driving ZEV uptake, Canada's vehicle emissions standard would need to be greatly strengthened, reaching a combined average of about 71 grams of CO_2e per km for light-trucks and cars in 2040. While it seems likely that compliance would occur by selling a mix of conventional, hybrid and zero-emissions vehicles, this outcome is not guaranteed. Ongoing improvements to the energy efficiency of hybrid vehicles could allow compliance to be achieved by selling mostly very efficient hybrids and few ZEVs.

Figure 1: Example of policy packages to achieve ZEV targets

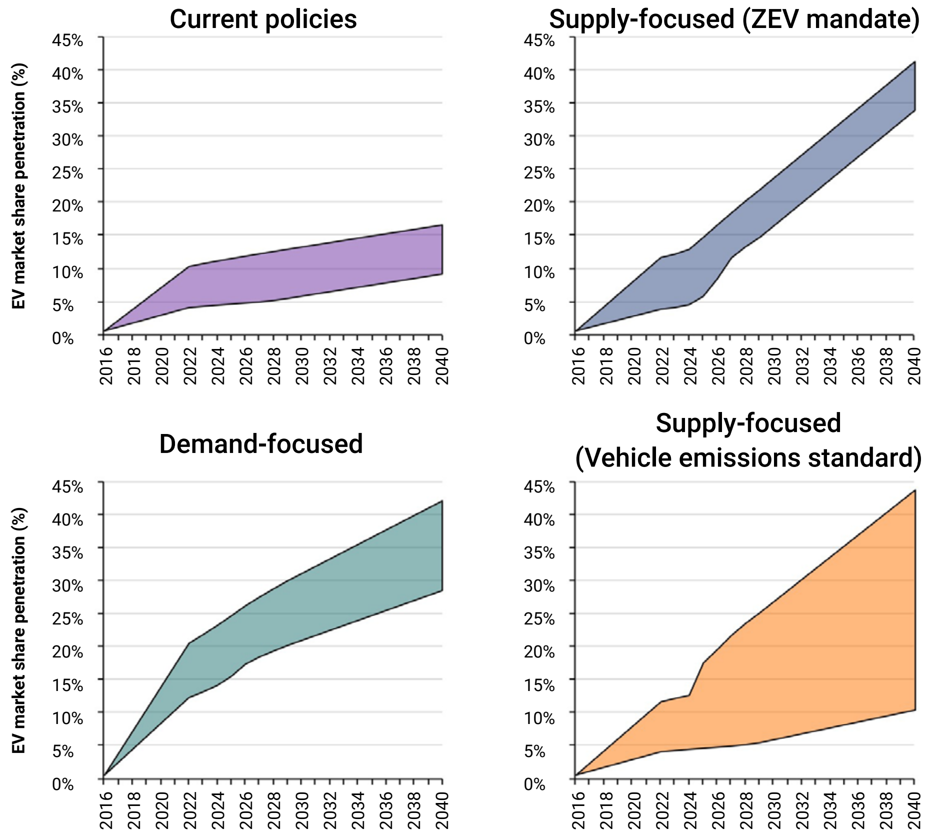


Table 3: Policy package evaluation

	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Demand-focused policy package	5	1	3	4	2
Supply-focused package (ZEV mandate)	5	5	4	2	5
Supply-focused package (vehicle emissions standard)	5	5	4	3	4

Policy insights

The *ZEV Policy Handbook* is a tool for policymakers to evaluate different policies and approaches for increasing ZEV adoption in Canada. We identify the following key policy insights for Canada:

1. Current policies are unlikely to encourage sufficient ZEV adoption to achieve Canada's ZEV targets or climate mitigation targets.

2. Only three types of Strong, national policies are likely to have a large impact on ZEV sales, while being reasonably acceptable to the public: financial incentives ($6,000 per ZEV for 20 years), a ZEV mandate (requiring 40% ZEVs by 2040), or a vehicle emissions standard (decreasing fleet emissions to 71 g CO_2e per km by 2040).

3. Strong financial incentives are simple to implement but come at a high (direct) cost to government. This cost may cause some public opposition in the long term.

4. A Strong ZEV mandate provides the highest certainty of effectiveness and a strong transformational signal at little (direct) cost to government, though it is complex to administer and may be opposed by some incumbent automakers.

5. A Strong vehicle emissions standard is likely simpler to implement than a ZEV mandate because it builds on existing policy, but the impact on ZEV market share is uncertain due to the variety of compliance options available to automakers.

Study limitations

Although this study relies on a thorough review of current literature, it nevertheless has some limitations. First, the impact of all policies is uncertain, especially over the long term, and depends on factors such as automaker strategies and the pace of technology development. We have incorporated a measure of uncertainty into the evaluation of effectiveness, but the ranges of values published in literature may not capture the full amount of uncertainty.

Second, despite this acknowledged uncertainty, we publish a single score out of five to aid with communicating the results. A drawback of this approach is that it could give a false sense of certainty with respect to policy impacts.

Finally, any analysis that rates policy impacts on a score out of five inevitably involves many simplifying assumptions. We document our approach throughout the report, and welcome feedback from stakeholders in how to improve this analysis.

Introduction

Introduction

Canada's climate mitigation targets and transport

Achieving Canada's greenhouse gas (GHG) reduction targets, including those implied by the COP 21 Paris Agreement, is likely to require significant decarbonization of all sectors of the economy by mid-century. Given that emissions from the movement of people and goods presently account for about one-quarter of Canada's GHG emissions [11], abating emissions from transport is particularly important for ensuring that climate targets are achieved.

Decarbonization of transport can occur through shifting from gasoline and diesel to alternative fuels such as low-carbon electricity, hydrogen and biofuels. For example, the International Energy Agency estimates that stabilizing global carbon dioxide (CO_2) concentrations at 450 parts per million (ppm) might require 40% of new passenger vehicle sales to be plug-in electric by 2040, with most remaining vehicles powered by biofuels [5]. Studies in Canada and the US suggest that meeting national and provincial GHG targets requires zero-emission vehicle (ZEV) sales to reach 80–90% of passenger vehicle sales by 2050 [12]–[14].

To support objectives related to climate change mitigation and local air pollution, various levels of government in Canada have implemented policies to encourage or require the adoption of ZEVs. The Government of Canada, along with 9 other countries, has committed to a sales target of 30% electric vehicles by 2030 as part of the Clean Energy Ministerial 30@30 campaign [2]. Finally, federal, provincial and territorial governments have committed to developing a strategy for ZEVs in 2018. The strategy will outline Canada's goals for ZEV adoption, as well as the policies and programs that will be put in place to support those goals.

Objectives

The purpose of this *Handbook* is to help a variety of stakeholders understand what ZEV policies are available, and to evaluate these policies according to several criteria. We build on our 2016 *Electric Vehicle Policy Report Card* [4], which evaluated the electric-vehicle supportive policies in place in each Canadian province—finding that Canada as a whole is not on track to meet 2040 adoption targets. Now that the Canadian government is developing a ZEV strategy, this *Handbook* evaluates the suite of policy options that are available to the government to inform that strategy.

The objectives of the *ZEV Policy Handbook* are to inform the development of Canada's ZEV strategy by:

1. identifying policy options,
2. evaluating policy options across multiple criteria, and
3. constructing potential policy packages for achieving climate mitigation targets.

We frame our evaluation around the level of ZEV adoption likely needed to meet deep greenhouse gas reductions, using the goal of 40% new vehicle sales or "market share" by 2040 [5]—a goal that is consistent with the Clean Energy Ministerial's "30% by 2030" target [2]. We focus on passenger light-duty vehicles although we note that ZEVs for medium- and heavy-duty applications will likely be important for decarbonizing transport.

This *Handbook* creates a common language with which to discuss policy options. Specifically, the *Handbook* can help readers identify and differentiate policy options in terms of their likely effectiveness, cost effectiveness, public support, simplicity and transformational signal in reshaping Canada's transportation system, while providing several illustrative policy packages that can meet our climate goals.

Structure of the *Handbook*

The *Handbook* is structured as follows:

- **Background** defines ZEVs and reviews the market for ZEVs in Canada
- **Our Approach** reviews the approach taken to evaluate ZEV-supportive policies
- **Policy Evaluation** evaluates key ZEV policies against five criteria
- **Policy Packages** demonstrates several policy packages that can achieve Canada's ZEV targets
- **Conclusions & Policy Insights** summarizes key policy insights for the development of ZEV policy in Canada

More detail about the evaluation methods and approach for developing the policy packages is included in the **Appendix**.

Background

Background

Defining zero-emission vehicles

Zero-emission vehicles (ZEVs) are vehicles with a propulsion system that can operate without producing GHGs or other air pollutants at the tailpipe, unlike vehicles powered solely by fossil fuels. According to the Canadian federal government's definition [6], these include three types of vehicles: those that are solely powered by electricity (battery electric vehicles or BEVs), such as the Tesla Model S; those that are powered both by electricity and gasoline (plug-in hybrid vehicles or PHEVs), such as the Chevrolet Volt; and those powered by hydrogen (hydrogen fuel cell vehicles or HFCVs), such as the Toyota Mirai.

Of course, GHG emissions can be created by the production of electricity or hydrogen. To effectively reduce emissions, ZEVs must be complemented by the development of low-GHG electricity or hydrogen supply. For example, a BEV fuelled from a zero-carbon electric grid will result in fewer economy-wide GHG emissions than one fueled by an emissions-intensive grid [7]. With Canada's current electric grid, an electric vehicle could reduce emissions 45% to 98% compared to a conventional gasoline vehicle [15].

Strictly speaking, biofuel-powered vehicles do not meet the definition of ZEVs because they generate "tailpipe" emissions. Nevertheless, biofuel-powered vehicles could generate low GHGs if biofuels are produced by low-carbon means.

Examples of ZEVs

Battery electric vehicles (or BEVs) run on electricity only. They are charged by plugging them into an electrical outlet. A BEV has a driving range between 100 and 500 kilometres, depending on the make and model. Examples of current vehicles in Canada include the Nissan Leaf, Mitsubishi i-MiEV, Chevrolet Bolt and Tesla Model S.

Plug-in hybrid electric vehicles (or PHEVs) can run on both electricity and gasoline. They are both fueled by plugging them into an electrical outlet and by fueling them at a gasoline station. Depending on the make and model, a PHEV can travel for the first 20 to 150 kilometers on electricity (with a fully-charged battery) and then run on a full tank of gasoline for up to 900 kilometers. Examples of currently available PHEVs in Canada include the Chevrolet Volt, Ford C-Max Energi and Toyota Prius Prime.

Hydrogen fuel cell vehicles (or HFCVs) run on hydrogen fuel and are fueled much like a gasoline car only with a special hydrogen fuel pump. The hydrogen in the vehicle is converted into electricity in a fuel cell, which powers an electric motor. Depending on the make and model, a HFCV can travel between 300 and 550 kilometers on a full tank. Although HFCVs are not widely available in Canada, examples of HFCV available in North America include the Hyundai Tucson Fuel Cell, Toyota Mirai and the Honda Clarity.

BEVs

PHEVs

HFCVs

The current market for ZEVs in Canada

Electric vehicles

Electric vehicle (i.e., including PHEVs and BEVs) sales in Canada have grown over the last few years. Between 2011 and 2017, the number of electric vehicles on the road increased from 1,500 to 39,000 [16]. In 2016, electric vehicles represented between 0 and 2.4% of new vehicles sales across Canadian provinces. Most of the sales (95%) were concentrated in Canada's most populous provinces, namely Quebec, Ontario and British Columbia (with a total of 10,000 BEVs and PHEVs), which account for 75% of the total population.

On a global scale, few countries have achieved electric vehicle sales beyond 1% of new market share. Since 2012, the number of EVs on the road globally has increased eleven-fold from 175,000 to 2,000,000 [17]. Jurisdictions like Norway (29% of vehicle sales), the Netherlands (6% of vehicle sales), and the US state of California (5% of vehicle sales) have experienced the highest market penetration of new electric vehicles in 2016 [17]–[19]. Such regions also tend to have several electric vehicle supportive policies such as vehicle purchase incentives, ZEV quotas or sales mandates, vehicle emissions regulations and ZEV fueling/charging infrastructure support [20].

Hydrogen fuel cell vehicles

Aside from a limited number of vehicles leased from Hyundai, hydrogen fuel cell vehicles are not available in Canada. It is possible that a greater number of fuel cell vehicles may be available to Canadians in the next few years, such as the Toyota Mirai, the Mercedes Benz GLC F Cell and the Honda Clarity [21]–[23]. Globally, sales of hydrogen fuel cell vehicles have also been limited. Since 2007 only about 4,000 such vehicles have been sold world-wide, with the majority of sales occuring in Japan, California and Germany [24].

Barriers to ZEV adoption in Canada

Although many Canadians are interested in ZEVs, potential consumers may not purchase them because of a variety of market barriers on the demand and supply side [15], [25]–[27]. Understanding these barriers is helpful for policymakers designing policies to encourage ZEV adoption.

Examples of barriers on the demand side include:

- **Consumer awareness is low.** Canadian consumers are confused about ZEVs, with less than 40% of new car buyers understanding how to fuel the most popular ZEV models on the road [28], [29].

- **Access to EV charging is constrained at home.** Up to one-third of new car buyers in Canada lack home charging access, with the majority of those without access living in apartments and condos [9]. Research suggests that access to EV charging at home is important to EV uptake and is linked to consumer interest [9], [29], [30].

- **Public charging and hydrogen refueling stations are limited.** Canada has 5,900 public charging stations, or 163 per one million Canadians [31]. This level is below that of jurisdictions that have higher electric vehicle market shares like Norway and California. Access to public hydrogen refueling stations is even more limited, with only a handful of publicly accessible stations either in operation or planned for Canada.

- **Vehicle prices are currently higher than gasoline and diesel cars.** In today's market, electric vehicles and hydrogen vehicles are more expensive than their gasoline counterparts. However, prices are likely to fall with increased production and technological improvements [17].

Examples of barriers on the supply side include:

- **ZEVs are currently available in only a few vehicle classes and the number of models available in Canada is limited [32].** As of September 2017, 19 non-luxury electric vehicle models (under $50,000) are available in Canada, of which 80% are sedans and compact cars, and only one hydrogen fuel cell vehicle is available [33], [34]. In contrast there were almost 400 gasoline models available for sale in Canada in 2016 [35].

- **Availability of ZEVs at dealerships is low.** Only a fraction of dealerships are certified to sell electric vehicles and an even smaller number keep models in stock and make them available for test drives [36], [37]. In 2015, close to half of Canadian dealerships were not certified to sell electric vehicles [36].

Our research finds that these barriers have a significant effect on Canadian consumer demand, and are in part responsible for the current low market share of electric vehicles [27]. Without additional policies to address these barriers, electric vehicle sales are unlikely to be more than 4 to 12% of the new vehicle market by 2030 [38]. Therefore, it is critical to address both demand and supply side barriers. For example, an informed consumer with home charging access is unlikely to buy an electric vehicle if they cannot find one in a nearby dealership or in the vehicle class they want.

Our Approach

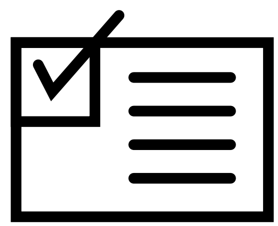
Our Approach

There are a number of policies that can support ZEVs, each with different strengths and weaknesses. To inform ZEV stakeholders and governments, this *Handbook* explains the policy types and evaluates each policy against five criteria. We then present three policy packages for achieving ZEV sales in-line with Canada's long-term GHG targets. We developed this *Handbook* in three steps:

1

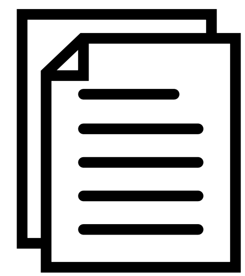
Identify policy options to support ZEV adoption in Canada.

2



Evaluate policies against five criteria: effectiveness, cost effectiveness, public support, policy simplicity and transformational signal.

3



Demonstrate effective policy packages that could achieve a 2040 ZEV sales goal consistent with Canada's GHG reduction targets, using different approaches reflecting the diversity of stakeholder interests.

In creating this *Handbook* we engaged several ZEV stakeholders in industry, NGOs, government and academia from across Canada to inform our understanding of the policies available as well as the diversity of perspectives on ZEV strategies [39].

In this section, we provide a brief description of each step. Additional information about our approach is provided in the **Appendix**.

Step 1
Identify policy options

A range of supply- and demand-focused policies are available to encourage or support the consumer adoption of ZEVs. Demand-focused policies encourage consumers to purchase ZEVs, for example by offering financial or non-financial incentives to consumers, making low emission vehicles more attractive through carbon pricing and improving charging or fueling availability.

In contrast, supply-focused policies generally encourage or require auto manufacturers to sell ZEVs, for example by specifying a minimum share of vehicles sold to be ZEVs or requiring that vehicles sold in a region meet a fleet average emissions intensity. Supply-focused policies can also target fuel suppliers, requiring them to reduce the carbon intensity of the fuels they sell in a region.

We review and evaluate the following eight types of policies that have been implemented in Canada:

Demand-focused policies

1 **Financial incentives:** government subsidy for the purchase of a ZEV (page 29)

2 **HOV lane access:** giving ZEVs unrestricted access to HOV lanes (page 31)

3 **Public charging:** supporting the deployment of charging infrastructure in non-residential areas (page 33)

4 **Building codes:** amending codes to require new residential buildings to install chargers or be electric vehicle friendly (page 35)

5 **Carbon pricing:** applying a price on conventional vehicle tailpipe emissions (page 37)

Supply-focused policies

6 **ZEV mandate:** regulation requiring auto manufacturers to meet a portion of their sales with ZEV equivalency credits (page 39)

7 **Vehicle emissions standard:** regulation requiring auto manufacturers to reduce the average fuel economy of their sales fleet (page 41)

8 **Clean fuel standard:** regulation requiring fuel suppliers to reduce the carbon intensity of their fuels by a specified amount (page 43)

Other policies exist that may support the impacts of the demand- and supply-focused policies listed above, such as educational campaigns, codes and standards or funding for research and development. For example, changes to codes, standards or permitting can make the installation of ZEV charging or fueling infrastructure easier and potentially cheaper, or information campaigns can help educate the public on how ZEVs operate and how they are powered. These policies are not considered in this *Handbook* because they are unlikely to drive a transition to ZEVs on their own—we consider these to be “supportive” policies that could potentially support a package of strong, binding policies.

Step 2
Evaluate policies

There are many factors to consider when evaluating and developing policies. For example, a $500/tonne carbon tax might create a strong push for the development and uptake of ZEVs, but such a high tax may experience public opposition. To reflect key considerations of policy development, we evaluate each policy against five criteria that are well-cited in the ZEV policy evaluation literature [1], [29], [40], as shown in Table 4:

- **Effectiveness:** How likely is a policy to impact ZEV new market share in the long term (2040)?
- **Cost effectiveness:** What amount of government spending is expected for each ZEV adopted?
- **Public support:** Does the public generally support or oppose the policy?
- **Policy simplicity:** How straightforward is the policy to implement and administer?
- **Transformational signal:** Does a policy provide a durable signal to stimulate investment in ZEVs now and in the decades to come?

Policies are evaluated based on their current implementation in Canada as well as a Strong version. The Strong version is intended to demonstrate the potential impacts of a national policy that could drive greater ZEV adoption.

Next, we briefly describe our methods for evaluating each criterion, where each criterion is evaluated on a five-point scale. Policies are given a score out of 5, where 5 denotes excellent performance while 1 denotes poor performance. Table 4 specifies the evaluation scale used for each criterion. Additional detail about our methods is reviewed in the **Appendix**.

Table 4: Overview of evaluation approach

Criteria	Evaluation metric	Evaluation scale	Key sources
Effectiveness	ZEV share of new vehicle sales in 2040	1 = 0–2.49% 2 = 2.5–9.9% 3 = 10–19.9% 4 = 20–39.9% 5 = 40%+	Melton, Axsen & Goldberg (2017); Jin et al (2014); Lin & Greene (2011) [29], [41], [42]; Authors' calculations using REPAC
Cost effectiveness	Government expenditures on financial incentives and charger deployment	1 = $2,001+/ZEV 2 = $1,001–2,000/ZEV 3 = $501–1,000/ZEV 4 = $0-500/ZEV 5 = $0/ZEV	Authors' calculations using REPAC
Public support	Public support	Low support (1/5) to high support (5/5)	Rhodes et al. (2017) [43]
Policy simplicity	Requirement for drafting new legislation, coordination within government, and monitoring and enforcement	Complex (1/5) to simple (5/5)	Expert judgment
Transformational signal	Durability and directionality	Not durable or directional (1/5) to durable and directional (5/5)	Weber & Rohracher (2012) [44]; Expert judgment

For more information about the evaluation approach, please see the **Appendix**.

Effectiveness

Criteria definition: How does a given policy impact ZEV market share in the long term?

We use a variety of sources to assess the potential impact of each policy on the share of light-duty passenger vehicle sales that are ZEVs in 2040. Our approach generally follows that established in Melton, Axsen & Golderg (2017) [29], which we have now updated to reflect recent policy developments and new evaluation methods where possible. For the purpose of this evaluation, we equate ZEV market share with electric vehicle market share, given that hydrogen fuel cell vehicles are virtually unavailable currently. To receive a score of 5/5, a policy must have a market share impact of 40% by 2040 [5], which is consistent with the Clean Energy Ministerial's "30% by 2030" target [2].

Cost effectiveness

Criteria definition: What is the direct government expenditure per ZEV adopted?

We use results from the evaluation of effectiveness (outlined on the previous page) to estimate the cost effectiveness of both current and Strong versions of the policies. Cost effectiveness is defined as the amount of direct government expenditure per ZEV adopted over the 2018–2040 timeframe.

We assume that direct government investment is required for financial incentives and development of public charging, but not of other policies. These costs are discounted to the present using a social discount rate of 3%. We assume that the cost of public charging averages $12,600 per charger [45], but that government incurs only half these costs (i.e., the remaining investment comes from the private sector).

Note that direct government expenditure provides insight into only one aspect of policy cost effectiveness. So-called "policy costs" or "welfare costs" can also include broader impacts to consumers, producers and related sectors—though definitions and methods of estimation are quite controversial. Direct government expenditure is relatively easy to estimate, while still providing a sense of the government resources required to implement a policy.

Public support

Criteria definition: Is there public support for this policy?

To evaluate public support, we draw on results from a recent study that explored public support for a range of policy types in Canada [43]. This study determined the level of support for market-based, regulatory, financial and voluntary energy and climate policies from a representative sample of over 1,300 Canadian citizens. We translate the percentage support using the methods described in the **Appendix**.

We supplement the evaluation of public support with insights about stakeholder support that were gained through our engagement with ZEV stakeholders in industry, academia and NGOs [39]. We consulted Canadian stakeholders in the automotive industry, the electric vehicle industry, academia, non-governmental organizations, and governments asking for their feedback about current government targets and several types of ZEV policies. Our discussions also provided us with their perspectives about how the status quo could be improved and about how they felt the ZEV landscape should evolve.

Policy simplicity

Criteria definition: How straightforward is the policy to implement and administer?

Simplicity is defined as the level of effort required by government to implement and administer a policy. We evaluate a policy's simplicity by considering its likely requirements for:

- **Drafting new legislation.** Does a policy require new legislation or can it be implemented by amending existing legislation? Is the legislation likely to be relatively more or less complex? For example, will new personnel need to be hired or re-assigned to develop it?

- **Coordination within government.** What level of coordination is likely to be required among government departments and across different levels of government? Can a policy be implemented by one level of government or is it likely to require coordination among multiple levels (e.g. federal, provincial and municipal)? Can a policy be implemented by a single government department or is it likely to require involvement of multiple departments (e.g. transport, environment, energy)?

- **Monitoring and enforcement.** What level of effort is required for monitoring the policy and/or enforcing policy compliance? For example, must government ensure compliance of a relatively large or small number of actors? Is compliance easily determined or are there multiple compliance pathways that necessitate more sophisticated monitoring?

Transformational signal

Criteria definition: Does a policy provide a durable signal to stimulate investment in ZEVs now and in the decades to come?

Transformational signal is defined as a policy's ability to stimulate development and investment in a ZEV transition over the long term. In other words, is a policy durable and does it provide certainty to consumers, suppliers, and stakeholders that it will support a ZEV transformation over the years and decades to come?

We evaluate a policy's transformational signal by assessing its performance against two characteristics:

- **Durability.** Does the policy tend to be durable? More durable policies set clear and consistent requirements or rules that last a decade or more.

- **Directionality.** Does the policy provide directionality [44] with respect to investments in ZEVs, or is it less technology specific (e.g. potentially encouraging investment in other technologies such as high efficiency internal combustion engines)?

Policies that are both durable and provide directionality with respect to ZEVs are evaluated as providing a strong transformational signal (5 out of 5). Those that are neither durable nor directional are evaluated as providing a weak transformational signal.

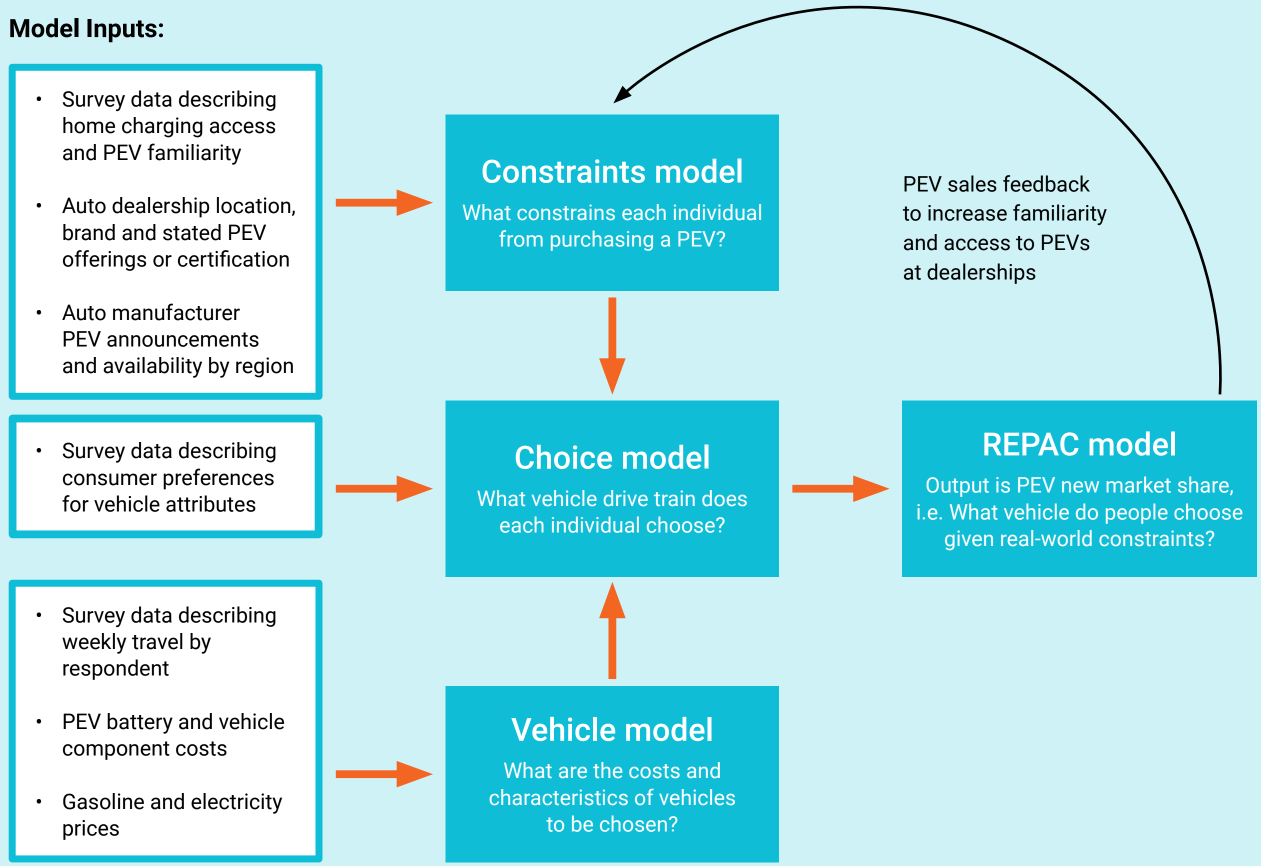
Step 3
Demonstrate effective policy packages

Depending on their goals and priorities, policymakers may have preferences for approaches that use different combinations of policies to increase ZEV uptake. To help inform this process, we employed the REPAC model to estimate the potential impact of different combinations of policies. REPAC has been used in several related studies (for example, see Axsen and Wolinetz, under review [38]; Wolinetz and Axsen, 2017 [8]).

The REPAC model

The **REspondent-based Preference and Constraint (REPAC)** model simulates electric vehicle new market share by representing key components of electric vehicle demand, electric vehicle supply and relevant policy (see Figure 2). REPAC uses a latent class discrete choice model estimated from data collected in a representative survey of over 1,700 new vehicle-buying households in Canada. REPAC treats these choice model results as a measure of unconstrained demand for electric vehicles, and then adds consumer constraints (electric vehicle awareness and home charging access) as well as supply constraints (limited variety and availability of electric vehicle models).

Figure 2: Structure of the REPAC-PEV market share simulation model



We begin with a forecast of how current policies implemented by governments across Canada are likely to impact ZEV market share. We then characterize three policy packages that could achieve the levels of ZEV uptake needed to achieve longer-term climate targets (i.e., 40% of ZEV sales by 2040) as shown in Table 5:

- A demand-focused policy package that includes national **long-term incentives** ($6,000 per ZEV for 20 years).
- A supply-focused policy package that includes a **national ZEV mandate** of 40% by 2040, coupled with short term incentives ($6,000 per ZEV for 2 years).
- An alternative supply-focused policy package that includes a **strengthened national vehicle emissions standard** of about 71g CO_2e by 2040 (for light-duty vehicles), coupled with short term incentives ($6,000 per ZEV for 2 years).

All three packages also include support for home and public charging infrastructure.

Table 5: Alternative policy packages

Policy type	Demand-focused (long-term financial incentives)	Supply-focused (ZEV mandate)	Supply-focused (strengthened vehicle emissions standard)
Demand-focused			
Financial incentives	$6,000 x 20 years	$6,000 x 2 years (2018–2019)	$6,000 x 2 years (2018–2019)
HOV lane access	All congested highways		
Public (non-home) charging	One public charger for every two gas stations	One public charger for every two gas stations	One public charger for every two gas stations
Building codes	Increasing home charging to 95% of consumers in 2030	Increasing home charging to 95% of consumers in 2030	Increasing home charging to 95% of consumers in 2030
Supply-focused			
ZEV mandate		ZEVs make up at least 5% of new vehicle sales by 2020, 22.5% in 2025, and 40% in 2040	
Vehicle emissions standard			Vehicle emissions standard tightened to about 71g CO_2e per km by 2040 (for light-duty vehicles)

Note: All policy packages also include policies as currently implemented in Canada.

Limitations of the approach

Although this study relies on a thorough review of current literature, it nevertheless has some limitations. First, the impact of all policies is uncertain, especially over the long term, and depends on factors such as automaker strategies and the pace of technology development. We have incorporated a measure of uncertainty into the evaluation of effectiveness, but the ranges of values published in literature may not capture the full amount of uncertainty. This uncertainty is discussed for each policy evaluated in the *Handbook* in Table 26 in the **Appendix**.

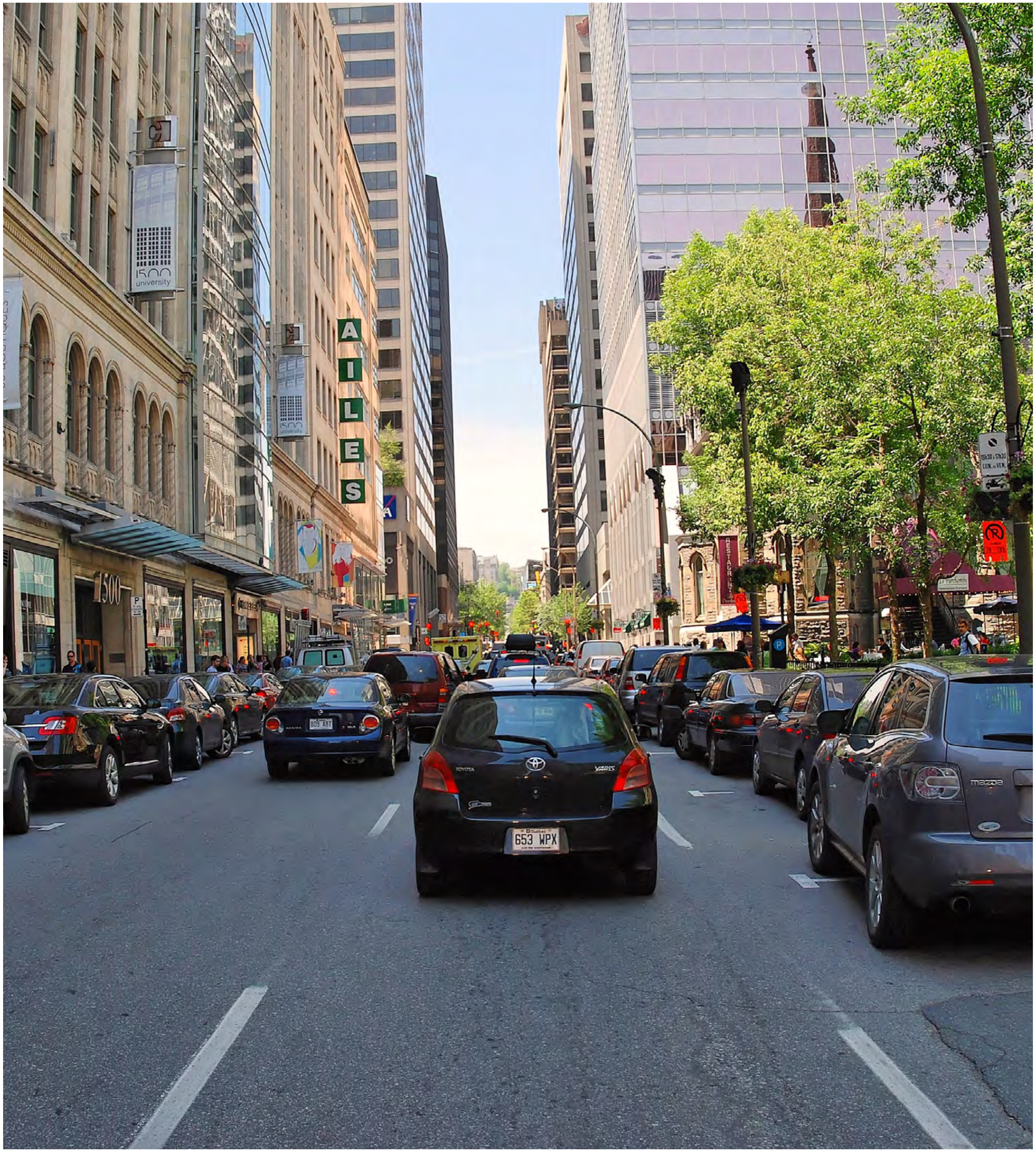
Second, despite this acknowledged uncertainty, we publish a single score out of five to aid with communicating the results. A drawback of this approach is that it could give a false sense of certainty with respect to policy impacts.

Finally, any analysis that rates policy impacts on a score out of five inevitably involves many simplifying assumptions. We document our approach throughout the report, and welcome feedback from stakeholders in how to improve this analysis.

Policy Evaluation

Policy evaluation

In this chapter we provide a summary of each policy type, as well as our evaluation of current and Strong versions of that policy. We describe policy effectiveness in terms of the resulting ZEV market share (% of sales) in 2040, or the change in "percentage points" of that market share relative to a scenario without policy (e.g. If ZEVs have a 10% market share without policy, an increase in 2 percentage points means the market share grows from 10% to 12%). At the time of writing this report, none of the Strong version policies have been implemented anywhere in Canada, nor has the Canadian government proposed them. Note that the full documentation of our evaluation is provided in the **Appendix**.

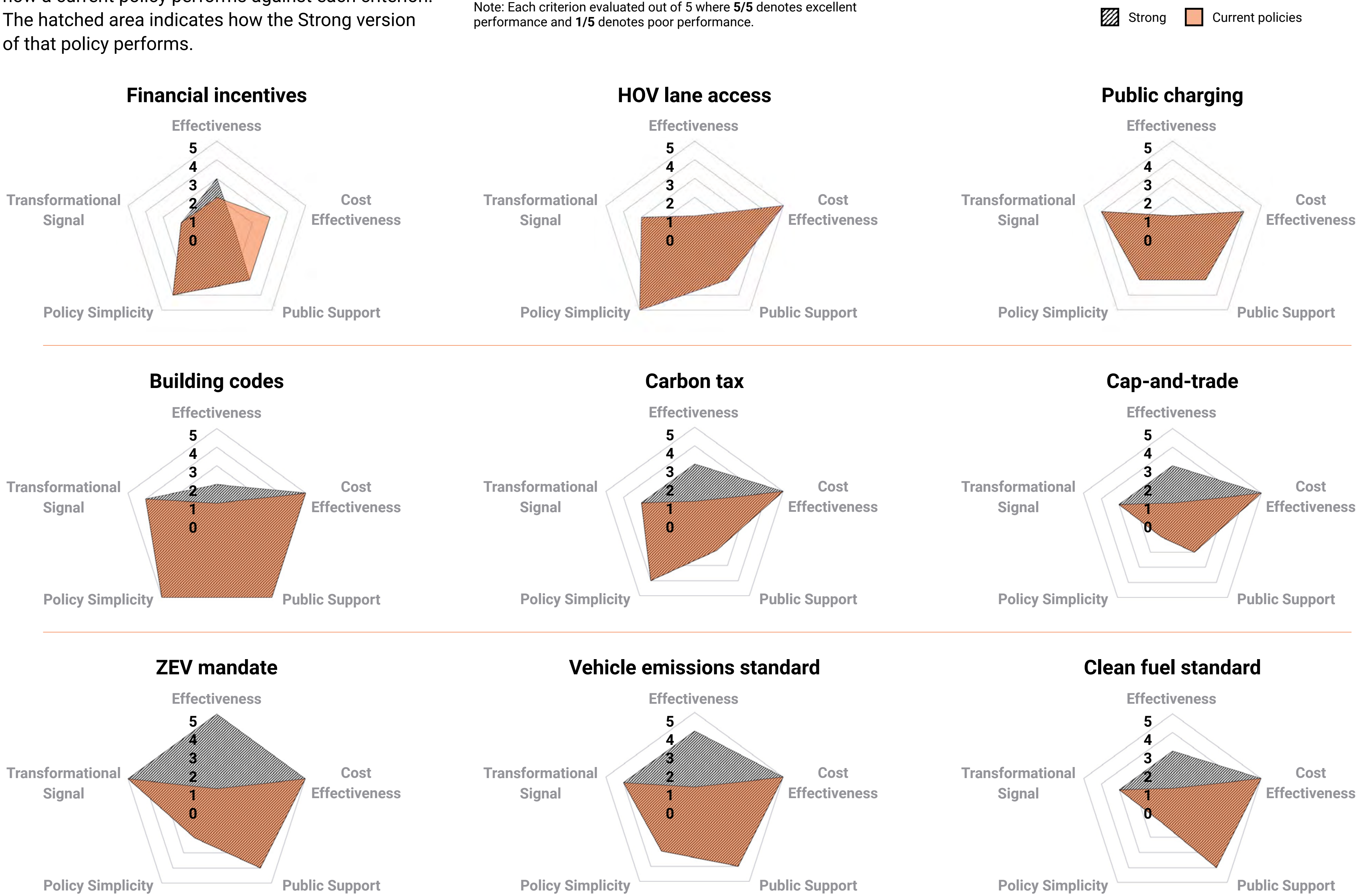


Interpreting the spider diagrams

In each figure, the area shaded orange indicates how a current policy performs against each criterion. The hatched area indicates how the Strong version of that policy performs.

Figure 3: Overview of ZEV policy evaluation

Note: Each criterion evaluated out of 5 where **5/5** denotes excellent performance and **1/5** denotes poor performance.



Financial incentives

By financial incentives we mean subsidies that reduce the upfront cost of purchasing a vehicle. Incentives make ZEVs more attractive for consumers by making them more cost-competitive with conventional vehicles. Options for financial incentives include point-of-sale incentives, rebate programs, tax exemptions, and tax credits. This is a popular policy in North America and globally, having been implemented in three Canadian provinces (BC, Ontario and Quebec), at both the federal and state level in the United States, and in several European countries [46]. Norway has had the strongest ZEV incentive policy, with incentives exceeding $30,000 per vehicle [20]. Ontario was the first Canadian jurisdiction to offer financial incentives with the Electric Vehicle Incentive Program in 2010 [47].

Policy adoption

Three provinces (British Columbia, Ontario and Quebec) currently have financial incentives for ZEVs as shown in Table 6. These incentives reduce the purchase price of a ZEV by $500 to $14,000 depending on the type of vehicle (e.g. whether it is a battery electric or plug-in hybrid, or depending on its range). The Strong policy version is a national incentive of $6,000 per ZEV sold over the next 20 years.

Table 6: ZEV financial incentives in Canada

Current policy		Strong version	
BC	Point-of-sale incentive under the Clean Energy Vehicle program ranging from $2,500 to $6,000 depending on vehicle type. First round of funding ran between 2011 and 2014, second round ongoing since 2015 [48]	**National**	Point-of-sale incentive adopted for 20 years between 2018 and 2038 with a value of $6,000 per vehicle sold
ON	Rebate incentive under the Electric Vehicle Incentive Program (EVIP) ranging from $3,000 to $14,000 depending on battery and passenger capacity. Initially introduced in 2010 and updated in 2016 [33]		
QC	Rebate under the Drive Electric program between $500 to $8,000 depending on vehicle price and type. Has been in place since 2012 [49]		

Financial incentives

Evaluation

Financial incentives have the potential to drive substantial ZEV adoption if they are strong enough and long lasting, but they are costly to government and often short lived (see Figure 4 and Table 7):

- **Effectiveness:** Current financial incentives are funded through 2018 and anticipated to increase ZEV market share by 1.5 to 5 percentage points in 2040, receiving an effectiveness score of 2/5. Financial incentives could increase ZEV market share by 15–20 percentage points if applied nationally in the Strong version of this policy ($6,000 per vehicle for 20 years), resulting in a score of 3/5.

- **Cost effectiveness:** The policy requires a high amount of direct government investment compared to other ZEV policies, resulting in a score of 3/5 in its current form and 1/5 in its Strong form.

- **Public support:** Financial incentives tend to be generally supported by the public (3/5) [43]. ZEV stakeholders also hold positive views on the policy, although this support may decline if incentives are in place for a longer period of time [39].

- **Policy simplicity:** This type of policy tends to be relatively simple for government to implement and administer because it does not require legislation and monitoring is straightforward (4/5).

- **Transformational signal:** The policy is rated as providing a relatively weak transformational signal (2/5) because financial incentives tend not to be very durable, with funds typically set aside for a period of one to several years at most. While incentives provide some directionality with respect to investment in ZEVs, this policy is not compulsory for automakers or other stakeholders.

Figure 4: Financial incentives evaluation

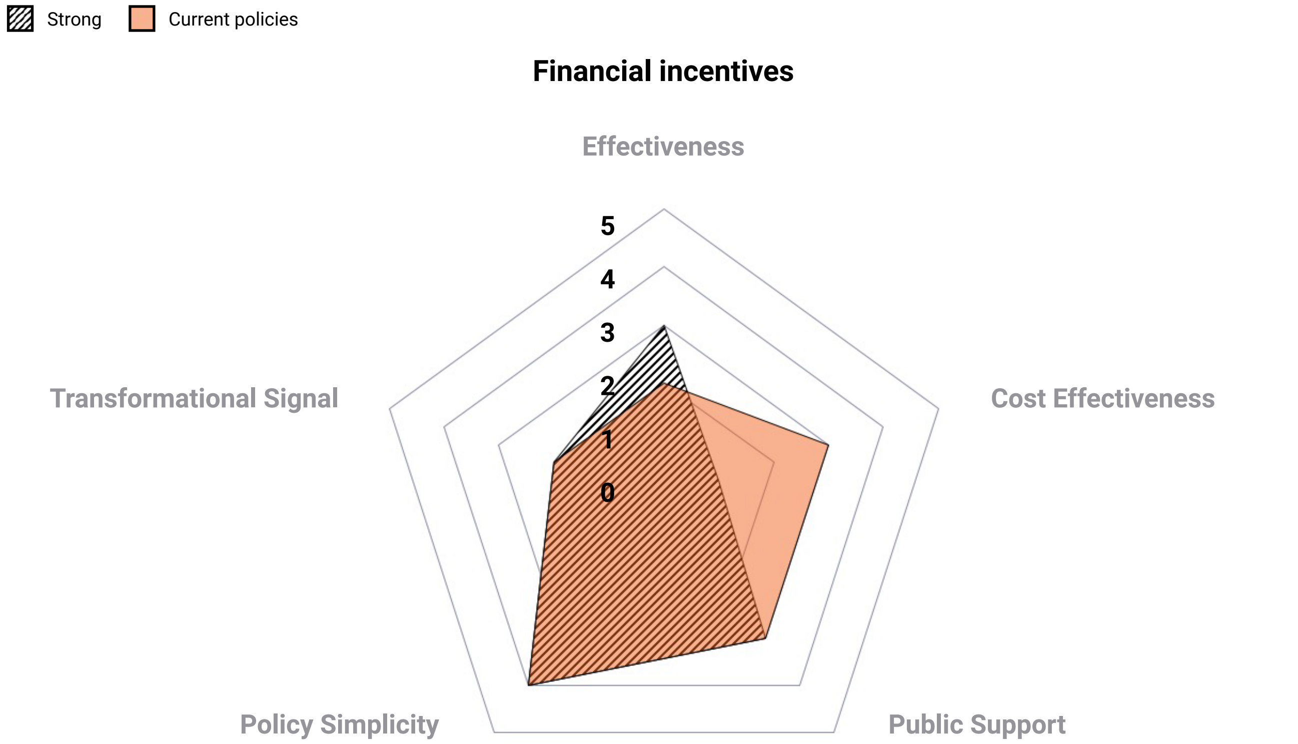


Table 7: Financial incentives evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	2	3	3	4	2
Strong version	3	1	3	4	2

HOV lane access

High occupancy vehicle (HOV) lanes are traffic lanes that can only be used by vehicles with a minimum number of occupants. These lanes provide a benefit to drivers by letting them travel faster during periods of traffic congestion. By providing access to ZEVs regardless of occupancy, HOV lanes can also provide an incentive for consumers to purchase and use such vehicles. This is a popular policy found in multiple jurisdictions across North America and in Europe [20], [41].

Policy adoption

Four provinces have HOV lanes in Canada. Of these, British Columbia, Ontario, and Quebec currently provide ZEVs with unrestricted access to these lanes as shown in Table 8. Under the Strong version of the policy, ZEV access would be extended to Alberta, the only other province with HOV lanes.

Table 8: HOV lane access in Canada

Current policy		Strong version	
BC	Electric vehicle official decal allowing ZEV access to all HOV lanes in the province [50]	**National**	ZEVs can access all HOV lanes in the country
ON	Green License Plate Program allowing ZEV access to all HOV lanes in the province [51]		
QC	ZEVs required to register with a green license plate allowing them access to all HOV lanes [52]		

HOV lane access

Evaluation

HOV lane access is a simple and popular policy option, but with limited effectiveness in Canada (see Figure 5 and Table 9):

- **Effectiveness:** The policy scores poorly in terms of effectiveness for both current policy and the Strong version of the policy (+ 0.2 percentage points, or 1/5), because there is a limited number of roads with HOV lanes in Canada and HOV lanes only benefit drivers during times of traffic congestion [29].
- **Cost effectiveness:** HOV lanes require relatively little direct government investment (5/5).
- **Public support:** Public support for HOV lane access is likely to be high given that research shows that support for incentives is generally high [43] (3/5). Stakeholders generally support the policy, although the potential exists for opposition from non-ZEV owners [39].
- **Policy simplicity:** This policy is simple for government to implement and compliance can be accomplished with existing traffic policing (5/5).
- **Transformational signal:** HOV lane access is rated as providing a moderate transformational signal (3/5) because its durability is uncertain (revoking HOV lane access is possible) and it provides at best a moderate level of directionality for investment in ZEVs.

Figure 5: HOV lane access evaluation

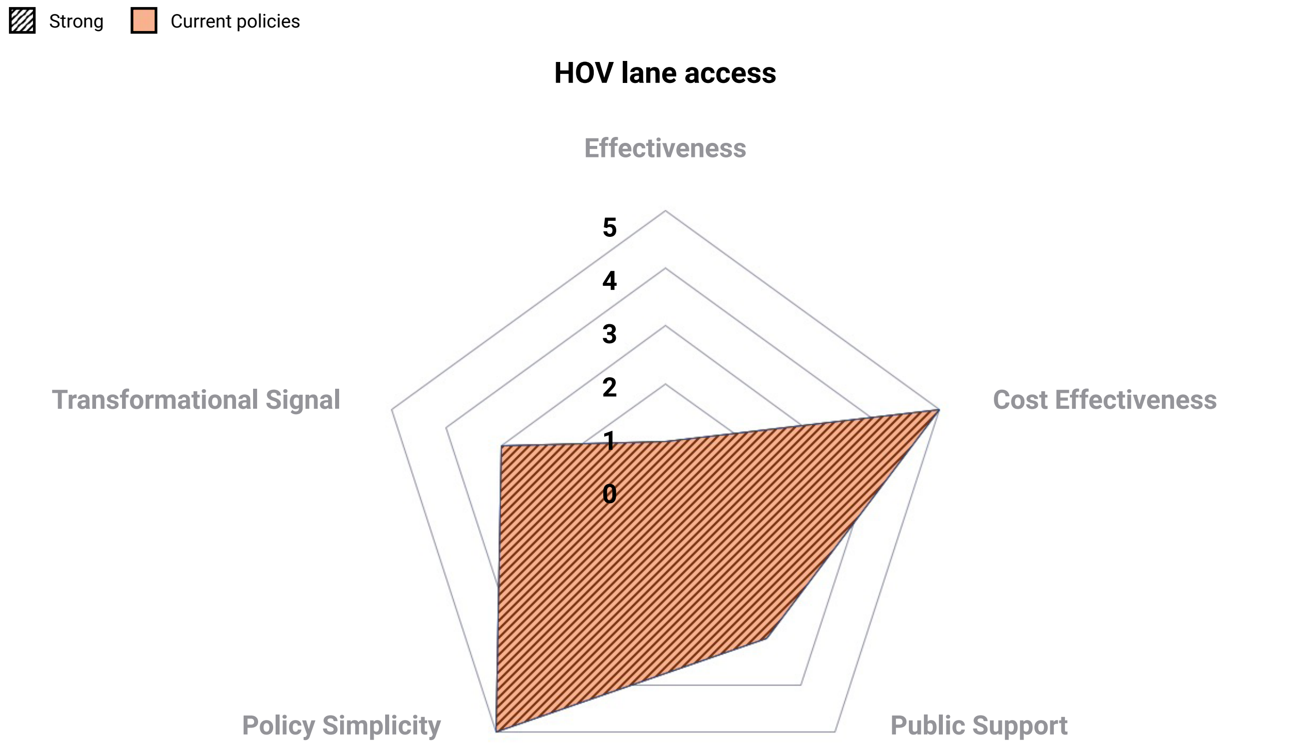


Table 9: HOV lane access evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	5	3	5	3
Strong version	1	5	3	5	3

Public (non-home) charging

If car buyers perceive that there is a broad network of easy-to-access public chargers, they may be more likely to purchase an electric vehicle. Further, public chargers might help existing electric vehicle owners to do more of their driving with electricity (by for example keeping their PHEV in electric mode or using their BEV instead of another vehicle). Government may be able to increase ZEV adoption by facilitating the provision of adequate access to public chargers. However, we note that most charging happens at home and at work among current electric vehicle owners, and potential buyers are most interested in home charging access [9], [15], [53], [54].

Policy adoption

There are many public charging initiatives that have taken place in Canada at various levels of government. The highest level of support for public chargers has been provided by several provinces (BC, Ontario and Quebec) and the federal government, as shown in Table 10. The table also shows the Strong version of the policy, which would increase the number of chargers so that one exists for every two gas stations [4].

Table 10: Public (non-home) charging in Canada

Current policy		Strong version	
BC	Community Charging Infrastructure (CCI) Fund allocated $2.7 million for 450 level 2 public chargers [55]	**National**	Federal government funding to increase charger availability from 0.15 chargers per gas station to 0.5 chargers per gas station
ON	Electric Vehicle Chargers Ontario (EVCO) allocated $20 million for 300 level 2 and 200 level 3 public chargers [56]		
QC	Hydro-Quebec covers up to 50% of costs of installing chargers linked to the “Electric Circuit” network, retaining up to 50% of the revenues [57]		
National	Federal government allocated a total of $182.5 million for the support of alternative fuel infra-structure in the 2016 and 2017 budgets [58]		

Note: For brevity, this table only lists select funding for public charging. For the purposes of evaluating the impact of public charging policy, we account for the current number of public chargers installed in each province (regardless of where funding originated).

Public (non-home) charging

Evaluation

Deploying public chargers is relatively simple and publicly acceptable, but is unlikely to be effective at driving ZEV adoption on its own (see Figure 6 and Table 11):

- **Effectiveness:** Public charging scores poorly in effectiveness for both current policy and the Strong version of the policy. The Strong version of the policy increases ZEV market share by only 2 percentage points in 2040, because most charging happens at home and at work among current electric vehicle owners, and potential buyers are most interested in home charging access [9], [15], [53], [54] (1/5).

- **Cost effectiveness:** The development of public charging requires some direct government investment (4/5).

- **Public support:** Public support for public (non-home) charging is likely to be high—research shows that support for other incentives is generally high [43] (3/5). Most stakeholders also view the policy positively although some question whether chargers can generate enough revenue to pay for themselves [39].

- **Policy simplicity:** The policy may require coordination among government and utilities and requires some level of ongoing monitoring (3/5).

- **Transformational signal:** Public charging infrastructure provides a relatively strong transformational signal because it is durable and it provides direction with respect to ZEVs (4/5).

Figure 6: Public charging evaluation

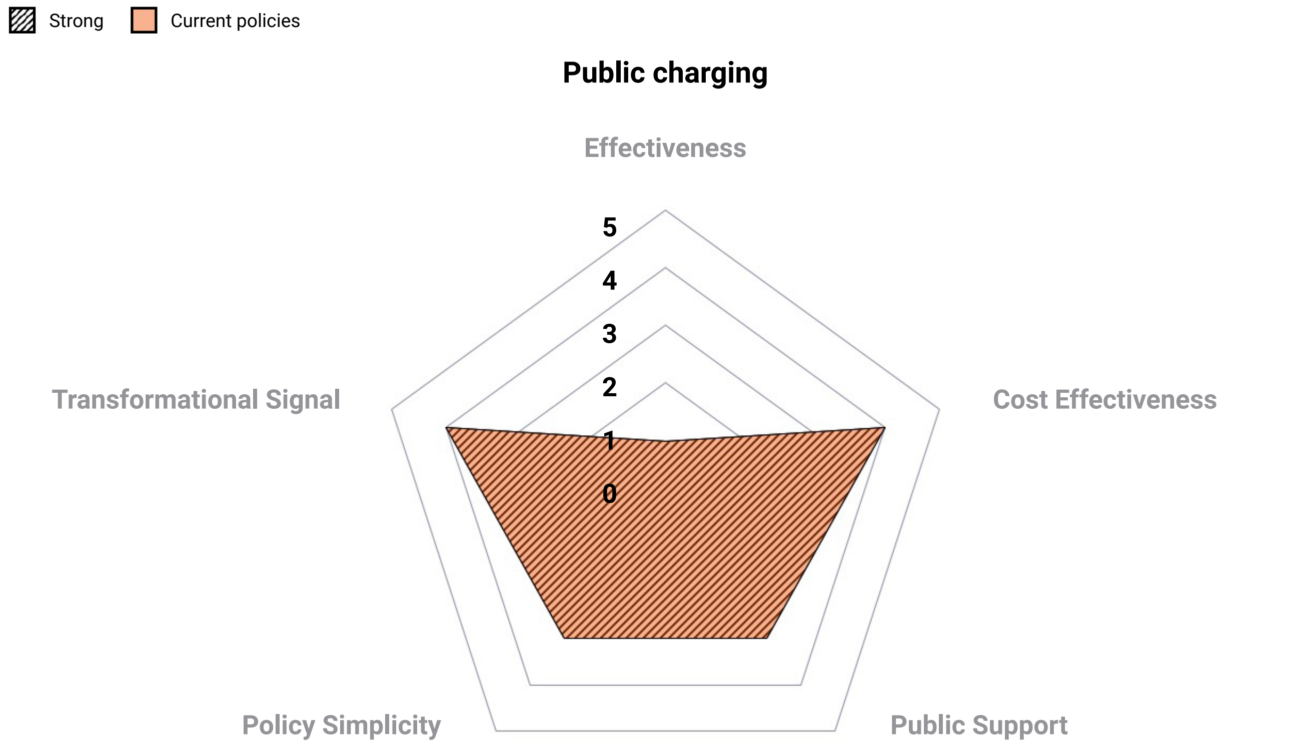


Table 11: Public charging evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	4	3	3	4
Strong version	1	4	3	3	4

Electric vehicle-ready building codes

Consumers are unlikely to purchase an electric vehicle if they cannot charge it at home, as is the case for many households living in multi-unit buildings and apartments [28], [30]. A recent survey found that around 40% of Canadians do not have access to charging at home [8]. Governments can help address this issue by updating the building code to require that all new residential buildings provide charging access.

Policy adoption

Ontario has amended its provincial building codes to require the installation of chargers in residential and commercial buildings, as shown in Table 12. British Columbia provides municipalities the option of including EV-ready clauses in their building codes. Quebec is in the process of changing its building code to require small residential buildings to be EV-ready. Under the Strong version of this policy, all provincial governments include the requirement in their building code.

Table 12: Electric vehicle-ready building codes in Canada

Current policy		Strong version	
BC	Provincial government makes it possible for municipalities to implement bylaws that require the installation of chargers in buildings [59]	**National**	All building codes require electric charger availability in all new residential buildings
ON	Ontario Building Code revised in 2017 to include provisions requiring electric chargers in buildings [60]		
QC	Quebec Building Code is currently being revised to include provisions requiring electric chargers in detached homes [61]		

Electric vehicle-ready building codes

Evaluation

Electric vehicle-ready building codes are publicly acceptable, simple and cost effective for government to implement, but require time to impact ZEV adoption due to the long life span of existing buildings (see Figure 7 and Table 13):

- **Effectiveness:** Building code changes may increase ZEV market share by 0.7–2 percentage points in 2040 under current policies (1/5), and 1.5 to 4.5 percentage points if applied nationally under the Strong version (2/5) [4]. The effectiveness of building codes is constrained due to the time it takes for new buildings to be constructed to code and replace existing buildings.
- **Cost effectiveness:** Amending the building code does not require any direct government investment (5/5).
- **Public support:** Changing the building code to be more electric vehicle-friendly is generally viewed positively by the public and by stakeholders [39], [43] (5/5).
- **Policy simplicity:** The policy is simple since it does not require new legislation (i.e., existing building codes can be amended) or monitoring beyond what already exists (5/5).
- **Transformational signal:** Buildings codes provide a relatively strong transformational signal (4/5) because they are durable and they provide directionality with respect to investment in ZEVs.

Figure 7: Building code evaluation

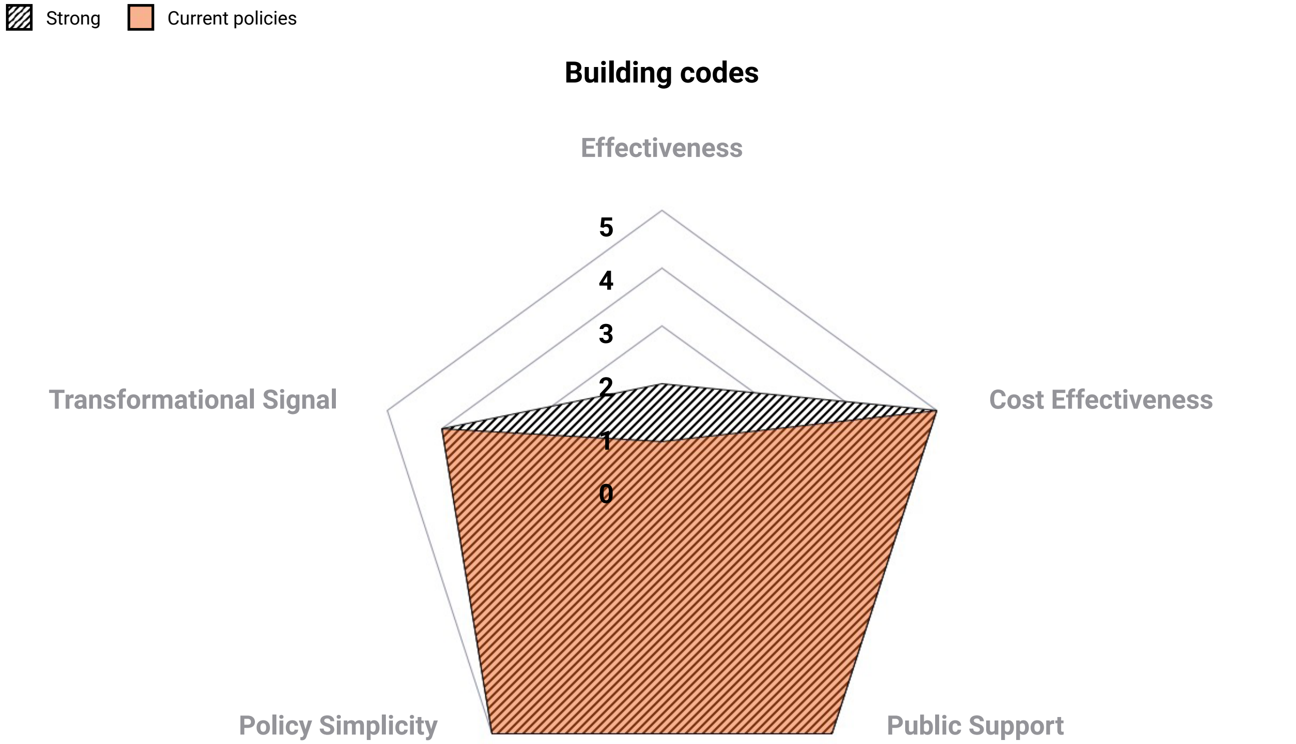


Table 13: Building code evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	5	5	5	4
Strong version	2	5	5	5	4

Carbon pricing

Putting a price on carbon increases the cost of fossil fuels relative to electricity or hydrogen produced by low-carbon sources, increasing the fuel-cost savings associated with owning a ZEV. A carbon price can take the form of a carbon tax or cap-and-trade system. Under a carbon tax, government directly applies the price to fossil fuels, including gasoline and diesel, which is typically paid by consumers filling up at a gas station. Under a cap-and-trade system, the price results from a cap on GHG emissions that is typically applied to fossil fuel distributors and covers the embodied CO_2 content of the fuels they sell.

Policy adoption

Alberta, BC, Ontario and Quebec have implemented various forms of carbon pricing as shown in Table 14. Additionally, the federal government has announced a minimum carbon price that will apply across Canada starting in 2018 and reach $50/tonne CO_2e in 2022. The Strong version of this policy is a Canada-wide carbon price rising to $150/tonne CO_2e by 2030.

Table 14: Carbon pricing in Canada

Current policy		Strong version	
AB	Carbon levy ramping up to $30/tonne in 2018 [62]	**National**	National carbon price floor rising to $150/tonne in 2030
BC	Carbon tax since 2008, has reached a current price of $30/tonne [63]		
ON	Cap-and-trade program with Western Climate Initiative since 2016 [64]		
QC	Cap-and-trade program with Western Climate Initiative since 2013 [64]		
National	Federal carbon price floor of $10/tonne in 2018 rising to $50/tonne by 2022 [65]		

Carbon pricing

Evaluation

Carbon pricing is typically a cost effective policy that can increase ZEV adoption, but its simplicity and popularity depend on the type of carbon pricing mechanism adopted (see Figure 8, Figure 9, Table 15, and Table 16):

- **Effectiveness:** At current levels, carbon pricing is unlikely to have a large impact on effectiveness (a 2 percentage point increase in 2040) due to a lack of consumer sensitivity to fuel prices, and receives a 1/5 [4]. The Strong version of the policy could increase ZEV new market share by 10 percentage points and receives a 3/5.
- **Cost effectiveness:** Carbon pricing does not require direct investment from government (5/5).
- **Public support:** Public support for carbon pricing is lower than any of the other policies examined [39], [43] (2/5).
- **Policy simplicity:** A carbon tax is relatively simple to implement (4/5), whereas a cap-and-trade is much more complex (1/5).
- **Transformational signal:** Carbon pricing provides a moderate transformational signal (3/5). Although carbon pricing is likely durable, it does not provide clear directionality to invest in ZEVs at the level of stringency examined here.

Figure 8: Carbon tax evaluation

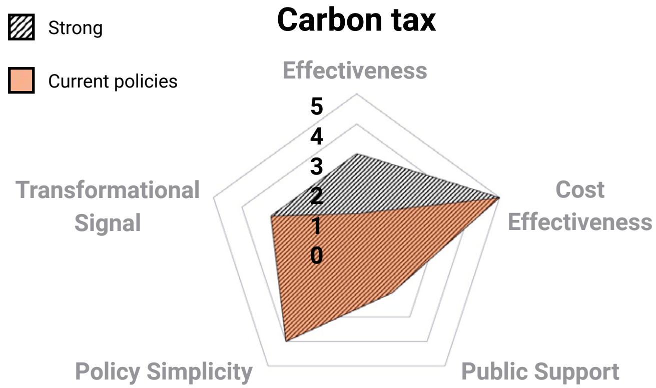


Figure 9: Cap-and-trade evaluation

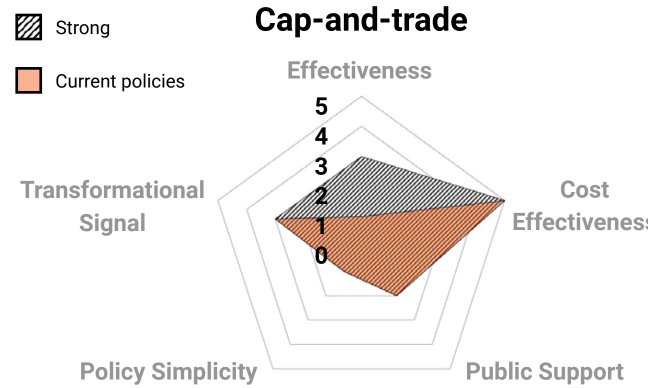


Table 15: Carbon tax evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	5	2	4	3
Strong version	3	5	2	4	3

Table 16: Cap-and-trade evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	5	2	1	3
Strong version	3	5	2	1	3

ZEV mandate

A ZEV mandate requires that ZEVs account for a minimum percentage of an automaker's overall sales in a given region over a specified duration (typically a year). The policy can include a flexibility mechanism allowing manufacturers to meet the requirements in different ways (such as with fewer long range BEVs or greater short range PHEVs) and by purchasing credits from automakers that exceed the standard. For example, the California ZEV mandate allows manufacturers to meet over 75% of the 2018 ZEV requirement with PHEV sales credits (capped at 1.25 credits for each vehicle), while the remaining 25% would have to be exclusively met with BEV or HFCV sales credits (capped at 4.0 credits for each vehicle) [66].

Policy adoption

Quebec is the only province that has implemented a ZEV mandate in Canada (see Table 17). It requires that 22% of total light-duty vehicle sales be ZEVs by 2025 [67]. The sales requirement can also be satisfied with ZEV equivalent credits, generated through the sale of long range ZEVs, in which case the resulting market share in 2025 could conceivably be lower. The Strong version of this policy is applied at a stringency that leads to ZEVs making up 40% of total vehicle sales by 2040.

Table 17: ZEV mandates in Canada

Current policy		Strong version	
QC	Manufacturers required that ZEVs or equivalent credits make up 22% of total sales by 2025 [67]	**National**	Policy stringency leads to ZEVs making up 40% of total sales by 2040

ZEV mandate

Evaluation

ZEV mandates provide a strong transformational signal that can increase ZEV adoption at little cost to government, but are less likely to receive support from the auto sector (see Figure 10 and Table 18):

- **Effectiveness:** The current policy achieves a modest national impact (+2 percentage points) because it only applies in Quebec (1/5) [67]. The Strong version is much more effective and by design achieves 40% ZEV market share in 2040 (5/5).

- **Cost effectiveness:** The policy does not require direct investment from government (5/5).

- **Public support:** Public support for a ZEV mandate is likely to be high because research shows that support for vehicle emissions standards is high—a supply-focused policy that is likely to viewed in a similar way among the general public [43] (4/5). Stakeholder support is likewise generally high, except among some incumbent automakers.

- **Policy simplicity:** The policy is complex to implement since it requires drafting new legislation, coordinating with several government agencies, and a thorough monitoring of compliance (2/5).

- **Transformational signal:** The policy sends the strongest transformational signal of all the policies examined (5/5). As a regulatory policy, it is likely durable and it also provides clear directionality with respect to investment in ZEVs (5/5).

Figure 10: ZEV mandate evaluation

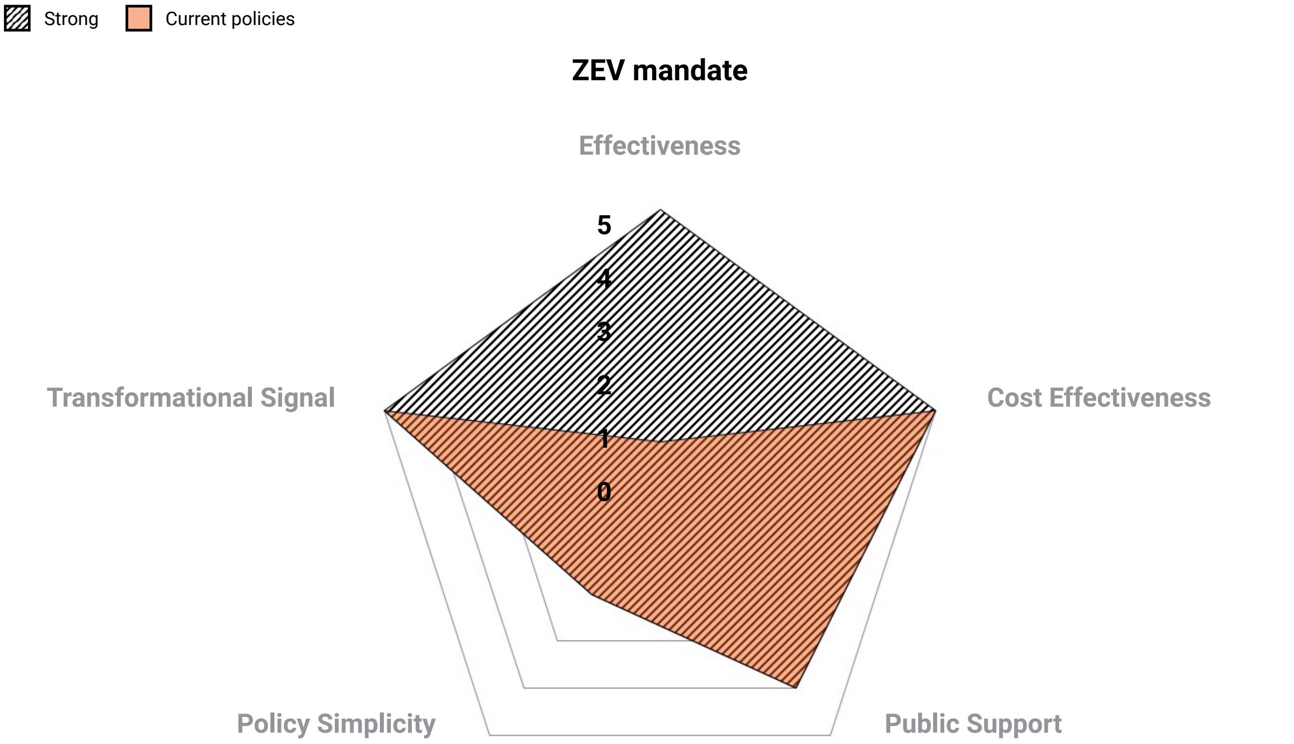


Table 18: ZEV mandate evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	5	4	2	5
Strong version	5	5	4	2	5

Vehicle emissions standard

A vehicle emissions standard is a policy requiring that a manufacturer's fleet average vehicle emissions not exceed a certain level, with emissions calculated based on fuel economy and fossil gasoline and diesel fuel. Although it doesn't directly require the deployment of ZEVs, these vehicles can help a manufacturer comply with the policy. For example, both US and Canadian vehicle emissions standards provide special credits for the sale of BEVs, HFCVs, and PHEVs that make it easier for manufacturers to meet compliance requirements [68].

Policy adoption

The federal vehicle emissions standard requires light-duty passenger vehicles sold in Canada to meet fleet-average tailpipe GHG emissions requirements. In 2025, these requirements reach 97 gCO_2/km for cars, and 140 gCO_2/km for light-trucks and SUVs. The combined fleet average requirement in that year will be roughly 119 gCO_2/km, 30% below the current required fleet average (see Table 19). For context, a 2017 Toyota Prius Hybrid has an emissions intensity of 105 gCO_2/km [35]. Emissions are based on vehicle fuel efficiency and conventional fossil fuel consumption. The Strong version of the policy requires strengthening the combined emissions requirement to 71 gCO_2/km by 2040, almost 60% below the current fleet average.

Table 19: Vehicle emissions standards in Canada

Current policy		Strong version	
National	Passenger Automobile and Light-Truck Greenhouse Gas Emission Regulation requires manufacturers to have a combined average fleet emissions of 119 grams of CO_2 per km by 2025 (for cars and light-duty trucks)	**National**	Increasing stringency of policy to about 71 grams of CO_2 per km by 2040 (combined light-trucks and cars)

Vehicle emissions standard

Evaluation

A relatively publicly acceptable policy, vehicle emissions standards have the potential to drive ZEV uptake at a low cost to government (see Figure 11 and Table 20):

- **Effectiveness:** Current policy might increase ZEV market share by 1–3% [10], receiving a score of 1/5. The Strong version could have a ZEV market share impact of 40% or more. While it seems likely that compliance would occur by selling a mix of conventional, hybrid and zero-emissions vehicles, this outcome is not guaranteed. Ongoing improvements to the energy efficiency of hybrid vehicles could allow compliance to be achieved by selling mostly very efficient hybrids and few ZEVs. Because of this uncertainty, we rate it as a 4/5.

- **Cost effectiveness:** The policy is cost effective because it does not require any direct government investment (5/5).

- **Public support:** The policy is supported by the public and most stakeholders [39], [43], although auto manufacturers may be less likely to support the Strong version (4/5).

- **Policy simplicity:** Vehicle emissions standards are relatively complex because they require thorough monitoring and enforcement, although they are built on an existing policy which should make them easier to implement (3/5).

- **Transformational signal:** The policy sends a moderately strong transformational signal (4/5). As a regulatory policy it is likely durable, and at an adequate level of stringency it likely provides relatively clear directionality in terms of investment in ZEVs (4/5).

Figure 11: Vehicle emissions standard evaluation

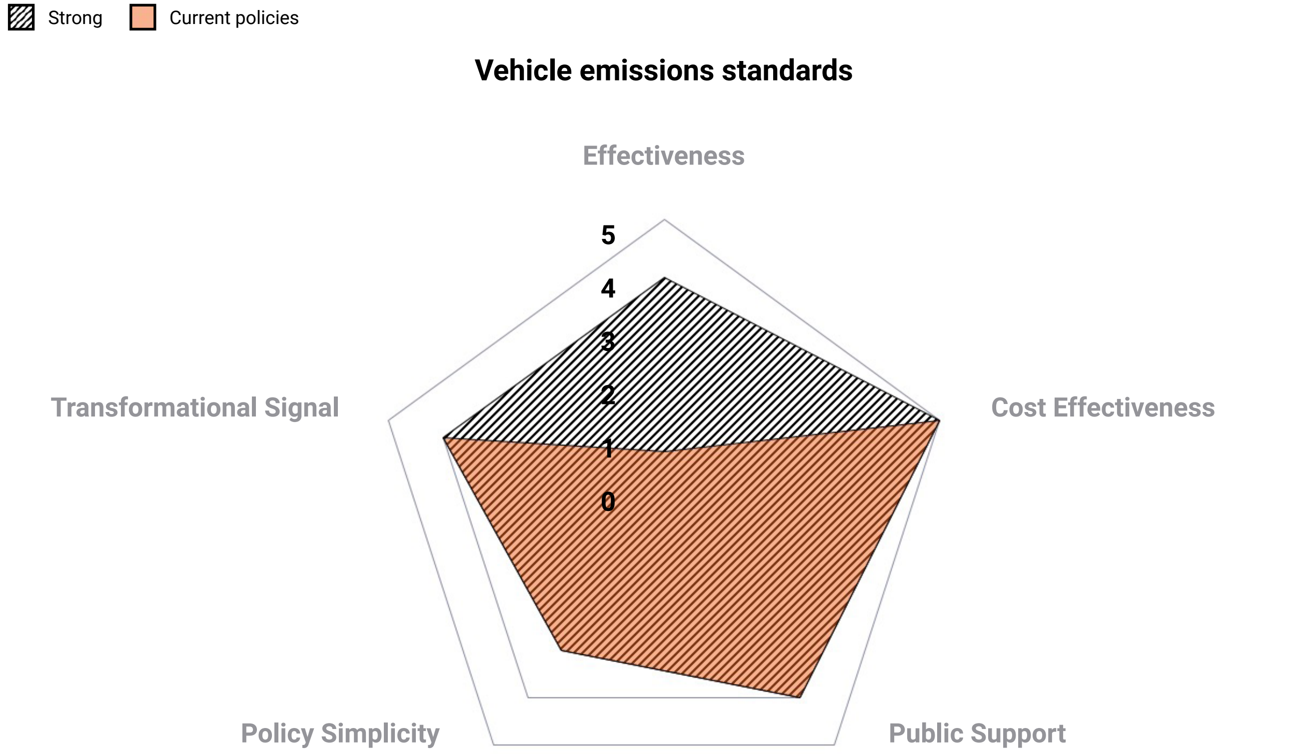


Table 20: Vehicle emissions standard evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	5	4	3	4
Strong version	4	5	4	3	4

Clean fuel standard

A clean fuel standard is a performance-based GHG reduction regulation that targets fuel suppliers, requiring them to reduce the lifecycle GHG intensity or carbon intensity of their fuels. The policy can encourage utilities to incentivize electric vehicle adoption if there is a credit system that rewards alternative fuel suppliers. For example, under BC's clean fuel standard, the provincial electrical utility (BC Hydro) can receive between 2.5 and 3 credits annually for each electric vehicle that is charged using its grid [69]. In addition, a nationwide clean fuel standard could also be designed to directly provide credits to automakers that sell ZEVs.

Policy adoption

Table 21 describes the clean fuel standard currently implemented in British Columbia and the one that has been proposed by the federal government. BC's policy requires a 10% carbon intensity improvement by 2020 while the proposed national policy requires a 15% improvement by 2030. The Strong version of the policy is a national requirement of 45% reduction in average carbon intensity by 2040.

Table 21: Clean fuel standards in Canada

Current policy		Strong version	
BC	Renewable & Clean Fuel Requirements Regulation requiring a 10% average carbon intensity reduction by 2020 relative to 2010 [70]	**National**	Clean fuel standard requiring carbon intensity reduction of 25% by 2030 and 45% by 2040 relative to 2010
National	Clean Fuel Standard expected to require a 10 to 15% average carbon intensity reduction by 2030 [71]		

Clean fuel standard

Evaluation

A clean fuel standard is a cost effective and generally popular policy that can support ZEV uptake (see Figure 12 and Table 22):

- **Effectiveness:** Current clean fuel standards may increase ZEV market share by 1–3 percentage points in 2040 [29], resulting in a score of 1/5. The Strong version receives a 3/5 because although it is much more stringent, it is unclear how the market for compliance credits would incentivize automakers to develop and sell ZEVs.

- **Cost effectiveness:** The policy does not require any direct government investment (5/5).

- **Public support:** The policy tends to be viewed positively by the public [43], although some stake-holders express concern that its potential impact on ZEVs is uncertain [39] (4/5).

- **Policy simplicity:** The clean fuel standard is particularly complex because it requires new legislation, coordination among government agencies, and monitoring of a large number of actors and compliance pathways (1/5).

- **Transformational signal:** The policy sends a moderately strong transformational signal (3/5). As a regulatory policy it is likely durable, but it doesn't provide clear directionality in terms of investment in ZEVs because of the complexity of the policy mechanism.

Figure 12: Clean fuel standard evaluation

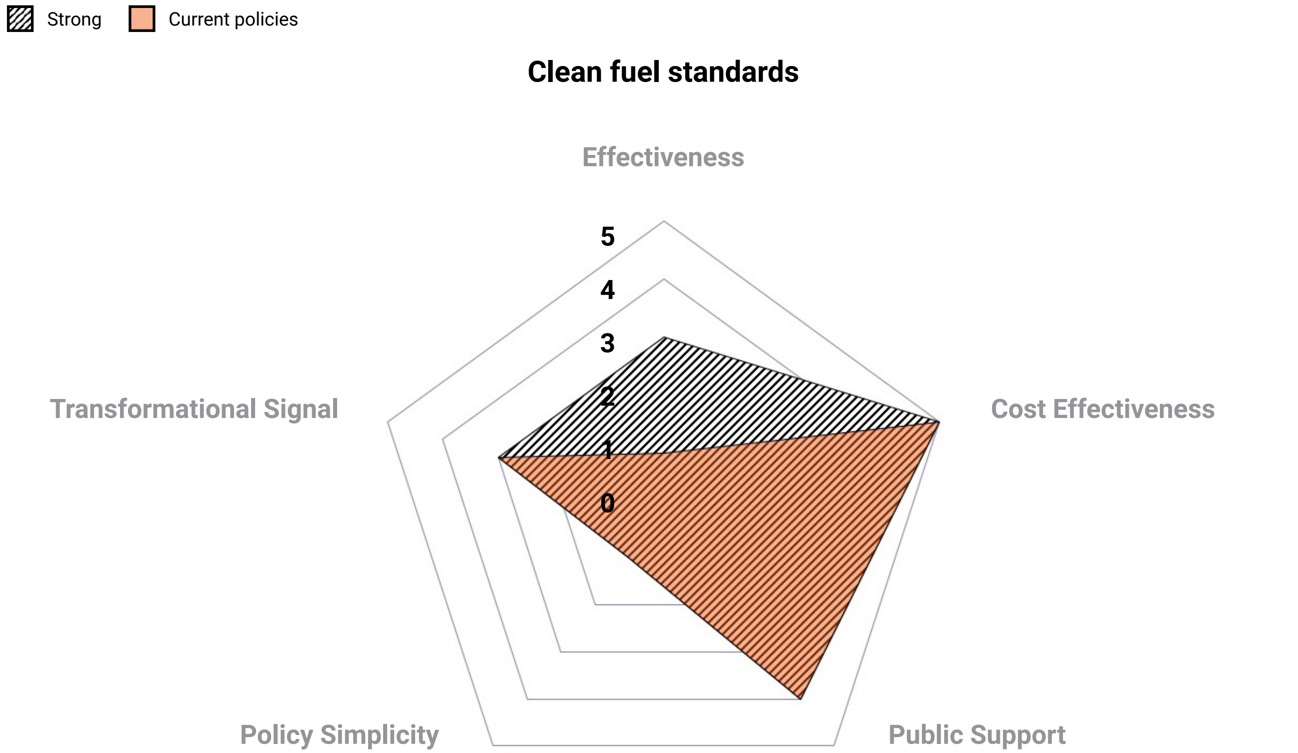


Table 22: Clean fuel standard evaluation

Stringency	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Current policies	1	5	4	1	3
Strong version	3	5	4	1	3

Policy Packages

Overview of policy packages

There are multiple policy pathways that can be effective in the long term, as demonstrated in regions that lead global ZEV sales, notably Norway and California. Each policy type offers different scores and trade-offs across evaluation criteria, so regions may have different notions of what makes an "ideal" policy package.

In this section we present three policy package options to support a ZEV transition in Canada. We design each option to include a mix of policies, which reflect a diversity of policy approaches. Each package reflects the Strong versions of the policies as described in the previous Chapter and is designed to achieve the levels of ZEV uptake needed to achieve our longer-term climate targets (i.e., 40% of ZEV sales by 2040).

First, we model the impact of each policy package using the REPAC model [27]. Second, we evaluate each package against the five evaluation criteria of effectiveness, cost effectiveness, public support, simplicity and transformational signal.

The three policy packages include:

1. A demand-focused policy package that includes national **long-term incentives** of $6,000 per ZEV for 20 years. This package is like Norway's approach to ZEV policy.

2. A supply-focused policy package that includes a **national ZEV mandate** of 40% by 2040, coupled with short term incentives ($6,000 per ZEV for 2 years). This approach is a Stronger version of California's approach to ZEV policy.

3. An alternative supply-focused policy package that includes a **strengthened national vehicle emissions standard** of about 71 g CO_2e by 2040 (combined average for light-trucks and cars), coupled with short term incentives ($6,000 per ZEV for 2 years) [10]. For context, the Strong emissions requirement is roughly 60% below the current fleet average. This emissions-based approach is like a stronger version of the European Union's approach to ZEV policy.

All three packages also include support for home and public charging infrastructure.

Market share results

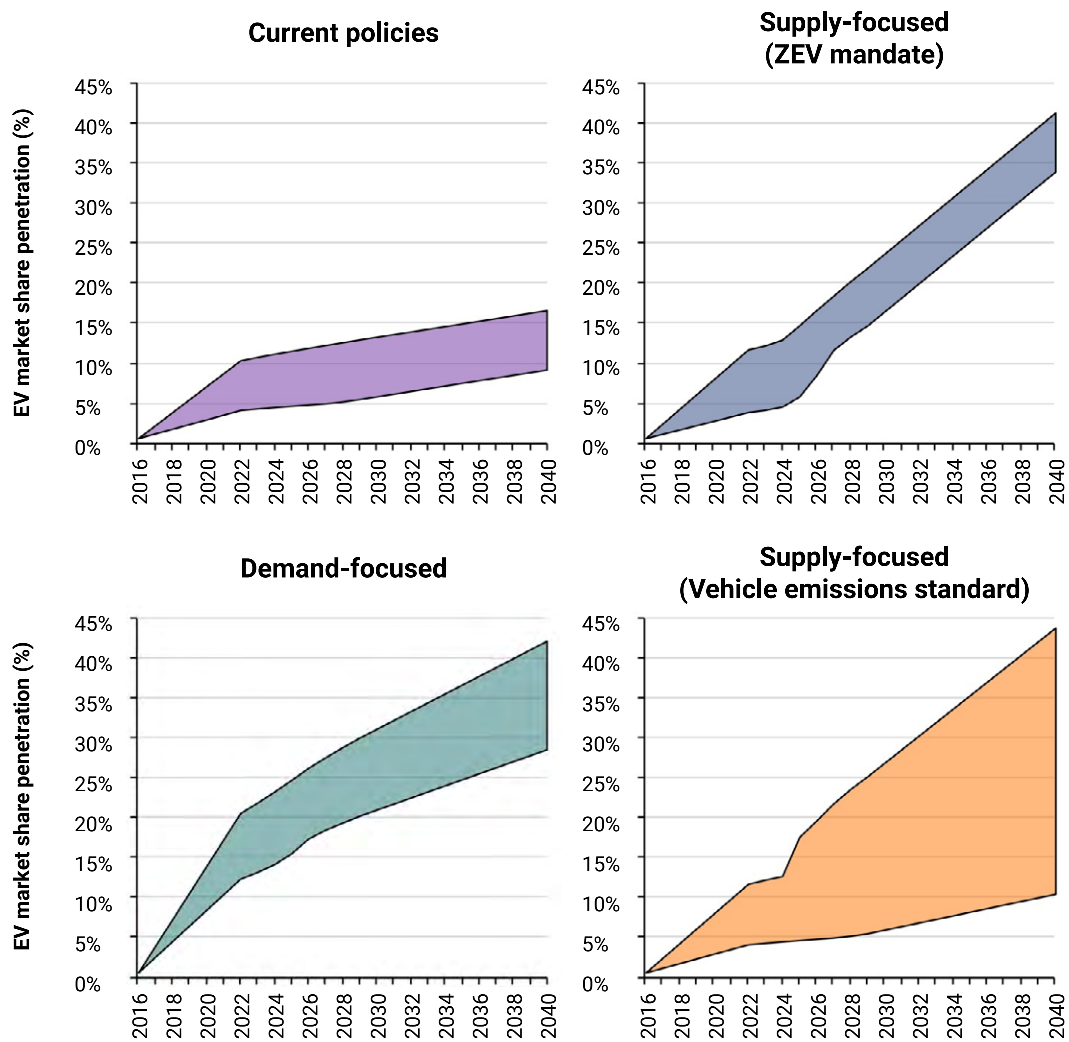
The impact of these policy packages on new ZEV market share is shown in Figure 13. Under current policies, electric vehicle new market share increases over time, from 0.6% in 2016 to between 8% and 17% in 2040.

By design, all three policy packages can achieve the 40% target in 2040. However, as shown in Figure 13, the likelihood of achieving that target differs among the approaches. The market share outcome is most certain following the supply-focused approach relying on a ZEV mandate, because this policy is the most prescriptive (i.e., it specifies that ZEVs account for a certain share of sales). Nevertheless, the compliance options available to manufacturers mean that a range of market share outcomes is possible.

The range of potential market share outcomes under the other two approaches is larger (i.e., ZEV market share is less certain). For the package relying on the demand-focused policies, consumer response to financial incentives is uncertain. Therefore, government may need to adjust the level of incentives and/or the duration for which it offers them to ensure their ZEV targets are achieved.

For the supply-focused package relying on a vehicle emissions standard, the market share outcome is uncertain because the policy doesn't explicitly require any specific market share of ZEVs to be sold. In using a vehicle emissions standard to get to 2040 targets, we assume that the current policy trajectory is maintained through 2025, and only after 2025 is the stringency tightened at a pace to meet the 2040 targets. Using REPAC to simulate compliance with this target results in approximately 40% ZEV sales by 2040. While it seems likely that compliance would be achieved by selling a mix of conventional, hybrid and zero-emissions vehicles, other compliance pathways are possible and the impact of this policy on ZEV sales is uncertain. For example, automakers could comply by investing in and selling mostly high-efficiency hybrid vehicles, or other high-efficiency technologies. This would reduce the need to sell ZEVs, a situation which corresponds with the lower ZEV market share boundary in the vehicle emissions standard graph in Figure 13.

Figure 13: Policy packages to achieve ZEV targets



Policy package evaluation

The packages are evaluated against our five criteria in Table 23. This evaluation reveals trade-offs among each of the approaches:

- A demand-focused approach is simple to implement but comes at a high cost to government. Additionally, this approach will only send a strong transformational signal if government can provide certainty that the incentives will be sustained over the long term (i.e., decades, rather than several years). However, the cost of maintaining incentives over a longer time period may diminish public support for this approach [39]. Furthermore, the impact on long-term ZEV sales is uncertain as it depends on future ZEV costs and consumer preferences.

- A supply-focused approach relying on a ZEV mandate provides a strong transformational signal at little cost to government, with high certainty of effectiveness. Careful implementation of this policy is important due to its complexity. Additionally, although support is likely high for this approach among the public and most stakeholders, it is less likely to be supported by the auto sector.

- A supply-focused approach relying on a vehicle emissions standard could achieve potentially similar market share outcomes as a ZEV mandate. To be equally effective at driving ZEV uptake, Canada's vehicle emissions standard would need to be continually strengthened, reaching about 71 grams of CO_2e per km for light-duty vehicles in 2040. However, while it seems likely that this policy would require ZEVs, it does not explicitly require the development of ZEVs, so its market share impacts are uncertain.

Table 23: Policy package evaluation

Policy package	Effectiveness	Cost Effectiveness	Public Support	Policy Simplicity	Transformational Signal
Demand-focused policy package	4	1	3	4	2
Supply-focused package (ZEV mandate)	5	5	4	2	5
Supply-focused package (vehicle emissions standard)	4	5	4	3	4

Conclusions & Policy Insights

Conclusions

We illustrate three pathways to achieve a level of ZEV sales consistent with meeting Canada's climate targets. Each policy package varies in its degree of cost to government, public support, simplicity and transformational signal, carrying with it a unique set of pros and cons. Ultimately, any policy package that is pursued at a national or pan-Canadian level will involve trade-offs and will be influenced by governments' preferred mechanisms, resources and capacity. For example, supporting a transition with long-term incentives requires a significant amount of investment from governments but need not involve regulating supply. By contrast, supporting a transition with a ZEV mandate or even a vehicle emissions standard does require regulating supply but is less costly for government. Because consumer adoption of ZEVs faces multiple barriers, policy packages that address the full spectrum of these barriers on both the demand and supply side have a greater chance of success, provide more certainty to consumers and industry, and are more likely to support a sustainable market.

Whichever policy approach is pursued, policymakers may wish to consider the following characteristics associated with effective policy making in alternative fuel technology transitions [1], [29]:

- **Directionality** implies that policies share a consistent vision (e.g. reaching ZEV uptake goals linked to GHG reduction targets), policy direction (where all policies combined will achieve goals or targets) and funding (where funding timeframe and amounts are transparent, planned and linked to the wider strategy).

- **Institutional capacity** is required of government if they are to implement and execute policies that are ultimately successful in bringing about a transition to ZEVs. The inherent uncertainty of technology transformations requires policymakers to monitor technological advancements and adapt policies as needed to changing conditions.

Policy insights

The *ZEV Policy Handbook* is designed to be a tool for policymakers to evaluate different policies and approaches for increasing ZEV adoption in Canada. Based on our evaluation of policies and policy packages, we identify the following key policy insights for Canada:

1 Current policies are unlikely to encourage sufficient ZEV adoption to achieve Canada's ZEV targets or climate mitigation targets.

2 Only three types of Strong, national policies are likely to have a large impact on ZEV sales, while being reasonably acceptable to the public: financial incentives ($6,000 per ZEV for 20 years), a ZEV mandate (requiring 40% ZEVs by 2040), or a vehicle emissions standard (decreasing average light-truck and car fleet emissions to 71 g CO_2e per km by 2040, roughly 60% below current fleet average emissions).

3 Strong financial incentives are simple to implement but come at a high (direct) cost to government. This cost may cause some public opposition in the long term.

4 A Strong ZEV mandate provides the highest certainty of effectiveness and a strong transformational signal at little (direct) cost to government, though it is complex to administer and may be opposed by some incumbent automakers.

5 A Strong vehicle emissions standard is simpler to implement than a ZEV mandate because it builds on existing policy, but the impact on ZEV market share is uncertain due to the variety of other compliance options available to automakers.

Although these conclusions are based on a thorough review of current literature, they are nevertheless subject to some limitations. We have incorporated a range of uncertainty into the evaluation of policy effectiveness, but this range may not fully capture the uncertainty that exists over the long term. As well, because this analysis rates policy impacts on a score out of five, it inevitably involves many simplifying assumptions. We have made this process transparent in the report, and welcome feedback from stakeholders in how to improve this analysis.

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Appendix: Policy Evaluation Method

This Appendix describes the method used to evaluate the ZEV-supportive policies (see Table 24) against the following criteria:

- **Effectiveness.** How does a policy impact ZEV market share in the long term?
- **Cost effectiveness.** What is the direct government expenditure per ZEV adopted?
- **Public support.** Do citizens generally support the policy or not?
- **Policy simplicity.** How straightforward is the policy to implement and administer?
- **Transformational signal.** Does a policy provide a durable signal to stimulate investment in ZEVs now and in the decades to come?

We evaluate each criterion using a 5-point scale, where a score of five reflects excellent performance and a score of one reflects poor performance. The following sections describe the evaluation in more detail.

Table 24: Evaluated ZEV policies

Policy type	Current policies	Strong policies
Financial incentives	Financial incentives in BC, ON, and QC (assuming funding will expire and not be renewed in 2018)	$6,000 (2015$) incentive for 20 years in all provinces
HOV lane access	HOV lane access in BC, ON, and QC; available indefinitely	HOV lane access in all provinces that have HOV lanes
Public (non-home) charging	Current charger to gas station ratio; does not change with time	Charger to gas station ratio to reach 0.5 by 2025 in all provinces
Building codes	ON, BC, & QC introduce EV-ready building codes	EV-ready building codes introduced in all provinces
Carbon pricing	BC, AB, ON, & QC have existing carbon price; federal price floor of applies to all provinces starting in 2018, reaching $50 by 2022 and remaining constant in nominal terms to 2040	Carbon price reaches and maintains $150 by 2030
ZEV mandate	QC ZEV mandate reaching 22.5% credits by 2025	National ZEV mandate resulting in 40% new market share by 2040
Vehicle emissions standard	Federal standards requiring average light-duty vehicle emissions to reach 119 gCO_2e/km by 2025	Federal standards requiring average light-duty vehicle emissions to reach about 71 g CO_2e by 2040
Clean fuel standard	Federal clean fuel standard with electric vehicle credits requires reduction in the lifecycle carbon intensity of transport fuels of 10–15% by 2030	Federal clean fuel standard with electric vehicle credits requires reduction in the lifecycle carbon intensity of transport fuels of 25% by 2030 and 45% by 2040

Effectiveness

Criteria definition: How does a given policy impact ZEV market share in the long term?

We use a variety of sources to assess the potential impact of each policy on the share of light-duty passenger vehicle sales that are ZEVs in 2040. Our approach generally follows that established in Melton, Axsen & Goldberg (2017) [29], updated to reflect recent policy developments and new evaluation methods where possible. For the purpose of this evaluation, we equate ZEV market share with plug-in electric vehicle market share.

We describe policy effectiveness in terms of the resulting ZEV new market share (i.e. % of sales), using a 5-point score based on the following scale:

1 = 0–2.49%
2 = 2.5–9.9%
3 = 10–19.9%
4 = 20–39.9%
5 = 40%+

We also describe effectiveness in terms of the change in "percentage points" of ZEV market share relative to a scenario without policy (e.g. If ZEVs have a 10% market share without policy, an increase in 2 percentage points means the market share grows from 10% to 12%).Table 25 shows the percentage point impact and effectiveness score of the current and Strong version of each policy:

Financial incentives. The market shares reflect results from the REPAC model which has been used in several studies [27], [8].

HOV lane access. We assign a monetized value to HOV lane access, following the method used by Melton, Axsen & Goldberg [29] and Jin et al [41].

Public (non-home) charging. We assign a monetized value to public charger availability, following the approach used by Melton, Axsen & Goldberg [4] and Lin & Greene [42].

Building codes. Building codes are modeled in REPAC by linearly removing the charging constraint for all consumers (except those that only have access to street parking) between 2015 and 2030. We assume the policy only applies to new buildings and therefore scale REPAC's results by the proportion of average building age (assuming 100 years) for which the policy is active.

Carbon pricing. The low end of the range reflects results from REPAC and the high end reflects results from CIMS modeling as described in Melton, Axsen & Goldberg [4]. We take estimates from both approaches to better account for uncertainty.

ZEV mandate. The Quebec government estimates that their ZEV mandate will result in a market share of 9.9% by 2025 [67]. Based on Quebec's share of the national vehicle market, this results in a 2 percentage point increase in ZEV market share for Canada.

We assume that the Strong version of the policy could be designed to require 40% ZEV sales by 2040. However, if a policy approach like that taken in California or Quebec is used, the ultimate market share impact is uncertain given auto manufacturers' flexibility for complying with the policy (e.g., producing a smaller number of ZEVs or a greater number of partial ZEVs).

Vehicle emissions standard. The impact of current policies is based on analysis by the US EPA [10]. To determine the ZEV market share impact of the Strong version of this policy, we use REPAC to determine the policy stringency that is likely to result in ZEVs accounting for 40% of sales by 2040. We find that the vehicle emissions standard will have to decline to an average of 71 grams CO_2/km (for passenger cars and light-duty trucks). While it seems likely that compliance would occur by selling a mix of conventional, hybrid and zero-emissions vehicles, this outcome is not guaranteed. Ongoing improvements to the energy efficiency of hybrid vehicles could allow compliance to be achieved by selling mostly very efficient hybrids and few ZEVs. Because of this uncertainty, we score it as 4/5.

Clean fuel standards. For current policy, we assume that credit prices reach $200 based on Yang (2013) [72]. We assume that half the credit price value is passed along by fuel suppliers to electric vehicle purchasers (representing an upfront subsidy of up to $338 in 2030), which is modeled in REPAC. For the Strong policy, we consider the combination of fuel use that could plausibly comply with the policy. On the one hand, fuel suppliers could comply with the policy exclusively by blending higher amounts of biofuels into gasoline and diesel pools. On the other hand, they could comply exclusively by incentivizing the adoption of electric vehicles (or hydrogen fuel cell vehicles). However, it is unclear how the market for compliance credits under this policy would incentivize automakers to develop and sell ZEVs. This policy therefore receives a 3/5 in terms of effectiveness.

Table 25: Effectiveness evaluation

Policy	Percentage point change in ZEV new market share in 2040		Effectiveness score	
	Current	Strong	Current	Strong
Demand-focused				
Financial incentives	3% (1.5–5%)	18% (15–20%)	2	3
HOV lane access	0.1% (0.06–0.2%)	No change	1	1
Public (non-home) charging	0.5% (0.3–0.8%)	2% (1–3%)	1	1
Building codes	1.5% (0.7–2%)	3% (1.5–4.5%)	1	2
Carbon pricing	2% (1–3%)	10% (3.5–15%)	1	3
Supply-focused				
ZEV mandate	2%	40%	1	5
Vehicle emissions standard	2% (1–3%)	40%	1	4
Clean fuel standards	2% (1–3%)	38% (0–76%)	1	3

Range provided by literature, modeling results or 50% on either side of mean estimate.

Limitations of the evaluation methodology are summarized in Table 26.

Table 26: Evaluation limitations

Policy	Notes and limitations
HOV lane access	• HOV lane access benefits were monetized at a value that might not be representative of real perceived value. • We don't consider the potential for new HOV lanes to be developed.
Public (non-home) charging	• Public charging benefits were monetized at a value that might not be representative of real perceived value.
Building codes	• The building stock turnover assumption is simplistic (it assumes all buildings have the same age) and does not account for the potential for retrofits.
Carbon pricing	• The survey used for REPAC shows that respondent's vehicle choices are fairly insensitive to fuel cost fluctuations. This limitation is addressed by incorporating results from CIMS.
ZEV mandate	• The strategy used by auto manufacturers to comply with a ZEV mandate is uncertain. Our approach accounts for a range of compliance pathways but does not consider which is more likely.
Vehicle emissions standard	• The strategy used by auto manufacturers to comply with vehicle emissions standards is uncertain. Again, our approach accounts for a range of compliance pathways but does not consider which is more likely.
Clean fuel standard	• The value of electric vehicle credits resulting from this policy is uncertain, as is the share of credit value that utilities may pass on to consumers.

Cost effectiveness

Criteria definition: What is the direct government expenditure per ZEV adopted?

We use results from REPAC [27] to estimate the cost effectiveness of both current and Strong policies. Cost effectiveness is defined as the amount of direct government expenditure per ZEV adopted over the 2018–2040 timeframe.

We assume that direct government investment is required for financial incentives and development of public charging, but not for other policies. These costs are discounted to the present using a social discount rate of 3%. We assume that the cost of public charging averages $12,660 per charger [45], but that government incurs only half these costs (i.e., the remaining investment comes from the private sector).

Table 27 shows the evaluation of government expenditure for each of the ZEV policies considered. A score of 5/5 is given to policies that are assumed not to require direct government expenditure, including HOV lane access, building codes, carbon pricing, ZEV mandates, vehicle emissions standards, and clean fuel standards.

Financial incentives are the costliest policy, scoring 3/5 at current policy stringency and 1/5 at strengthened stringency. Public chargers receive a 4/5 at both current and Strong versions of the policy.

Note that direct government expenditure provides insight into only one aspect of policy cost effectiveness. So-called "policy costs" or "welfare costs" can also include broader impacts to consumers, producers and related sectors—though definitions and methods of estimation are quite controversial. Direct government expenditure is relatively easy to estimate, while still providing a sense of the government resources required to implement a policy.

Table 27: Government expenditure evaluation and average NPV per vehicle sold

Policies	Current policies	Strong	Current policies	Strong
Demand-focused				
Financial incentives	$1,167	$2,804	3	1
HOV lane access	$0	$0	5	5
Public (non-home) charging	$542	$747	4	4
Building codes	$0	$0	5	5
Carbon pricing	$0	$0	5	5
Supply-focused				
ZEV mandate	$0	$0	5	5
Vehicle emissions standard	$0	$0	5	5
Clean fuel standards	$0	$0	5	5

Public support

Criteria definition: Is there public support for this policy?

To evaluate public support, we draw on results from a recent study that explored public support for a range of policy types in Canada [43]. This study determined the level of support for market-based, regulatory, financial and voluntary energy and climate policies from a representative sample of over 1,300 Canadians. We translate the percentage support for a given policy type from this study to a five-point scale, such that support of under 20% scores 1/5, support of 20–40% scores 2/5, and so on. The results of the evaluation are shown in Table 28.

The policy types assessed by Rhodes et al. [43] don't perfectly align with the ZEV supportive policies examined in this *Handbook*. In such instances, we use a proxy measure of public support based on support for a similar policy type. For example, Rhodes et al. [43] did not assess support for a ZEV mandate. We take support for a similar policy type (in this case, a clean electricity standard) as indicative of support for a ZEV mandate. Although there are important differences between a clean electricity standard (which requires electric utilities to generate a certain percentage of electricity from clean sources) and a ZEV mandate (which requires auto manufacturers to sell a certain percentage of ZEVs), public perceptions of policies are largely based on a more general understanding of policy types. A wide body of literature finds consistent levels of public support for different policy types, where regulations, voluntary policies and financial incentives are consistently reported to have high public support relative to carbon pricing measures [73]–[76].

Table 28: Evaluation of policy support

	Public support
Demand-focused	
Financial incentives	3
HOV lane access	3
Public (non-home) charging	3
Building codes	5
Carbon pricing	2
Supply-focused	
ZEV mandate	4
Vehicle emissions standard	4
Clean fuel standards	4

Policy simplicity

Criteria definition: How straightforward is the policy to implement and administer?

Simplicity is defined as the level of effort required by government to implement and administer a policy. We evaluate a policy's simplicity by considering its likely requirements for:

- **Drafting new legislation.** Does a policy require new legislation or can it be implemented by amending existing legislation? Is the legislation likely to be relatively more or less complex? For example, will new personnel need to be hired or re-assigned to develop it?

- **Coordination within government.** What level of coordination is likely to be required among government departments and across different levels of government? Can a policy be implemented by one level of government or is it likely to require coordination among multiple levels (e.g. federal, provincial and municipal)? Can a policy be implemented by a single government department or is it likely to require involvement of multiple departments (e.g. transport, environment, energy)?

- **Monitoring and enforcement.** What level of effort is required for monitoring the policy and/or enforcing policy compliance? For example, must government ensure compliance of a relatively large or small number of actors? Is compliance easily determined or are there multiple compliance pathways that necessitate more sophisticated monitoring?

We evaluate simplicity using a five-point scale, where the most complex policies score 1/5 and the simplest policies score a 5/5. Table 29 summarizes the scoring for each policy.

Drafting new legislation

A number of policies can be implemented by amending existing legislation or without the need for new legislation at all. These policies are rated 5/5, as shown in Table 29. For example, EV-ready building codes can be added to existing building codes; a carbon tax can be created by amending excise fuel taxes; and the existing vehicle emissions standard can be strengthened. Financial incentives and providing HOV lane access to ZEVs can also generally be pursued without the need for new legislation.

Other policies are likely to require the development of new and sometimes complex legislation, such as cap-and-trade, ZEV mandates and clean fuel standards. Cap-and-trade and fuel standards are likely the most complex and are rated 1/5, while ZEV mandates are rated as 3/5.

Coordination within government

Several demand-focused policies can (at least theoretically) be implemented by a single department at a single level of government, such as financial incentives, building codes and HOV lanes. These policies are rated as a 5/5. Due to its breadth, carbon pricing is likely to require the involvement of more than one government agency. We rate a carbon tax as being simpler to coordinate (3/5) than cap-and-trade (2/5).

The supply-focused policies can be implemented by a single level of government, but due to their complexity are likely to involve participation from multiple government departments (e.g. environment, transport and finance). We rate a ZEV mandate and vehicle emissions standard as 3/5. We rate clean fuel standards as 2/5 because of the breadth and complexity of the policy.

Monitoring and enforcement

HOV lane access, building codes and a carbon tax are rated as the simplest policies against this dimension because monitoring and enforcement can be conducted within existing mechanisms (e.g. existing traffic enforcement, building code compliance mechanisms and the taxation framework). Each of these policies is rated as 5/5.

The supply-focused policies as well as cap-and-trade likely require the most comprehensive monitoring and enforcement regimes. These regimes must track a large number of participants while taking into account a range of compliance options. Therefore, these policies are rated as 1/5.

Financial incentives and public chargers are rated as 3/5 because some new form of monitoring is generally required (e.g. that incentives are received and that chargers built and maintained).

Overall simplicity

Each policy's overall simplicity rating is determined by averaging its score across the three simplicity dimensions as shown in Table 29. Using this method, HOV lane access and building codes are rated as the simplest policies and score 5/5. Cap-and-trade and fuel standards are rated as the most complex and may require governments to develop substantial new institutional capacity (1/5).

Table 29: Summary of simplicity evaluation

	Drafting new legislation	Coordination within government	Monitoring and enforcement	Overall simplicity score
Demand-focused				
Financial incentives	5	5	3	4
HOV lane access	5	5	5	5
Public (non-home) charging	4	3	3	3
Building codes	5	5	5	5
Carbon pricing				
Carbon tax	5	3	5	4
Cap-and-trade	1	2	1	1
Supply-focused				
ZEV mandate	3	3	1	2
Vehicle emissions standard	5	3	1	3
Clean fuel standards	1	2	1	1

Transformational signal

Criteria definition: Does a policy provide a durable signal to stimulate investment in ZEVs now and in the decades to come?

Transformational signal is defined as a policy's ability to stimulate development and investment in a ZEV transition over the long term. In other words, is a policy durable and does it provide certainty to consumers, suppliers, and stakeholders that it will support a ZEV transformation over the years and decades to come?

We evaluate a policy's transformational signal by assessing its performance against two characteristics:

- **Does the policy tend to be durable?** More durable policies set clear and consistent requirements or rules that last a decade or more. Policies that result in the development of physical infrastructure (e.g. building codes and installation of public chargers) are deemed to be most durable. Regulatory policies are moderately durable, and assessed as being more so than carbon pricing which tends to face more public opposition. Finally, financial incentives tend to be least durable policy because they typically involve funds that are set aside for a period of one to several years at most.
- **Does the policy provide directionality?** Does the policy provide directionality [44] with respect to investment in ZEVs, or is it less technology-specific (e.g. potentially encouraging investment in other technologies such as high efficiency internal combustion engines)? A ZEV mandate is deemed as providing the clearest signal to invest in ZEVs. Other policies are deemed as providing less direction because they are either not technology-specific (e.g. a vehicle emissions standard, carbon pricing) or they are not compulsory (e.g. financial incentives). Clean fuel standards are rated as providing the least directionality because the mechanism by which the policy would encourage ZEV uptake is not entirely clear.

Policies that are both durable and provide directionality are evaluated as providing a strong transformational signal (5 out of 5). Those that are neither durable nor directional are evaluated as providing a weak transformational signal.

This evaluation reveals several groupings of policies as shown in Table 30. The Strong ZEV mandate is the most durable and effective policy examined, receiving a transformational signal score of 5/5.

**Table 30:
Evaluation of ZEV policy transformational signal (Strong policy version)**

	Durability	Directionality	Overall transformational signal score
Demand-focused			
Financial incentives	1	3	2
HOV lane access	3	3	3
Public (non-home) charging	5	3	4
Building codes	5	3	4
Carbon pricing			
Carbon tax	3	2	3
Cap-and-trade	3	2	3
Supply-focused			
ZEV mandate	4	5	5
Vehicle emissions standard	4	3	4
Clean fuel standards	4	1	3

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