Electrifying demand: Increasing zero emission vehicle adoption in Vancouver

by

Molly Henry

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Name:	**Molly Henry**
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Examining Committee: **Chair:** John Richards
Professor, School of Public Policy, SFU

Doug McArthur
Senior Supervisor
Professor

Kora DeBeck
Supervisor
Assistant Professor

Maureen Maloney
Internal Examiner
Professor

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Abstract

Light duty vehicles account for approximately one-third of Vancouver's annual greenhouse gas emissions. To reduce these emissions, Vancouver has committed to transition to 100 percent renewable energy for all light duty transportation in the city by 2050. However, the cost difference between zero emission vehicles and the dominant internal combustion engine is identified as a barrier to adoption for many consumers. This study examines how municipal policy can minimize this difference. Key considerations are identified through interviews with experts and a jurisdiction scan of three cities. Four policy options are assessed against criteria of effectiveness, public acceptability, government cost, and administrative complexity. An education campaign and discounted parking are recommended for immediate implementation, and further analysis should be done on the development of a toll zone. At the same time, mode-shifting away from private vehicles to active transportation and public transit should remain a top policy priority.

Keywords: Zero emission vehicles; renewable energy; municipal government

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Executive Summary

Climate change is one of the most urgent challenges of our time, and the burning of fossil fuels is a major contributor of greenhouse gas (GHG) emissions. Recognizing the importance of shifting away from fossil fuel energy sources, the City of Vancouver has adopted the Renewable City Strategy which sets a target for 100% of the energy used in Vancouver, including all energy for transportation, to come from renewable sources before 2050. Like many cities, Vancouver is currently highly reliant on fossil fuel vehicles, with light duty vehicles accounting for approximately one-third of Vancouver's annual GHG emissions. For Vancouver to meet the target of 100% renewable energy for all transportation by 2050, all vehicles in the city will need to transition to zero emission fuel sources. The focus of this study is on two types of zero emission vehicles, plug-in electric vehicles and plug-in hybrid electric vehicles.

Research indicates that while public support for zero emission vehicles (ZEVs) continues to grow, the price of ZEVs relative to internal combustion engine vehicles (ICEVs) is a commonly cited barrier to adoption for buyers. However, as fuel and maintenance costs are lower for ZEVs, the total cost of ownership over the lifetime of a ZEV can be similar to an ICEV. The challenge for governments is therefore how to incentivize the switch from ICEVs to ZEVs, while continuing to encourage residents to move away from personal vehicles where ever possible. To achieve this balance, this study examines how municipal policy can reduce the cost difference between ICEVs and ZEVs, while ensuring the total costs of vehicle use do not decrease.

This study uses multiple qualitative methods to develop a comprehensive understanding of cost as a barrier to the adoption of ZEVs, and how municipal policies can be used to overcome this barrier. The selected methods are a literature review, a scan of policies in three leading cities (Stockholm, Oslo, and San Francisco), and semi-structured interviews with experts.

An overview of product diffusion trends, transportation mode-share in Vancouver, and costs of ZEVs is provided for context, and an examination of consumer knowledge about this technology provides an understanding of the scale of the problem. Overall,

knowledge and familiarity with both ZEV technology and the costs of ownership for vehicles is low for the average consumer.

Four policy options are developed for the City of Vancouver. These include an education and outreach campaign, discounted parking, access to bus lanes, and the development of a toll zone. These options are evaluated using the criteria and measures of effectiveness, public acceptability, government cost, and administrative complexity.

Two policies are recommended for immediate implementation. First, an education and outreach campaign is an important starting point to address common consumer concerns, and increase their knowledge and familiarity with the technology. This option also lays the groundwork for future policies. Second, discounted parking should be implemented, with modeling used to determine the specific discount rate. This report also recommends further analysis be done on the development of a toll zone given the anticipated effectiveness of this policy on ZEV adoption.

While addressing the cost of ZEVs will help to minimize this barrier, there are a number of other social and technical challenges that need to be resolved in order for ZEVs to become mainstream. This transition will require overcoming a century's worth of experience and associations with ICEVs, while convincing consumers to adopt new ways and patterns of fueling, maintaining, and driving their vehicles. Consequently, cost related policies need to be situated within and integrated into the City's broader ZEV strategy. At the same time, mode-shifting away from private vehicles to active transportation and public transit remains the top transportation policy priority for the City, and ZEV adoption efforts should complement, not impede, this work.

Chapter 1. Introduction

Climate change is one of the most urgent challenges of our time. From reductions in economic productivity and damage to infrastructure, to widespread social conflicts and loss of human life, the negative impacts of climate change have now been extensively documented (IPCC, 2014). It is also clear that the burning of fossil fuels is a major contributor to greenhouse gas (GHG) emissions, and our reliance on this form of energy has put us on a track towards significant climate change (IPCC, 2014). Consequently, the world has reached a point where the costs of fossil fuels outweigh the benefits, and carbon emissions must be reduced.

The City of Vancouver recognizes the importance of reducing the use of fossil fuels, and in 2015 City Council adopted the *Renewable City Strategy*. This strategy sets a target for 100% of the energy used in Vancouver, including all energy for transportation, to come from renewable sources before 2050 (City of Vancouver, 2015)[1]. Vancouver is a world leader in this area as one of only a few cities that has committed to 100% renewable energy for all electricity, heating and cooling of buildings, and transportation.

Like many cities, Vancouver is highly reliant on fossil fuel vehicles, and light duty vehicles account for approximately one-third of Vancouver's annual GHG emissions (City of Vancouver, 2015). While the City's top transportation priority is to encourage residents to shift to public transit and active transportation (walking, cycling, skateboarding, etc.) and away from private vehicle use, there will be some residents who must, or will choose to, continue driving. In order for Vancouver to meet the target of 100% renewable energy for all transportation by 2050, all remaining vehicles in the city will need to transition to zero emission fuel sources.

[1] In this paper, the use of the term "City" (with a capital "C") refers to the municipal government, while the term "city" (with a lower-case "c") refers to the geographical area of Vancouver.

While research indicates that public support for zero emission vehicles (ZEVs) continues to grow (Egbue & Long, 2012), the price of ZEVs relative to internal combustion engine vehicles (ICEVs) is a commonly cited barrier to adoption for many buyers. It is important to note that ZEV prices are currently on a downward trend; for example, in BC, the 2015 Ford Focus Electric (with a 23-kWh battery) had a MSRP of $35,449, while the 2017 model (with a larger 33.5-kWh battery) has a lower MSRP of $31,998. Despite these improvements, ZEVS remain significantly more expensive to purchase than comparable ICEVs; the regular 2017 Ford Focus has a MSRP of $17,398, close to half the price of the electric version (the price discrepancy is largely due to the cost of batteries, which is forecasted to continue declining over the next decade). While consumers in BC may qualify for up to $11,000 in provincial rebates, a $3,600 price difference remains in this example.

It is important to note that the purchase price only accounts for a portion of the overall cost of the vehicle, which also includes fuel and maintenance. Once these ongoing costs are factored in, the total cost of ownership over the lifetime of a ZEV can be similar to an ICEV. As a result, policies which decrease the purchase price of ZEVs make the overall costs of owning and operating a ZEV even lower than an ICEV, thereby incentivizing private vehicle use. This undermines other government work to reduce energy use and congestion by shifting residents from cars to active transportation and public transit.

ZEVs also face a number of less tangible ‘costs’ to consumers, such as changes to their fueling patterns, range anxiety, and overcoming apprehension about this unfamiliar technology (Rogers, 2003; Sovacool & Hirsh, 2009). The challenge for governments is therefore how to incentivize the switch from ICEVs to ZEVs, while encouraging residents to move away from personal vehicles where ever possible. To achieve this balance, government policy should aim to reduce the cost difference between ICEVs and ZEVs, while ensuring the total costs of vehicle use do not decrease.

There are currently a variety of policies in place at the municipal, provincial, and federal levels to support ZEV adoption, including several to address the price of the vehicles; however, all of the existing policies will only result in ZEVS accounting for 1% of

new vehicle purchases in BC in 2020 (Axsen et al., 2015) and 10% by 2040 (Axsen, Goldberg, & Melton, 2016) without additional policy interventions. Modeling also indicates that the policy mix implemented in Vancouver thus far is insufficient to meet the targets of the *Renewable City Strategy,* and additional policies are essential to ensure all vehicles use renewable energy by 2050 (Zuehlke, Jaccard, & Murphy, 2017). While there are a variety of policies that the provincial and federal governments could use to significantly increase ZEV adoption rates, such as a zero emission vehicle mandate, neither government has indicated that they are planning to pursue such policies in the foreseeable future.

Given these factors, the problem this report examines is how the City of Vancouver can minimize the real and perceived cost difference between ZEVs and ICEVs as a mechanism to increase ZEV adoption rates.

There are a number of types of ZEVs which could replace the dominant ICEV. The focus of this research will be on adoption of plug-in hybrid electric vehicles (PHEVs) and plug-in electric vehicles (PEVs) as these technologies are already commercially available, while others such as fuel cell and hydrogen vehicles are not currently available for mass consumption in Vancouver. In this paper PHEVs and PEVs will be collectively referred to as ZEVs.

Though hybrid electric vehicles (HEVs) are projected to make up part of Vancouver's vehicle base in a 100% renewable energy scenario (City of Vancouver, 2015), they will need to use biofuels to meet the renewable energy target; as renewable biofuels are not currently available on a mass scale, HEVs still use fossil fuels as their primary fuel source, and are therefore not zero emission. HEVs are also already closer in price to ICEVs. Consequently, HEVs are not included in this report.

Table 1-1. Explanation of PEV and PHEV Technologies

Vehicle Type	Description	Examples
Plug-in hybrid electric vehicle (PHEV)	PHEVs can travel for some distance using electrical energy from a plug-in battery. These vehicles also have an on-board combustion engine. Depending on the vehicle, the combustion engine either acts as a generator to fuel the battery when the charge is low (this type of vehicle may be called a range extended electric vehicle), or the vehicle switches directly to the internal combustion engine (ICE) when the charge is low or more power is needed. While these vehicles use fossil fuels, the majority have an electric range that would meet average daily driving distances in Vancouver.	BMW i3 Chevrolet Volt Ford Fusion Energi
Plug-in electric vehicle (PEV)	PEVs are fully electric with no ICE. Energy is received by plugging the vehicle in to an electricity source, and the electricity is stored in a battery. The travel range on these vehicles is currently more limited due to battery capacity.	Mitsubishi MiEV Nissan Leaf Smart fortwo Electric Tesla Model S

1.1. Scope

This research focuses on the adoption of ZEVs by private citizens, and excludes both the municipally-owned fleet and commercial fleets (such as taxis and car-shares) as each of these groups have unique barriers and opportunities, and therefore require different policy approaches.

The adoption of ZEVs will also increase demand for electricity and biofuels to power these vehicles. While energy production and distribution are important questions that must be considered by the City, they are outside the scope of this research.

An additional consideration is the rise of autonomous (driverless) vehicles, which are expected to have significant implications for our transportation network. Industry

experts anticipate that individual car ownership may decline in the coming decades as shared cars and driverless taxi services become the norm. At the same time, programmable vehicles could reduce the need for parking (impacting one of the policy tools that cities have). The current timeline for the technical feasibility of autonomous vehicles is not certain, but the industry has estimated the vehicles will be ready for public use between 2020 and 2030. Autonomous vehicles are not currently legal in Canada, and the governments of Canada, BC, and Vancouver are each studying the policy implications of this technology, including privacy and security concerns, insurance liability, and ethical questions related to programming and operations, as well as public trust and acceptance (Meyerson, 2016). With almost every major car maker working on some form of automation (Waldrop, 2015), it is important to keep developments in autonomous vehicles in mind while devising ZEV policies.

1.2. Report summary

In Chapter 2, I describe the methodology used in this study. Chapter 3 then outlines background information on the wider context for the policy problem, and a summary of the policy actions taken to date by the governments of Canada, British Columbia, and Vancouver. In Chapter 4 I explore the tangible and perceived costs of ZEVs for consumers, as well as the state of consumer knowledge regarding ZEVs. Chapter 5 reviews policies implemented by the cities of Stockholm, Oslo, and San Francisco to understand how other jurisdictions which face similar challenges to Vancouver approach the issue of vehicle cost. Chapter 6 outlines the criteria and measures used to assess the proposed policy options, which are presented in Chapter 7. An analysis of each option is presented in Chapter 8, and final recommendations are made in Chapter 9.

Chapter 2. Methodology

This study uses multiple qualitative methods to develop a comprehensive understanding of cost as a barrier to the adoption of ZEVs, and how municipal policies can be used to overcome this barrier. The selected methods are a literature review, a scan of the policies in three leading municipalities, and semi-structured interviews with experts. Multiple methods are used to increase the reliability of the data and ensure a diversity of perspectives on the issue. Each method is described further in the following sections.

2.1. Literature review

An initial literature review was conducted to gain an understanding of consumers' views on ZEVs, and determine the most prominent barriers to ZEV adoption. From this first scan of the literature, cost emerged as a primary and ongoing concern. Based on this finding, I then conducted a more focused review, looking at two areas: first, how consumers perceive costs as a barrier to ZEV adoption, and second, the policy mechanisms that can be used to address this issue. Data for the literature review was collected through research of publicly available documents, including journal articles, books, newspapers, reports, and other online content.

2.2. Interviews

Interviews were chosen to expand my understanding of the policy area, collect information for the review of other cities, and provide insights into the different policy options. A semi-structured approach was selected as this style allows for flexibility and exploration of unanticipated topics during the interview, but ensures the conversation remains relevant to the research.

Themes and questions for the interviews were developed after the initial review of the literature. Given the comprehensive research available on the issue of cost as a barrier to ZEV adoption, the goal of the interviews was not to provide additional insights into the policy problem itself; instead, the interviews were used primarily to identify the

strengths and weaknesses of policies, how those policies have been implemented, and potential improvements to the policies. Interviews were conducted with a city staff member from Stockholm, San Francisco, and Vancouver, respectively, as well as an area expert from Vancouver. I requested an interview with the City of Oslo, but did not receive a reply. Participants were selected for their area specific knowledge and familiarity with existing policies. Information gathered from the interviews was instrumental in the formation and analysis of the policy options in this report. Contact information for all participants was obtained from publicly available web sources.

2.3. Scan of municipal policy approaches

A scan was selected to identify and examine the range of policies used in different cities. As municipal ZEV policy is a relatively recent phenomenon and only exists in a handful of cities globally, there are a limited number of jurisdictions available for review. From these, the cities of Stockholm, Oslo, and San Francisco were chosen as they share social, geographical, and economic qualities which are similar to Vancouver's, and each city has achieved unusually high levels of ZEV adoption. All three cities also either currently use, or have committed to use, 100% renewable energy for their electricity.

As there is some overlap in the types of policies that have been used by the different cities, this approach allows for comparison between how policies have been designed and implemented.

Data for the scan was collected through publicly available documents, including newspapers, journal articles, reports, government websites, and other online content, and was supplemented by information from the semi-structured interviews.

Chapter 3. Background

3.1. Emissions from transportation

Emissions from the transportation sector now account for almost a quarter of global energy-related emissions, and have increased at a faster rate than any other energy end-use sector. Since 1970, GHGs have doubled and approximately 80% of this increase has been attributed to road vehicles (Sims et al., 2014). If the world is to stay within 2°C of warming, thereby limiting the more extreme impacts of climate change, the transportation sector must transition to low carbon fuel sources within the next few decades (International Energy Agency, 2015).

Light duty vehicles are an important component of this energy transition as modeling has shown that there is a significant role for alternative-fuel light duty vehicles in reducing GHGs emissions. Vehicles fueled using electricity can be particularly effective at reducing emissions as the electricity may be created from renewable resources or, if made from carbon intensive fuels, utilize carbon capture and storage. The use of biofuels also has the potential to reduce tailpipe emissions (Kyle & Kim, 2011).

3.2. Overcoming technology lock-in

The transition to ZEVs will require significant changes to our transportation system, including how, when, and where we use and fuel our vehicles. Over the last century, much of our global transportation system has become locked into fossil fuel energy through self-reinforcing path-dependent processes and increasing returns to scale. The widespread adoption of ZEVs will therefore require policy interventions which address the spectrum of ‘‘socio-technical’’ obstacles to ZEV adoption, including technological, engineering, cultural, social, political, and economic barriers (Sovacool & Hirsh, 2009; Unruh, 2002). The issue of cost must therefore be considered within this larger context.

Successful adoption also requires policies that persist long enough – on the order of several decades – for the ZEV market to become self-sustaining. How quickly this

threshold is reached is based on a wide number of variables such as consumer choice, awareness of ZEVs, and the average life of vehicles, among others (Struben & Sterman, 2008).

3.3. Market for ZEVs

All successful new products undergo a process of diffusion whereby the innovation is communicated over time among members of a social system. The characteristics of an innovation, as perceived by the members of a social system, determine its rate of adoption. Characteristics that improve the likelihood of adoption are an innovation's relative advantage, compatibility, trialability, and observability, while complexity decreases the likelihood of adoption (Rogers, 2003). People's actions are also generally influenced by what they believe others are doing, and they tend to want to conform to group norms (Thaler & Sunstein, 2008).

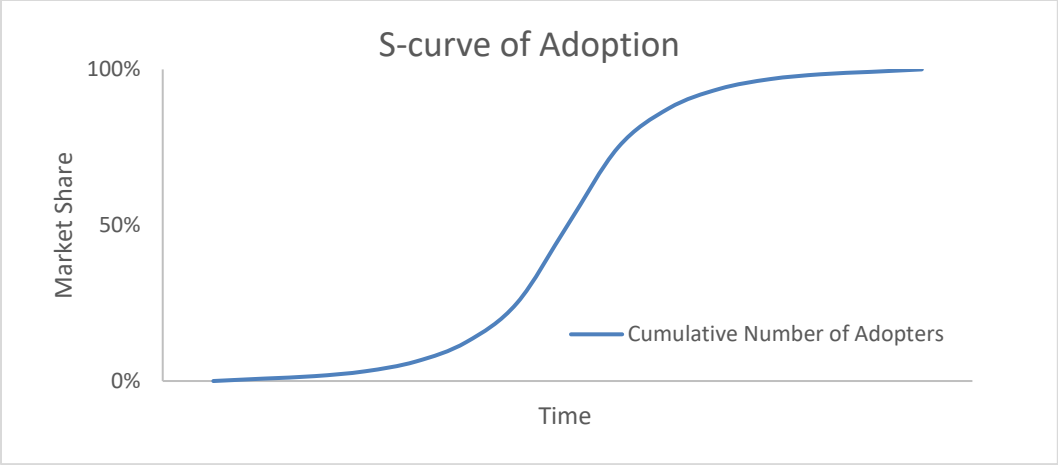
Like with any technology, there are different segments of consumers for ZEVs, each with their own preferences and priorities for vehicles. Consumers can be categorized into five groups: innovators, early adopters, early majority, late majority, and laggards. Members of each group tend to have common attributes in terms of socioeconomic status, personality variables, and communication behaviour. As a result, each group requires a unique strategy to encourage diffusion (Rogers, 2003).

In the case of ZEVs, innovators are a small group who will purchase ZEVs quickly, often regardless of their performance and price (Axsen et al., 2015; Carley, Krause, Lane, & Graham, 2013; Hidrue, Parsons, Kempton, & Gardner, 2011; Sovacool & Hirsh, 2009). These consumers are more open than the average consumer to PEVs, which represent a relatively radical departure from existing technology (Sierzchula, Bakker, Maat, & Van Wee, 2014). Innovators have often been found to be interested in ZEVs for symbolic and cultural reasons, such as environmental concerns. At the same time, Axsen et al. (2015) found that just over half of innovators in their study reported that they would not have purchased their ZEV without a purchase rebate.

The majority of consumers fall into the mainstream categories. For mainstream users, a technology must be seen as being easily inserted into their daily life in order for it to be accepted (Hård & Knie, 2001; Sovacool & Hirsh, 2009). Along these lines, PHEVs and HEVs are more likely to be seen as accessible by mainstream consumers as they combine familiar technology (gasoline) with unfamiliar technology (electric) (Axsen & Kurani, 2013), and these consumers are more likely to indicate interest in PHEVs or HEVs than PEVs (Axsen, Goldberg, et al., 2015). While the 'early adopters' and 'early majority' represent the next frontier of consumers in ZEV adoption, those in the later segments will likely require significant changes in terms of policy, costs, technology, and cultural norms before they become buyers (Axsen et al., 2015).

Successful adoption of an innovation usually follows an S-shaped curve when looking at the cumulative number of adopters. Once approximately half the population has adopted an innovation, the diffusion rate slows. The critical mass is the point at which enough individuals have adopted the innovation that diffusion becomes self-sustaining (Rogers, 2003). Vancouver is currently in the early stages of ZEV diffusion, with a very low market share.

Figure 1-1. S-Curve of Innovation Adoption



3.4. Transportation in Vancouver

Encompassing an area of 115 sq. km, Vancouver is currently home to approximately 630,000 people, with the city's population projected to grow by 170,000 by 2050. While Vancouver has one of the lowest GHG emissions per capita in the developed world, its transportation system is highly reliant on fossil fuels, with approximately one third of the GHG emissions produced in the city coming from light duty vehicles (City of Vancouver, 2015a).

Vancouver is particularly well positioned for the transition to ZEVs. In 2010 the provincial government created the *BC Clean Energy Act,* which sets an objective to have at least 93% of the electricity generated in BC come from clean or renewable resources. As a result, emissions from private vehicles in BC could be reduced by more than 80% if electricity is used as a primary fuel source (Axsen et al., 2015). BC also has relatively inexpensive electricity, with an average rate of $0.1029/kWh (the residential rate is slightly lower, while the rate for businesses is higher and depends on their load requirements). Electricity in BC is regulated by the British Columbia Utilities Commission, which helps to stabilize the price over time.

Zero emission vehicles are relatively new to Vancouver, with PHEVs and PEVs only coming to the market in 2011 (HEVs became available in 2000). Given the short amount of time that these vehicles have been available it is unsurprising that only a small fraction of private vehicles in Vancouver are currently ZEVs. As of mid-2016, there were approximately 270,000 light duty vehicles registered in Vancouver; of these, around 2,500 were PHEVs/PEVs, comprising slightly less than 1% of all registered vehicles.

Despite these low numbers, research shows that there is a demand for ZEVs in BC. For instance, a 2015 survey of over 420 British Columbians found that about one-third of respondents are interested in a PHEV or PEV for their next vehicle (Axsen et al., 2015). The City of Vancouver also recently conducted a survey on ZEVs which explores topics such as vehicle buying plans, barriers to purchasing ZEVs, and desired public infrastructure locations. The survey received over 2,100 responses, and found that 49% of respondents planned to or would consider purchasing a ZEV in the next five years, while 36% responded 'maybe', and only 15% indicated they were not planning to purchase

a ZEV in the next five years. Of consumers in the 'maybe' and 'no' categories, the majority of those respondents (58%) cited cost as a top barrier (City of Vancouver, 2016b). A separate survey commissioned by the City at the beginning of 2017 similarly found that 32% of residents definitely or probably would purchase an electric or hybrid for their next vehicle, while 33% might or might not, 12% probably would not, and only 7% definitely would not. The remaining were unlikely to buy a vehicle. That survey also found that 81% of residents perceive increasing the use of renewably powered vehicles to be an effective strategy in reducing Vancouver's environmental footprint, and two-thirds of residents would be interested in learning more about increasing the use of renewably powered vehicles (Mustel Group, 2017).

At the same time, Vancouverites are increasingly moving towards car-sharing, with Vancouver becoming the only city in the world to have more than 100,000 Car2Go members in 2016 (Robinson, 2016). There are a variety of benefits to car-sharing, such as making it easier for people to embrace a multi-modal approach to transportation and reducing the need to own a car. The impact of car-sharing on our transportation system should not be underestimated, as research shows that for the year 2015, 9 privately owned vehicles were removed from Vancouver's roads for every Car2Go vehicle (Martin & Shaheen, 2016). There are currently four car-share companies in Vancouver, and they are continuing to grow. The four companies have a total of over 2,500 vehicles, including more than 1,000 HEVS, and a small contingent of PEVs (exact numbers are not publicly available).

The City has predicted that, while the number of private vehicles per person will likely decline over time, the total number of vehicles will increase by 15% by 2050 as the population grows (City of Vancouver, 2015). As the city's fleet continues to grow, it will become increasingly important for new vehicles to be ZEVs in order to reduce emissions. There is also a lag time between policy implementation and outcomes, given an average vehicle turnover time of 7 to 10 years. Consequently, more action must be taken soon to ensure that all vehicles are ZEVs by 2050.

3.5. Current Policies

The following section provides an overview of the jurisdiction accorded to the governments of Canada, British Columbia, and Vancouver regarding ZEVs, and the policies enacted by each over the last decade.

3.5.1. Federal Government - Canada

The federal government is responsible for vehicle fuel efficiency and pollution standards for new vehicles. Over the last decade, the federal government's policy approach to ZEVs has focused on biofuel research. With the election of a new government in 2015, the focus has transitioned to electric charging and fuelling infrastructure development. There have been no policies which directly target the cost of ZEVs.

3.5.2. Provincial Government – British Columbia

The province has the jurisdiction and legislative power to facilitate the adoption of ZEVs through a wide range of policies. To date, the provincial government has focused their policies primarily on rebates and other financial incentives for vehicles and charging infrastructure, and they have invested directly in charging infrastructure.

Table 3-1. Provincial policies

Policy	Year(s)	Funding	Description
Greenhouse Gas Reduction (Vehicle Emissions Standards) Act	Introduced in 2008, but was not brought into force	N/A	Provides BC the authority to require larger vehicle manufacturers to include a percentage (or set number) of zero emission vehicles in their fleets per year. The legislation would be brought into force through regulations based on California's zero emission vehicle mandate, and would target both GHG emissions and air pollutants. However, the legislation was superseded by the enactment of Federal legislation that aligned with U.S. EPA regulations, and the BC government chose not to pursue a zero emission vehicle mandate.

Clean Energy Vehicle program (Phase 1)	2011-2014	$14.3 million	Provided funding for a point-of-sale incentive program for the purchase or lease of eligible clean energy vehicles (PEVs, natural gas vehicles, and hydrogen fuel cell vehicles), charging infrastructure, and support for the "Emotive" education campaign. The CEV program (Phase 1) was designed to support market adoption of clean energy fuels and vehicle technologies in the light duty transportation sector by helping to overcome barriers including higher vehicle cost, limited fueling infrastructure, and a lack of awareness and knowledge about CEVs. Overall, the program supported the deployment of 950 CEVs.
Clean Energy Vehicle program (Phase 2)	2015-2018	$13.5 million	This round of the CEV program includes point-of-purchase incentives, with rebates of up to $5,000 for residents, businesses, non-profit organizations, and local governments who purchase or lease qualifying new CEVs. The fund was expected to last until March 2018, but high demand for CEVs reduced the fund to approximately $670,000 by January 2015. In March 2016, the Province announced an additional $6 million for purchase incentives. They simultaneously amended the program so that CEVs with a manufacturer-suggested retail price above $77,000 are no longer eligible for a purchase incentive.
Access to HOV lanes in BC	2016--present	N/A	Eligible electric and hydrogen fuel cell vehicles displaying an official decal are allowed in high-occupancy vehicle lanes throughout the province regardless of the number of passengers in the vehicle.
BC Climate Leadership Plan	August 2016	N/A	The Plan announced that the Clean Energy Vehicle program will be expanded to support new vehicle incentives and infrastructure, education and economic development initiatives, and the development of policies to facilitate installing electric vehicle charging stations in strata buildings and developments. The Plan did not include any further details, implementation strategies, or timelines for these policies.

Clean Energy Vehicle program (expansion)	2017-2020	$40 million	In February 2017, the BC government announced an additional $40 million in funding. These funds will be used to continue the vehicle rebate program, expand fueling infrastructure, support research and job training in the ZEV sector, increase public awareness of ZEVs, and provide incentives when residents scrap older vehicles. The exact amount of funding that will be dedicated to each part of the program is not clear.

The Province also sponsors a number of programs with other organizations, including BC Hydro, the Fraser Basin Council (FBC), academic institutions, regional governments, communities, and businesses. One example is *Plug in BC,* an initiative co-chaired by the BC Ministry of Energy and Mines and BC Hydro to lay the groundwork for plug-in electric vehicles and related electric charging infrastructure in British Columbia. Work by *Plug in BC* to connect auto manufacturers and BC fleets led to the roll-out of BC's first Mitsubishi iMiev, Nissan Leaf, Chevrolet Volt, and Mercedes-Benz Smart Fortwo Electric in 2011 (Fraser Basin Council, n.d.).

A related initiative is the *BC Scrap-It Program*. This non-profit organization is funded by grants and contributions from government and program partners, and provides incentives for British Columbians to voluntarily retire higher polluting vehicles and replace them with cleaner forms of transportation. Since 2015, *BC Scrap-It* has provided a $3,000 rebate towards the purchase of a qualifying new ZEV when a vehicle from the year 2000 or older is scraped. This amount was increased in February 2017; consumers are now eligible for up to $6,000 towards the purchase of a new ZEV, and up to $3,000 for a used ZEV. This can be combined with the *Clean Energy Vehicle* rebate for a total incentive of up to $11,000.

The Province is also signatory to a number of intergovernmental agreements to support ZEV adoption. In October 2013, they signed the *Pacific Coast Collaborative Action Plan* with the governments of Washington, Oregon, and California. The plan calls for the signatories to take actions to expand the use of ZEVs, and aimed for these vehicles to make up 10% of new vehicle purchases in public and private fleets by 2016; BC failed to meet that target. In December 2015, the province signed the *International Zero-Emissions*

Vehicle Alliance pledge, joining several other provinces, states, and nations which have agreed to strive to make all new passenger vehicles in their jurisdictions PHEVs, PEVs, and fuel cell vehicles by no later than 2050. The Province has not announced a plan for how they intend to meet this goal.

3.5.3. Municipal Government – Vancouver

While cities generally have little to no direct jurisdictional control over personal vehicle purchases, the City of Vancouver does have control over municipal infrastructure (such as roads, parking, etc.), as well as regulatory powers which allow the City to guide development and urban design, including how infrastructure is planned and space allocated. These are important tools as how we design our communities affects our travel requirements and choices. The development of compact communities and complete streets also encourages active transportation and transit use (City of Vancouver, 2015).

Table 3-2. Municipal policies

Policy	Year(s)	Funding	Description
Changes to the Vancouver Building Bylaw	2008-present	N/A	Requires 20% of parking stalls in apartments and condos, and all stalls in houses, to be electric vehicle ready by installing infrastructure to support Level 2 (240V) charging.
Development of charging infrastructure	2008-present	Unknown	To support the transition zero emission private vehicles, the City has worked to develop charging infrastructure for EVs. The City currently manages 78 Level 2 public charging points throughout Vancouver, and one DC Fast Charger. There are approximately 175 additional charging points that are managed by parking garages, hotels, shopping malls, and other services.
Greenest City 2020 Action Plan	2010-2020	Provided on a project-by-project basis	A broad set of long term goals that guide environmental policy for the City. One of the 10 goal areas is 'Climate and Renewables'; this part of the plan calls for an eventual elimination of dependence on fossil fuels in Vancouver.

Changes to the Vancouver Building Bylaw	2013-present	N/A	Requires that 10% of stalls in mixed-use and commercial buildings be electric vehicle ready by installing infrastructure to support Level 2 (240V) charging.
Renewable City Strategy	2015-Present	Provided on a project-by-project basis	Sets the goal of deriving 100% of the energy used in Vancouver (including all energy for transportation) from renewable sources before 2050, and includes high level strategies to achieve that goal. The *Strategy* covers the area within city limits, as well as any facilities owned or operated by the City of Vancouver outside those limits.
Electric Vehicle Ecosystem Strategy	2016-2021	$3 million	Establishes 32 priority actions to expand access to home and workplace charging, improve the public charging network, and integrate EV infrastructure planning into core City processes. One of the goals of the strategy is to improve ZEV affordability by reducing the cost of charging infrastructure.

The City is also encouraging local car-share organizations to add electric vehicles to their fleet by letting them access City-operated charging stations. Furthermore, Vancouver has the biggest municipal electric vehicle fleet in Canada with over 30 electric vehicles, and will continue to replace ICEVs with ZEVs as the vehicles age out.

3.6. Stakeholders

In addition to the various levels of government, there are numerous stakeholders involved in this policy area. These include: BC Hydro, private energy producers and distributors (both fossil fuels and renewable energy), auto manufacturers, non-governmental organizations (ZEV lobby groups, those involved in implementing government grants such as the Fraser Basin Council, etc.), other groups filling emerging spaces in this industry (like charging infrastructure), and the public. Each of these groups plays a pivotal role in this policy space, and should be involved in policy creation.

Chapter 4. Understanding cost

In recent years a growing literature has explored public opinion on ZEVs, with the results generally showing support for these vehicles (Egbue & Long, 2012). However, while ZEV purchase prices continue to decline, cost remains one of the most commonly cited barriers to adoption, and is a significant deterrent for many buyers (Axsen & Kurani, 2013; Carley et al., 2013; Egbue & Long, 2012; Graham-Rowe et al., 2012; Hidrue et al., 2011; Sovacool & Hirsh, 2009). The following sections outline the costs of ZEVs and examines how the costs of ZEVs, both real and perceived, act as a barrier to widespread adoption.

4.1. Costs of zero emission vehicles

As mentioned in Chapter 1, the costs for a vehicle are divided between the up-front purchase price of a vehicle, and the operating costs. Though ZEVs are generally more expensive to purchase than a comparable ICEV model due to higher production costs, lower maintenance and fueling costs can help to offset the initial investment. However, the cost efficiency of ZEVs compared to ICEVs is highly dependent on the annual driving distance, driving habits, the vehicle class, and the relative cost of fossil fuels versus renewables (Contestabile, Offer, Slade, Jaeger, & Thoennes, 2011; Wu, Inderbitzin, & Bening, 2015).

4.1.1. Vehicle purchase price

In Canada, ZEVs currently range from $26,990 for a Smart fortwo PEV (2-door) to over $100,000 for the highest-level Tesla PEV. A number of new models are expected to enter the Canadian market over the next few years, increasing the variety of styles, battery range, and price points available to consumers.

Despite these advancements, it is a widely-held industry understanding that the cost of battery packs will need to fall below US$150 per kWh for the purchase price of ZEVs to be cost-competitive with ICEVs. There has been significant movement in this

area in recent years, with the cost of battery packs reaching US$300 per kWh in 2015, having declined by 8% annually from 2007 to 2014 (Nykvist & Nilsson, 2015). While estimates vary as to the date that batteries will reach the $150/kWh threshold, many experts believe this will occur in the next decade.

As ZEVs are fairly new to BC there are a limited number of second-hand vehicles available for purchase, but this market should expand as time passes.

4.1.2. Maintenance

Overall, ZEVs are less expensive to maintain than ICEVs. PEVs in particular require less maintenance than ICEVs as the battery, motor, and associated electronics require little to no regular maintenance. There are also fewer fluids to change and far fewer moving parts relative to an ICEV. While batteries do have finite life spans (impacted by a variety of factors such as frequency and type of use, and temperature), the majority of manufacturers provide a warranty ranging from 5-10 years or 100,000 miles, and some provide a warranty for up to 40% battery capacity loss. Batteries also continue to meet the daily travel needs of most drivers even after losing 20% of their original capacity (Saxena, Le Floch, Macdonald, & Moura, 2015). Because PHEVs have internal combustion engines, their maintenance requirements are closer to those of conventional vehicles (U.S. Department of Energy, 2015).

The average ICEV is owned for nine years in Canada, and most of these vehicles are designed, engineered, and constructed to provide a 10-year/250,000-km lifespan with a reasonable amount of maintenance and repair (Turner, 2015). Due to the lower maintenance requirements, ZEVs may have longer lifecycles than ICEVs. However, this may lead to a slower creation of a second-hand vehicle market.

4.1.3. Fuel

ZEVs are less expensive to fuel than ICEVs, and this is particularly true in Vancouver. Current BC Hydro residential electricity rates mean that the cost to charge a vehicle at home is equivalent to purchasing gasoline that costs about $0.20 to $0.30 per litre (in reality, gas prices in Vancouver ranged from $1.03 to $1.52 per litre over the last

five years (Statistics Canada, n.d.)). As previously mentioned, BC Hydro rates are also highly regulated, ensuring greater certainty for fuel costs.

Electric charging infrastructure represents another cost for owners. Although the majority can be charged through a standard 120V plug, this is very time consuming (the average distance driven in Vancouver would require at least four hours per day of charging) (City of Vancouver, 2016b). At the same time, many existing homes in Vancouver do not have enough electrical capacity to support electric vehicle charging, and retrofit costs can be very high depending on the age and existing conditions of the building's electrical system (City of Vancouver, 2016b). Recognizing that the cost of charging infrastructure can be a barrier, the City plans to develop programs to encourage retrofitting of multi-unit residential buildings and workplace parking, and expand public charging access.

4.1.4. Associated costs

Like ICEVs, ZEVs have a variety of associated costs such as car insurance, parking, and time spent in traffic. There are not currently any price differences for between ZEVs and ICEVs for these associated costs. While cities do not have jurisdiction over insurance rates, they can create policies that impact other associated costs to reduce the price difference between ZEVs and ICEVs, including parking and road access.

There is one existing policy that impacts only ZEVs: these vehicles are allowed in the high-occupancy vehicle lane on provincial highways, regardless of the number of occupants. This works as an incentive by saving ZEV drivers time and fuel costs.

4.2. Intangible costs

In addition to financial costs, ZEVs present a number of less tangible 'costs' to consumers, such as changes to their fueling patterns, range anxiety, and overcoming apprehension of this unfamiliar technology (Rogers, 2003; Sovacool & Hirsh, 2009). For example, instead of fueling their vehicle once a week or every few weeks at a gas station, a ZEV will require drivers to charge their vehicle everyday or few days. This presents

challenges for residents who do not have easy access to charging infrastructure. While there are more than 250 publicly and privately managed charging locations across Vancouver, and the City's recent *EV Ecosystem Strategy* will make a significant impact on building out the charging network (particularly fast-chargers), it will take a number of years for these policies and programs to come into effect and a more robust charging infrastructure to develop.

As a result, even if ZEV purchase prices were to become on par with ICEVs, many mainstream consumers will still see these 'costs' as a barrier. Consequently, these consumers will require incentives and benefits above and beyond a reduction in purchase price to 'balance out' these intangible costs.

4.3. Consumer knowledge

ZEVs are essentially an unknown product for the average consumer, and knowledge about these vehicles remains extremely low amongst the public. While many consumers are able to identify the purchase price range for new ZEVs, they are typically unable to identify other basic characteristics such as what types of fuels the vehicles use, how fueling works, approximate driving ranges, and operating costs (Axsen et al., 2015; Caperello & Kurani, 2012; Krause, Carley, Lane, & Graham, 2013).

Consumers often indicate that cost is an important concern in their decision-making; yet, in reality, people generally don't use any sort of systematic process, such as a detailed benefit-cost or lifecycle cost analysis, when purchasing vehicles (Diamond, 2009; Turrentine & Kurani, 2007). When they do perform cost calculations, consumers tend to want unrealistically short payback periods for the higher purchase price, and use discount rates that are significantly higher than those used by economists (Sovacool & Hirsh, 2009).

The average consumer is also ill-equipped to perform an accurate cost calculation. Firstly, most people do not keep track of their fuel costs over any significant period of time (Turrentine & Kurani, 2007). Consequently, they don't have a reliable understanding of these costs, nor do they have an accurate baseline to compare to. Secondly, though they

recognize that ZEVs have lower energy costs, they are unable to identify the differences in cost as many are not aware of electricity prices or how much electricity the vehicles use (Graham-Rowe et al., 2012). As a result, consumers typically significantly underestimate the magnitude of energy cost savings offered by ZEVs (Carley et al., 2013). Similarly, many are unable to calculate the maintenance costs for ZEVS, assuming they are similar to ICEVs or even considerably more expensive (Krause et al., 2013). These uncertainties can lead consumers to doubt that higher purchase costs could be offset by lowered running costs (Caperello & Kurani, 2012; Graham-Rowe et al., 2012), and higher uncertainty decreases the initial amount that consumers are willing to pay for these vehicles (Sierzchula et al., 2014). However, consumers are warranted in their skepticism, as an individual must own a vehicle for an extended period and/or drive extensively before the lower operating costs balance out the higher purchase price.

Consumers also tend to be unaware of available ZEV incentives. A study of consumers in 21 major American cities found that more than 95% of respondents are unaware of the state and local policies promoting PEV ownership that are available to them. For example, only two out of 758 survey respondents living in areas where subsidies for home charging equipment are offered were aware of their availability (Krause et al., 2013).

The issues described in this section can be mitigated with information, but how information is presented to consumers has a significant impact on their behavior. While the fuel or monetary savings of ZEVs are often presented in monthly or annual savings, this information does not appear to impact consumer assessments of these vehicles. On the other hand, information on the total cost of ownership seems to trigger consumer interest in ZEVs (Dumortier et al., 2015). Framing also matters. Humans are loss averse, meaning that they react more strongly to losses than gains (Thaler & Sunstein, 2008); as a result, consumers are likely to respond differently to information that highlights the savings from ZEVs, than to information that highlights how much they're 'losing' to the cost of fuel and maintenance with an ICEVs.

The lack of knowledge described in this section is relevant for policy makers and policy design, as government programs will have little effect on uptake rates as long as

the majority of consumers are uncomfortable with these technologies (Egbue & Long, 2012; Eppstein, Grover, Marshall, & Rizzo, 2011).

Chapter 5. Scan of select City government approaches

The previous section has illustrated how costs are a barrier to the widespread adoption of ZEVs. As long as this problem remains, we are unlikely to see a significant increase in the proportion of ZEVs in the vehicle base. Over the last few decades, a number of cities around the world have taken action to increase ZEV adoption by using policies to reduce or compensate for this barrier. In this chapter I survey three of these cities to examine the variety of policies that are being used. The selection rationale for these cities is outlined in Chapter 2.

Table 5-1. Cities in jurisdiction scan

	Vancouver	Stockholm	Oslo	San Francisco
Population	630,000	912,000	635,000	852,000
Size (km^2)	115	188	454	121
Percent of trips made by private vehicle	49%	32.5%	Unknown	46%
Light duty vehicles	270,000	330,000	275,000	407,000
ZEVs	2,500	7,300	35,000	5,300

For each city, I begin with a review of the policy landscape, followed by a description of the cost-related policies in place. In reviewing the approaches taken by these cities, three main policy mechanisms emerged: education, incentive, and regulatory-based policies.

5.1. City of Stockholm

The City of Stockholm's work on zero and low emission vehicles extends back to 1994 when the *Clean Vehicles in Stockholm* program was created. The goal of this program is to speed up the transition to clean vehicles[2] (CVs) and renewable fuels. The supply of CVs on the market was almost non-existent when the program started, but the

[2] Stockholm has focused on HEVs, PHEVs, biofuel, and natural gas vehicles (referred to as clean vehicles), and less emphasis has been placed on PEVs.

City has seen significant sales since. In 2003, Stockholm City Council set a target that 4% of new vehicles sales should be CVs by 2006. This target was met in 2005. The *Stockholm Environmental Programme 2008-2011* set a target for 2010 that 35% of new car sales will be clean vehicles which was also met early. By the end of 2008 the share of CVs in Stockholm was approximately 8%, while it was only 5% across Sweden.

Stockholm's CV plan is connected to a broader portfolio of actions that aim to reduce private vehicle use (Planning & Environment Unit of the Environment and Health Administration in Stockholm, 2014). Stockholm has also recently set the goal of being fossil fuel free by 2050. The City intends to build on existing policies, with a focus on: positive/negative incentives, such as differentiated congestion tax, parking fees, reserved parking spaces, and bans in certain areas on vehicles that are noisy/run on fossil fuels, amongst other policies (Planning & Environment Unit of the Environment and Health Administration in Stockholm, 2014).

One unique factor is that companies account for around 70% of all new car purchases in Stockholm, while private citizens largely purchase their vehicles on the secondhand market.

There are two main cost-related incentives offered by the Swedish government. The first is a rebate which was introduced in 2012 to cover the purchase of 5,000 new vehicles; consumers receive a 40,000 SEK rebate (approximately $6,000 CAD) for cars that emit no more than 50 grams of carbon dioxide per kilometer. Most ZEVs qualify, though the rebate was halved for PHEVs in 2016. Secondly, ZEVs are also exempt from the annual circulation tax for five years from the first time the vehicle is registered.

5.1.1. Education

Clean Vehicles in Stockholm has dedicated extensive resources to CV education campaigns, and essentially functions as a resource centre. In 2000, *Clean Vehicles* began publishing an external newsletter, and a dedicated communications staff member was appointed in 2002. Between 2001-2005, as the market started to expand, *Clean Vehicles* began to engage in broader public information campaigns on clean vehicles and fuels. As surveys showed consumers had low interest in environmental issues and little to no

knowledge about CVs, the City decided to focus on educating consumers about the price and performance of CVs, as well as available models and fuels. Companies and private individuals that had chosen clean vehicles were highlighted, and *Clean Vehicles in Stockholm* provided journalists with facts and contacts. Another campaign, "Clean Vehicles Are Better" was carried out in 2003 with car dealers and fuel suppliers to increase knowledge about clean vehicles. The campaign was targeted at large scale producers and consumers, as well as the media, and featured actions such as information distribution, test driving of vehicles, and individual consultations. This campaign helped to establish the concept of CVs and media coverage of CVs increased by 700%.

An information website (www.miljofordon.se) was launched in 2004 in collaboration with the cities of Gothenburg and Malmö. The website is actively maintained, and consumers can search for and compare clean vehicles, and find filling stations for renewable fuels.

5.1.2. Incentives

Free residential parking permits for CVs were introduced in May 2005, and continued until the end of 2008. The free permits were limited to the city centre, which is a dense area with limited on-street parking. This saved the average resident up to 40 SEK per day ($6.80 CAD) or 600 SEK per 30-day period ($102 CAD). As permits were issued, the Traffic Administration checked that the vehicles met clean vehicle requirements. Statistical analysis shows that free parking had significant impacts on the adoption of CVs in Stockholm, though surveys indicate that CV buyers were split on the value of free residential parking, rating it either an important factor in their decision to buy an CV or not at all important (City of Stockholm Environment and Health Administration, 2009). While this policy was removed as it wasn't used to the extent that had been anticipated, residents have since inquired as to why the policy was taken out (Informant Interview, Personal Communication, October 25, 2016).

5.1.3. Regulations

Stockholm has had a tax for traffic entering the inner city since 2007. The tax was introduced in 2006 as a six-month trial, with CVs exempted from paying the tax. During the trial the City of Stockholm used the term ‘‘environmental charges”, and an extensive monitoring and evaluation program was carried out. During the trial, the charges had a positive impact on traffic congestion and air quality, and these results were communicated to the public following the trial. There was significant public resistance before the tax was introduced, and opponents of the charges forced a referendum on whether the zone should be made permanent. However, support had increased during the trial and the referendum resulted in majority support for keeping the charge. Research shows that a belief in the effectiveness of the charge, general environmental attitudes, low car dependence, and good transit supply all contributed to the high acceptance rate (Eliasson & Jonsson, 2011).

The policy consists of a toll cordon around the inner city. Around two-thirds of Stockholm’s inhabitants live within the toll zone. The cost of passing the cordon ranges from 20 SEK during peak hours to 10 SEK during slower periods. Revenues from the tax are earmarked for road investments. Beginning in 2009, the CV tax exemption was phased out and CVs registered after this date are no longer exempt (though CVs registered before this date remained exempt until 2012). This incentive was removed as the City was concerned too many vehicles were eligible for the free parking (Informant Interview, Personal Communication, October 25, 2016).

During the trial period in 2006, 2% of trips into the city were alternative fuel vehicles; by December 2008, the share of CVs had increased to 14% (however, only 3.2% of cars crossing the cordon were privately owned CVs, with commercial vehicles making up the majority) (Börjesson, Eliasson, Hugosson, & Brundell-Freij, 2012). Statistical analyses indicate that exemption from congestion charges in Stockholm has been an important incentive for CV adoption, increasing sales of alternatively fueled vehicles by between 10% (Whitehead, Franklin, & Washington, 2014) and 23% in the year following the policy’s implementation (City of Stockholm Environment and Health Administration, 2009).

5.2. City of Oslo

Oslo has the highest per capita number of PEVs of any major city in the world, with ZEVs making up over 30% of all new cars sold in Oslo in 2015 and 2016. This strong uptake of ZEVs has taken place in only a few years, growing from essentially zero ZEVs in the region in 2009 to close to 35,000 in 2016 (City of Oslo, n.d.).

ZEV policies in Oslo and Norway began in the 1990s, and the City has adopted a series of connected strategic plans for this work. In 2016, the City of Oslo adopted a new *Climate and Energy Strategy* which sets the target of phasing out fossil fuel-based vehicles by 2030. Pedestrians, cyclists and public transport users are prioritised in this plan, and the City aims to reduce car traffic by 20 per cent by 2020 and by 33 per cent by 2030. From the City's perspective, the most important measures for fossil-free transport include introducing low/zero emissions zones, environmentally differentiated tolls, and lanes reserved for public and environmentally friendly transport (City of Oslo Agency for Climate, 2016). Oslo also has an extensive charging network. Sustainability programs in Oslo have been framed around improving quality of life for residents by providing a cleaner, healthier urban environment with better air quality.

State level policies for ZEVs are differentiated based on vehicle type. PEV policies include: no tax on the vehicle purchase, no Value-Added Tax, and free transport on ferries (an important policy given the island geography of Norway). The incentive package will be revised and adjusted to match market development in 2018 (Haugneland, Christina, & Hauge, 2016). At the same time, Norway has focused on making ICEVs more expensive – for example, vehicles must be registered annually, with a typical compact car charged a registration fee of 5000-10000 euros the first time the vehicle is registered. The tax is progressive, resulting in extremely high taxes for large luxury vehicles (Figenbaum, Assum, & Kolbenstvedt, 2015). The incentives for PEVs, combined with the extra costs for ICEVs, have made them cost competitive. However, the importance of incentives is illustrated by the low sales of PHEVs relative to PEVs. The first PHEVs were launched in Norway at the end of 2012, but high prices and a lack of incentives (only slightly lower registration tax than traditional hybrid vehicles and none of the PEV incentives) resulted

in lower sales. In 2013, PHEVs were allowed access to public charging stations, and the registration tax was reduced slightly (Figenbaum et al., 2015).

5.2.1. Education

The Norwegian Electric Vehicle Association was started in the 1990s as an initiative from Oslo Energy and the City of Oslo, and is now a primary source of information on ZEVs in Norway. The Association provides a wide range of information services, including arranging opportunities for the public to learn more and test drive different vehicles. The association also has a web site that distributes news about ZEVs, and hosts an online forum.

5.2.2. Incentives

In 2003, the government implemented a trial to allow PEVs and PHEVs to drive in bus lanes on selected road sections (including most of the bus lanes in the greater Oslo region, with some minor exceptions in Oslo's inner city). The system became permanent in 2005.

Electric vehicles have been able to park free of charge in municipally-controlled public parking areas since 1999, saving ZEV drivers €2 - 5 per hour.

5.2.3. Regulations

Since 1990, all roads leading into Oslo have had automated toll stations. The purpose of the toll ring is to reduce congestion, air pollution, GHG emissions, and noise. Revenues are used to facilitate more walking, cycling, and public transit trips through investing in better infrastructure. The City credits the toll with increasing the public transit share from 21% to 32% of trips from 2005 to 2015, and for decreasing the car share from 45% to 34%. Oslo is aiming for a further 15% reduction in traffic by 2019.

ZEVs have had free access to the toll area since 1997; however, a toll for these vehicles will begin in January 2018, at which point they will pay €1.10, plus an extra €1.10 during rush hour. Another increase of €1.10 will take place in January 2020. The toll ring

charges for light duty diesel and petrol vehicles have also been increased as of March 2017, from €3.60 to €5.20. They are set to remain at this price through 2020.

5.3. City of San Francisco

San Francisco has set the goal of becoming the ZEV capital of the United States, and has one of the highest shares of shares of ZEVs in the US (Lutsey, Searle, Chambliss, & Bandivadekar, 2015).

San Francisco introduced a *Climate Action Plan* in 2004, which was subsequently updated in 2013 with the San Francisco *Climate Action Strategy*. This new strategy sets targets to source 100% of residential and 80% of commercial electricity from renewable sources, and for 50% of all trips to be made outside of personal vehicles. San Francisco also recently launched an Electric Vehicle Working Group to develop recommendations to facilitate PEV market transformation; the Working Group has established a goal that 15% of the vehicles driven in San Francisco will be PEVs by 2025.

California has focused on both supply and demand policies, but has implemented one of the strongest supply side mechanisms, a zero emission vehicle mandate. This mandate requires that by 2025 at least 15% of new car sales conform to the ZEV emissions performance criteria, and establishes minimum thresholds for the production of qualified ZEVs, as well as a structure of financial penalties and credit trading for manufacturers. The *California Vehicle Rebate Program* has also provided several hundred million dollars in direct-to-consumer incentives in the form of purchase rebates, and the Senate has established Charge Ahead California, setting a goal of placing 1 million PEVs and near PEVs in service by 2023, and increasing access to these vehicles by disadvantaged, low, and moderate-income communities and consumers.

5.3.1. Education

Charge Across Town was started in 2012 in collaboration with San Francisco's Department of the Environment to provide basic consumer education at the community level, as well as outreach to the business sector. *Charge Across Town* educates

consumers on the benefits, costs, and feasibility of owning or sharing PEVs and PHEVs, and provides opportunities for people to get behind the wheel and test drive the cars. *Charge Across Town* hosts an annual “EV Week”, a free five-day event held throughout the Bay area that provides “ride and drives” in electric vehicles, and information on ZEV infrastructure, utility rate information, and state and federal rebate and incentive programs. Additionally, “EV Week” features PEV technology forums and discussions, and opportunities for vehicle manufacturers and infrastructure companies to interact with the public in a non-sales environment.

5.3.2. Incentives

San Francisco has not implemented any incentives such as free parking or access to bus lanes. However, a recent report prepared by City staff has recommended that San Francisco consider preferential street parking zones for ZEVs, other fee exemptions, and HOV lane expansion in combination with transit lanes (City and County of San Francisco Department of the Environment & EV Alliance, 2017).

5.3.3. Regulations

San Francisco has not created any regulations to directly impact the price of ZEVs. However, the same report noted in the previous section recommends the City explore congestion pricing zones with preferential pricing/access for ZEVs (City and County of San Francisco Department of the Environment & EV Alliance, 2017).

5.4. Lessons from Scan

- Policies impact which vehicle technologies are adopted. Stockholm did not focus on PEVs, resulting in very limited awareness, experience, and knowledge of PEVs, and sales of these vehicles lag other CVs. Similarly, Oslo focused on PEVs, which have outsold PHEVs.
- A dedicated City team helps ensure a coordinated approach and implementation. *Clean Vehicles in Stockholm* has been involved in all of Stockholm’s CV policies, and the team includes a dedicated communications staff member, ensuring there are sufficient resources for strategic information and communication efforts.

- A strong public transit system makes regulations more acceptable for residents by providing a viable alternative.
- The effectiveness of free or discounted parking as an option remains unclear. One interpretation is that a parking policy for ZEVs influences certain groups of drivers more than others.
- Where possible, maintaining even a low level of an incentive is preferable to removing a policy entirely in order to signal to consumers that ZEVs are a better choice than ICEVs.
- Partnerships with local associations and community stakeholders, such as business or environmental groups, allows municipalities to leverage existing expertise and experience.
- Cities should be deliberate about the order in which policies are introduced. For example, incentives are less effective if there is not adequate charging infrastructure, while policies are less likely to have a strong impact if consumers know nothing about the vehicles.
- Success takes time: *Clean Vehicles in Stockholm* has been operating for fifteen years, and the turning point in vehicle sales did not occur until 2005, 11 years after the start of the project. Norwegian policies have also been in place for a significant period, while strong uptake of ZEVs has largely taken place over the last few years.

Chapter 6. Criteria and measures

The following section outlines the objectives, criteria, and measures that will be used to assess the policy options in Chapter 7. First, I selected two societal objectives (effectiveness and public acceptability), and two government objectives (cost and administrative ease). I then created one or more criteria for each of the objectives. Lastly, I chose measures for each of the criteria so that the policy options can be measured in a consistent manner. The measures were formed using information from the literature, the scan of cities, and expert interviews.

6.1. Effectiveness

From the information presented in earlier chapters, it is clear that costs remain a significant barrier to widespread ZEV adoption. This report uses two criteria for analyzing the effectiveness of policies. The first is how successful the policy is in reducing the problem outlined in Chapter 1: minimizing the cost difference between ZEVs and ICEVs. The second criterion approaches the impact from a different angle by assessing the effectiveness of a policy on increasing the number of ZEVs in the vehicle base. This criterion is important to include separately from the cost criteria as some policies which do not directly lower the cost of a vehicle still have the possibility of increasing adoption rates, which is the ultimate goal.

Objective	Criteria	Measures
Effectiveness	Impact on reducing the cost of ZEVs relative to ICEVs	High = significantly minimizes cost difference
		Medium = somewhat minimizes cost difference
		Low = does not reduce cost difference
	Impact on increasing the number of ZEVs in the vehicle base	High = Significant impact
		Medium = Moderate impact
		Low = No/small impact

6.2. Public Acceptability

Though there are a variety of stakeholders associated with ZEV policy, the relevant stakeholders in this assessment are the public (taxpayers) as they are most directly impacted by policy implementation and outcomes. There are a number of variables which contribute to stakeholder acceptability:

- Equity – A policy should not (appear to) unfairly assist one segment of the population, particularly at a cost to other taxpayers.
- Cost – The policy should avoid placing an excessive cost on residents and businesses, which could contribute to further unaffordability in an already expensive city.
- Proportionality – The policy response should feel proportionate to the policy problem.
- Effectiveness – There should be a clear rationale for why the policy is expected to be effective, and a process for reporting on outcomes.

Objectives	Criteria	Measures
Stakeholder Acceptability	Equity Cost Proportionality Effectiveness	High = Meets 3 or more of the criteria Medium = Meets 2 of the criteria Low = Meets 1 or none of the criteria

6.3. Government cost

Policies vary greatly in their cost to the City, both during launch and ongoing administration. Cost is considered using a net approach, encompassing the direct expenses of a policy, the loss of existing revenues, and the addition of new revenues; however, the costs used in this study are estimates as I do not have access to the required information. Costs must also be kept in mind relative to spending on other priorities, both in this same area (such as investing in policies that promote transportation mode-switching), and other areas (City services, housing, etc.).

Five years of operating costs was chosen for use in the criterion as ZEV prices are expected to remain higher than ICEVs until at least the early 2020s. Several of the policies

outlined in Chapter 7 also require extensive investments for implementation, and would be in place for an extended period or permanently.

Objectives	Criteria	Measures
Cost	Cost to the City of implementing the policy and 5 years of operations	High = costs less than $500,000
		Medium = $500,000-$1,000,000
		Low = costs more than $1,000,000

6.4. Administrative ease

Administrative ease refers to the number of procedural changes required to implement a policy option. The number of actions required for each policy option determines the administrative burden it places on the City, with fewer required actions corresponding to greater ease. Actions include:

- Public consultation
- Re-writing bylaws
- Changing existing programs/policies
- Creating new programs/policies
- Creating partnerships with external organizations and agencies
- Lobbying other levels of government
- Complexity of enforcement

Objectives	Criteria	Measures
Administrative Ease	Public consultation Changing existing programs Creating new programs Re-writing bylaws Partnering with external organizations Lobbying other levels of government Complexity of enforcement	High = Less than 3 actions
		Medium = 3 to 4 actions
		Low = More than 4 actions

Chapter 7. Policy options

This chapter outlines four policy approaches the City of Vancouver could use to address the cost of ZEVs and increase adoption rates. The options draw on approaches taken in other jurisdictions, as well as insights from the literature and interviews with experts.

Option 1 is an education policy, consisting of a City-run informational website and an outreach campaign in partnership with external organizations. Options 2 and 3 are incentives, focused on discounted parking and the use of bus lanes, respectively. Option 4 is a combined regulatory and incentive-based approach comprising the creation of a toll zone with differentiated entry pricing.

Several additional policy options were also identified which are not considered here. First, the status quo is not included as an option given the urgent need to reduce emissions from vehicles. Second, the creation of additional upfront financial incentives (such as a rebate) is not considered. This option would be very costly for the City, requiring millions of dollars in funding for the rebates to be of any significant size and/or be available to more than a handful of residents. In addition, while upfront costs are cited as one of the most significant barriers, there is conflicting information on how effective purchase incentives are in persuading consumers to make a purchase that they weren't already planning to make. In other words, financial purchase incentives may subsidize consumers who would have bought a ZEV even without the incentive. Third, there are several ways that public parking can be used as a policy lever; one variation is a regulatory approach, where certain spots are designated ZEV-only parking. This approach incentivizes ZEVs by providing access to parking spots, and simultaneously disincentivizes ICEVs by making it less convenient to park these vehicles. However, given the current market share of ZEVs, it would be challenging to determine the number and location of these parking spots, and it is possible these spots would be left empty most of the time. This would likely produce backlash and negative associations as parking is already considered to be at a premium in many locations across the city.

7.1. Option 1: Education and outreach

As outlined previously, ZEVs adoption rates are likely to remain low as long as consumers lack a basic understanding of the technology. Option 1 is an education campaign to increase understanding of and awareness about the cost of ZEVs amongst the public. This campaign would include a City-run website featuring information on the total cost of ownership for ZEVs, as well as the various incentive programs available at the provincial and municipal level. The City's campaign would fill a gap by consolidating this information from a variety of sources, and would make cost information tangible and applicable to residents' unique needs through interactive tools such as a cost calculator. This website would also be used to share other information on ZEVs such as the various types of vehicles and how they work, the models available in BC, fuelling options, a charger map, and the health and air quality benefits of ZEVs. Messaging in the education campaign would be tailored for specific audiences, beginning with those in the early adopter and early mainstream categories. The website would be linked to from the City's regular website, and advertised through social media channels and a media campaign at the launch.

A second component of the campaign would be to provide grants to community ZEV groups to hold public engagement events. These events would provide opportunities for residents to see different vehicles up close, speak with drivers who use ZEVs, ask questions, and test drive vehicles. A grant amount of up to $25,000 per year to be split between up to two organizations is recommended. This is in line with existing amounts available through Vancouver's *Greenest City Grants* program (which average $35,000 to $45,000 per project), and could be administered through this existing program.

7.2. Option 2: Discounted parking

This policy option entails discounted parking fees for ZEVs in City-controlled parking locations, including on-street metered parking, parking permits in neighbourhoods, and City-owned parking lots. Modeling would be needed to determine the specific rates.

There are two options for structuring this policy: either the City maintains existing rates for ICEVs and receives lower revenues from parking fees, or rates can be raised for ICEVs for total revenue to be kept constant. Given that ZEVs currently account for a small portion of all vehicles, it would likely not have a significant impact on the City's revenues to maintain existing rates and simply discount ZEVs. Consequently, this is the chosen policy structure at the current time.

This policy option does not include parking spots located at electric vehicle chargers, which require a unique pay structure.

7.3. Option 3: Bus lane access

The City of Vancouver has several streets on which the curb lane is designated for buses during rush hour traffic, including Broadway, Granville Street, Burrard Street, and Pender Street. This policy option would allow ZEVs to travel in these lanes as well, which would reduce travel time (and therefore fuel consumption) for ZEV drivers. The policy would rely on the provincial government's decal program (qualifying ZEV owners can apply for a white decal which allows them access to high occupancy vehicle lanes in British Columbia). As fuel cell vehicles qualify for the decal, these vehicles would be given bus lane access as well.

7.4. Option 4: Toll zone

This option takes a regulatory and incentive-based approach by creating a toll zone. This option would consist of creating an initial zone focused on the downtown peninsula. Vehicles would be charged to enter based on the type of vehicle, with ZEVs charged a lower rate than ICEVs. Modeling would be required to determine the specific rates.

This option, as proposed in this report, only considers the use of a toll zone as a tool to reduce the cost of ZEVs relative to ICEVs, and does not consider additional benefits of the policy such as reducing air pollution and traffic congestion.

It is important to note that the City would not be able to implement this policy without the approval of the provincial government, as municipalities do not have the power to levy additional taxes.

Chapter 8. Analysis

This chapter presents an analysis of each of the four policy options in Chapter 7, using the criteria and measures outlined in Chapter 6. A summary of the analysis is shown in Table 8-1, with the strengths, weaknesses, and trade-offs of each policy described in the following sections.

Table 8-1. Summary of policy analysis

	Education	Parking	Bus lane access	Toll zone
Effectiveness (Cost)	Low	Med	Low	High
Effectiveness (Adoption rate)	Med	Med	Low	High
Public acceptability	High	High	Med	Low
Cost	High	Med	High	Low
Administrative Ease	High	Med	High	Low

8.1. Option 1: Education and outreach

An education campaign scores low on the first measure of effectiveness as this policy does not directly reduce either the upfront or ongoing costs. However, this policy could impact cost indirectly by increasing demand for ZEVs, thereby bringing the cost of ZEVs down by lowering marginal production costs.

This option is expected to have a moderate impact on the second effectiveness measure, adoption rate. Consumers are more likely to purchase a product when they understand it, and education is an important first step in correcting common misperceptions about cost. An education campaign is also particularly suitable for this policy problem as it is one where the full effect of the consumer's choice is delayed, and deciding which vehicle to purchase is a difficult and infrequent occurrence which only offers feedback on the choice they make (as opposed to all the alternatives). By providing tools and information on ZEVs, this option helps consumers to develop an accurate understanding of the total cost of ownership, and reduces the effort consumers must

engage in to make an informed decision. A cost calculator tool is particularly valuable as it allows consumers to receive instant feedback on the outcomes of choosing different vehicles, helping them learn what options make the most sense for them in the long-term. The website would also help support and amplify the provincial rebates available.

The public outreach component of this option provides real world experience with ZEVs, which can be challenging to obtain otherwise as many dealerships do not have sufficient stock or a variety of models for test driving. Public events also present the opportunity for ZEV users to share their experiences. Such word-of-mouth information is a valuable tool for disseminating interest and information about ZEVs, and this method of communication is expected to facilitate diffusion amongst mainstream consumers. As mentioned previously, most mainstream consumers are also strongly influenced by what they believe others are doing; increasing the visibility of ZEVs therefore helps increase the perception that 'everyone's doing it'.

This multi-form approach (using both online and in-person methods) allows the City to speak to the different segments of consumers; for example, diffusion theory indicates that innovators and early adopters may be persuaded to purchase a ZEV purely based on information obtained through mass media, while mainstream adopters are generally more influenced by word-of-mouth and personal communications.

It is important to note that more accurate consumer understanding of ZEVs and related policies does not automatically stimulate purchases and greater usage. If, for example, a consumer underestimates the purchase price of a ZEV, and then learns that it is more expensive than they had thought previously, the more accurate information could decrease their interest.

An education campaign scores high on public acceptability as it is likely to be viewed as an equitable, relatively low cost, and proportional response. While the effectiveness of the policy may not be immediately clear to the public, policy implementation and outcomes can be easily tracked and reported on.

The cost to the City of an education campaign can be easily scaled depending on the exact programs put into place. For the development of a website, this can be done at

no additional cost to the City if existing staff are reallocated to work on this project. The grant component of the policy would not be complex to set up, and a grant of up to $25,000 per year would be adequate to support outreach efforts by local organizations. The size of the grants can also be scaled, though these should not vary substantially year-over-year to ensure partner organizations have predictability in their funding. Consequently, this option scores high on cost to the City.

An education campaign requires few administrative changes. The website would only require staff hours, while the grant could be administered through existing *Greenest City* grants program. This option therefore scores high on administrative complexity.

8.2. Option 2: Discounted parking

This option would have varying cost impacts on drivers, depending on their driving habits. For example, a driver who has access to free parking at home and at work, and only occasionally pays for street parking, will not see significant savings, while a driver who pays for a parking permit at home and a parkade for work could potentially save hundreds of dollars a year, depending on the discount given. As a result, the option scores a medium on cost reduction.

On balance, discounted parking, in the current form, scores moderately on adoption rate. Firstly, as previously mentioned, the policy will impact certain segments of drivers more than others. Second, results of this policy from other cities indicates that, overall, it has not been identified as a significant driver for consumers to switch to ZEVs. However, this proposed policy would cover all pay parking locations in Vancouver, while others have only focused on specific areas/locations. The discount rate can also be changed in order to increase or decrease the impacts of this incentive. The larger the relative difference between the cost of ZEV parking and ICEV parking, the more effective the policy is expected to be on ZEV adoption rates.

This option scores high on public acceptability overall. The policy would likely be disliked by some ICEV drivers who believe existing parking prices are unfair, and may question the equity of the policy; that being said, as the policy does not raise the cost for

ICEV drivers, this policy is not actually inequitable to them. It would also not place an undue cost on the public, and is not out of proportion to the problem. While some may question the effectiveness of the policy, this is not anticipated to be a significant concern.

This option scores moderately on cost. The primary cost to the City results from initial upgrades to parking meters and pay-by-phone applications to accommodate the differentiated pay structure. On an ongoing basis, the cost depends largely on the number of ZEVs taking advantage of the policy as this will determine the revenue lost to the City. Consequently, the discount rate should be reviewed annually, and altered as ZEV adoption increases.

This option scores moderately on administrative ease. As described in the previous paragraph, initial implementation of the policy is the most complex aspect, requiring substantial changes to City equipment and software, and amendments to parking by-laws. Enforcement of the policy would be relatively simple, with vehicle models checked against an eligible list.

8.3. Option 3: Bus lane access

Like the last option, bus lane access would have varying cost impacts on drivers, depending on their driving habits. For those who drive frequently in rush hour traffic, this option has the potential to save them time and fuel. However, given the limited number of streets with bus lanes in Vancouver, there are many drivers who do not use these streets or drive primarily outside of rush hour. As this option would only impact a portion of ZEV drivers (and even then the reductions in cost are largely indirect) it scores low on effectiveness in terms of cost reduction.

Using the same logic, this option scores low on effectiveness in terms of impacting the adoption rate. This policy is also somewhat unusual as the more people who use the bus lanes, the less effective the policy becomes due to overcrowding of the lanes. While the number of ZEVs are currently low enough that this is not an immediate concern, the policy would need to monitored to ensure it was phased out before this occurred. Taxis also have access to Vancouver's bus lanes, meaning the pressure on these lanes is

already elevated. Uptake of this policy would eventually also impact the flow of buses, which is counterproductive to the City's goal of making transit more reliable and efficient.

Preferential access to bus lanes scores moderately on public acceptability. This option may appear unfair to some ICEV drivers, and the effectiveness may also be questioned, particularly if it is seen to have any negative impact on bus flows. However, it would not place an undue cost on the public, and does not appear out of proportion to the problem.

This option scores high on cost as it does not require any additional infrastructure or annual funding. The primary cost is to replace or amend street signage to indicate ZEV access to the lanes, with no ongoing costs.

Preferential access to bus lanes has few administrative complexities, requiring only bylaw changes, and is easily added to existing traffic law enforcement activities. Consequently, it scores high on this criterion.

8.4. Option 4: Toll zone

A toll zone is the most effective option for reducing the cost of ZEVs relative to ICEVs, and has been shown in other cities to have a significant impact on the uptake of ZEVs. As a result, this option scores high on both measures of effectiveness. At the same time, this option uses a price mechanism to disincentivize the use of all personal vehicles, helping alleviate congestion. Like the parking option, the discount rate can be changed over time in order to increase or decrease the impacts of the policy. The larger the difference between the cost charged for a ZEV to enter the toll zone and the cost for an ICEV, the more effective the policy is expected to be on ZEV adoption rates.

This option is expected to have low public acceptability in the current political climate, particularly if it is framed (solely) as a climate issue. In this case, the public is likely to see it as unfair and costly, increasing their already high daily expenses. This stems from the larger issue of climate change not being a salient concern for the average resident, whose attention is more focused on everyday challenges, particularly the cost of

housing and other living expenses (City of Vancouver, 2016a). Inadequate ZEV adoption is not a significant problem in the eyes of most residents, and a regulatory approach which 'penalizes' drivers would feel like government overreach to many. As such, more work needs to be done to raise the salience of climate change for this policy to gain public acceptability. There also need to be better alternatives in place (particularly fast, reliable, and affordable public transit), otherwise this policy has the potential to be highly inequitable to lower income households. A framing approach which incorporates the ability of the policy to address congestion issues and improve air quality could also help increase acceptance.

The creation of a toll zone would require the development of new infrastructure, including toll stations at the main entry points to the downtown core. The east side of the downtown area would present the most significant challenge as traffic is not currently directed to specific entry points, but can be accessed through any street. Consequently, traffic diversions would need to be placed and designated entry points located (likely along several main arteries). Other costs depend on the monitoring system chosen by the City, and all would require the development of a payment system. Given these implementation and operating requirements, the policy would exceed a cost of $1,000,000 over the first five years and therefore scores low on cost. However, the program would eventually earn income for the City, with the payback period depending on a variety of factors outside the scope of this research, such as infrastructure investments, entry rate, and the number of vehicles travelling into the zone, amongst others.

This option is quite administratively complex, and requires permission from the provincial government before the toll zone could be implemented. If that permission was granted, the toll zone would require public consultation, new City staff for ongoing operations, infrastructure development, bylaw revisions, collaboration between multiple City departments, and more. Consequently, this option scores low on administrative complexity.

Chapter 9. Recommendations

With each passing day, the urgency to act on climate change becomes greater, and action must be taken to reduce emissions from vehicles as soon as possible. However, the actions outlined in this report should be integrated into a comprehensive ZEV strategy which escalates strategically over time. Given the current state of the ZEV market in Vancouver and the remaining challenges to adoption (charging infrastructure, limited ZEV models and availability, etc.), it is recommended that the City begin with education and incentive-based policies. These will be key to building public support and buy-in for ZEVs, and will lay the groundwork for regulations-based policies which will ultimately be needed to reach the City's 100% renewable energy target. It is also important that actions are prioritized so that measures that need continuous work and/or are expected to take a long time to implement are begun at a sufficiently early date.

First, an education and outreach campaign is recommended for immediate implementation. This program is important given how little knowledge consumers have about the technology and its costs, as well as the available incentives. Education also acts as a primer for other ZEV policies by helping consumers to understand the concept of total cost of ownership. This will allow them to incorporate the impact of other policies into their decision-making more easily. The website component of the policy does not have a recommended endpoint, as it can provide valuable information to consumers at all levels of knowledge and throughout the diffusion period. The outreach component of the campaign should be reviewed at the end of the initial five-year period to determine if it is still required.

Secondly, it is recommended that the City begin implementing a discounted parking policy. The first step is to conduct modeling to determine the specific discount rates that ZEVs should receive. The policy could be applied to permit parking first as this requires the fewest changes, while staff develop a plan to integrate the differentiated charges into infrastructure upgrades and operations for metered parking and parking lots. As previously mentioned, the discount rate should be reviewed and adjusted as necessary.

Finally, this report recommends that the City move forward with modeling and a cost-benefit analysis of developing a toll zone. Such an analysis was beyond the scope of this study and requires access to information such as the numbers of vehicles driving into downtown, street engineering costs, etc. While a final decision on whether to move forward with this option is contingent on additional research, this option is projected to have a significant impact on ZEV adoption rates, and is therefore worthy of further examination. As this option requires permission from the provincial government, the modeling and cost-benefit analyses are the first step in making the case for this policy. I also recommend this work incorporate an assessment of the impacts on air quality, and be integrated with the City's other work to reduce congestion.

Option 3, bus lane access, is not recommended at this time. While the policy scores well on public acceptability, cost, and administrative ease, the low effectiveness of the policy means it is not the best use of staff time and City resources.

The policies presented in this report are intended to be a starting point, and in their current form will likely have a limited impact on transitioning Vancouver's vehicle base to 100% renewably energy. Consequently, as ZEVs become more widely available and begin to constitute a greater proportion of the vehicle base, stronger approaches should be explored. Options include increasing the cost of parking for ICEVs, and raising the rate to enter the toll zone (if this option is adopted). Regulatory approaches should also be considered as 2050 nears, such as banning high emission vehicles from the toll zone area, and reducing/eliminating parking spots available to ICEVs. Further research and analysis should be conducted on these policies and a timeline for implementation developed.

9.1. Considerations

There are a number of additional considerations that are connected to the recommendations in this study, outlined in the following sections.

9.1.1. Equity

This research focuses on individual vehicle ownership. While a second-hand ICEV may be a feasible transportation option for lower income residents, ZEVs generally require a moderate to higher income given their upfront investment costs. As a result, options 1, 2, and 3 would be unlikely to have an impact on lower income residents who cannot afford to purchase a ZEV in the first place; however, these policies, as presented in this report, would not negatively alter the current costs of vehicle ownership for lower income households. On the other hand, the issue of equity underscores why it is important that the City not implement regulations which penalize ICEV drivers at this time. Given lower income households will face the most significant challenges in the transition to ZEVs, they would be most impacted by policies which place additional charges on or otherwise disadvantage ICEVs.

It is anticipated that this issue will decline over time as more secondhand vehicles come onto the market at a lower price point. Nonetheless, the issue of equity in ZEV access and use should be more fully addressed in subsequent City policies. For example, work could be done to make car-sharing fleets more affordable, and reliable, frequent, and affordable rapid public transit should be prioritized to ensure viable options to personal vehicles are available.

9.1.2. Risks

Batteries for ZEVs are expected to continue to drop in price and increase in capacity over the next decade. However, as with any new technology there is a great deal of uncertainty, and prices may fall or battery capacity increase at a slower pace than is anticipated, prolonging the diffusion of these vehicles.

9.1.3. Communications

Communication is key to ensuring public acceptance of the policies recommended in this report. In particular, the City should focus on communicating the immediate impacts of these policies on the average resident, with a particular emphasis on costs, affordability, and how the policies will impact consumer choices. The timeline for each policy and the

overall strategy should also be easily available on the City's website so consumers understand how they will be impacted over time and are not surprised by changes.

9.1.4. Related policies

Business fleets such as taxis and car-sharing companies represent an opportunity to transition thousands of vehicles to ZEVs, and effort should be directed to this work in the near term.

9.1.5. Limitations

This research encountered limitations that prevented me from gathering all the information I had hoped to. Full information on the policies in place in other jurisdictions was not always available, or was not available in English, and cities often do not report on the outcomes of their policies. Attempts to speak with staff in Oslo and Amsterdam (an additional city considered for the scan) went unanswered, and the other interviews did not provide all the information I hoped. This was due in part to the interviews with other cities being conducted before I had refined the scope of the problem. While these interviews provided an understanding of the context and approaches taken by these cities, it would have been valuable to conduct a second follow-up interview on specific details about their cost-related policies.

Had time permitted, it would also have been useful to conduct a survey of residents. Topics of interest would be consumer's knowledge of existing policies at the provincial level (the variety of purchase rebates) and feedback on the policy options outlined in this report.

9.2. Conclusion

Light duty transportation represents a significant opportunity for the City of Vancouver to reduce its GHG emissions and fight climate change. Reducing the cost difference between ICEVs and ZEVs would remove or minimize a significant barrier for many consumers, with research and real-world experience indicating these policies can

have a significant impact on ZEV adoption rates. At the same time, it is important to remember that consumers do not base their purchasing decisions solely on costs; for most people, a vehicle is a reflection of their values, socio-economic status, and much more. This transition will also require overcoming a century's worth of experience and associations with ICEVs, while convincing consumers to adopt new ways and patterns of fueling, maintaining, and driving their vehicles. Cost related policies therefore need to be situated within and integrated into a broader ZEV strategy to ensure these different issues are addressed in a coordinated manner.

Research from around the world also shows that ZEV adoption is most successful in jurisdictions which have ZEV policies in place at all levels of government. Though the BC government has continued to extend their rebate program, this policy is inconsistent and could be removed at any point, which would drastically slow ZEV adoption (as long as vehicle purchase prices remain high). More consistent policies send a stronger message to both consumers and vehicle providers that the government is serious about increasing ZEV adoption; as such, municipal governments, along with civil society and academic institutions, need to continue to push for greater support for ZEVs from higher levels of government.

Finally, it must be emphasized once again that the City's efforts and resources should continue to be directed first and foremost to shifting travel away from private vehicles towards public transit and active transportation, and policies to promote clean vehicles must complement, not impede, this work.

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