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Cost Benefit Analysis of Vehicle Emissions Reduction Policies in Canada: A Case Study of Zero-Emission Vehicles

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Abstract: Canada has been at the forefront of mitigating climate change by adopting strategies that align with the international objective of limiting global warming. For instance, the Canadian government has intervened in the transport sector by enacting vehicle emission reduction policies such as the ZEVs policy that encourages the adoption of EVs, FCVs, and PHEVs. The policy aligns with the Canadian government's ambitious target of getting more ZEVs on Canadian roads as a strategy to achieve "100 percent zero-emission vehicles by 2040, with interim goals of 10 percent by 2025 and 30 percent by 2030". However, although ZEVs offer Canada an opportunity to reduce its GHG emissions in the transport sector, there has been concern about the upfront costs associated with adopting ZEVs, which continue to be a major deterrent despite their operation and maintenance costs being low. The following research paper conducts a CBA on ZEVs compared to CVs in Canada in terms of ownership costs and environmental impact.

Keywords: Zero-Emission Vehicles, Greenhouse Gas Emissions, Cost-Benefit Analysis, Canada

1. Introduction

As a major global player, Canada has been at the forefront of mitigating climate change by adopting strategies that align with the international objective of limiting global warming to "1.5°C above pre-industrial levels" by curbing activities in their economy that contribute to GHGs [1]. Worldwide, one such sector in the global economy is the transportation sector. In Canada, transportation "accounts for more than 20%" of the total GHG emissions [2]. GHG emissions have caused a market failure because they have many negative externalities associated with the costs and impact, they have on the wider society that warrant government intervention. GHG emissions affect local air quality and contribute to global warming, negatively affecting Canadian health. Transport sector GHG emissions between 1990 and 2021 grew by 27% [3]. Hence, in recent years, the Canadian government has intervened in the transport sector by enacting vehicle emission reduction policies such as ZEVs policy that encourages the adoption of EVs, FCVs, and PHEVs. The policy aligns with the Canadian government's ambitious target of getting more ZEVs on Canadian roads as a strategy to achieve "100 percent zero-emission vehicles by 2040, with interim goals of 10 percent by 2025 and 30 percent by 2030" [4]. However, although ZEVs offer Canada an opportunity to reduce its GHG emissions in the transport sector, the upfront costs associated with adopting ZEVs, such as electric platforms, continue to be a major deterrent despite low operation and maintenance costs. Therefore, through a CBA, the paper compares the costs and benefits of ZEVs and CVs to examine their production, purchase, operation, utilization costs, and environmental costs as a strategy to outline and offer recommendations on whether zero-emission vehicles are an optimal vehicle emissions reduction policy for the environment and if it can help Canada achieve its GHG emission reduction plan and achieve net-zero emissions.

1.1. Problem Statement

This study uses the cost-benefit analysis approach to examine whether the promotion of zero-emission vehicles is an optimal vehicle emissions reduction policy and whether it can help curb GHG emissions in the transport sector, which in 2018 accounted for 23%of GHG emissions in Canada, as shown in Figure 1.

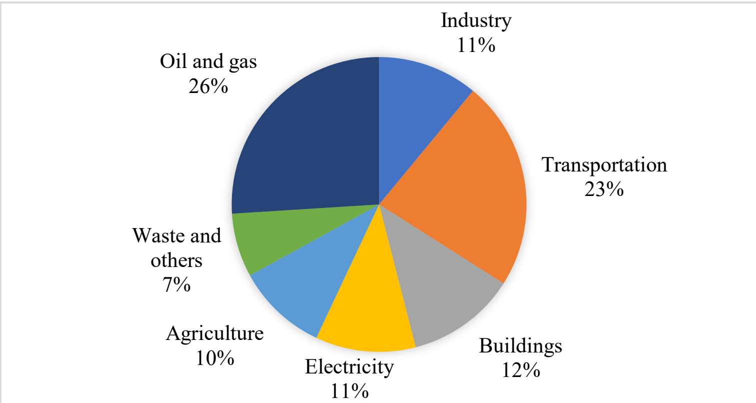

Figure 1: Greenhouse gas emission by economic sector in Canada
(Source From: Maroufinashat &Fowler, 2018, p.2 https://doi.org/10.3390/wevj9030038)

For a country that wants to become “net-zero emissions by 2050”, this is a serious problem. Overall, Canada needs to rethink its transportation system, fuel source, and infrastructure to meet its sustainable development goals and transition to a transport system with net-zero emissions [4]. This explains why the Canadian government has taken radical initiatives and adopted policies to curb RPP use in the transport sector. One strategy they have adopted under the vehicle emissions reduction policy is promoting a zero-emission vehicles policy. Adopting ZEVs can reduce vehicle emissions because, unlike CVs, they function without emitting GHGs [4].

However, understanding whether the use of ZEVs is an optimal policy in reducing vehicle emissions is necessary because the issues of GHG emissions and sustainable development are one of Canada’s pledges as it strives to lower its GHG emissions by “at least 30 below 2005 levels by 2030” [4]. Overall, as a country that seeks to shift from the use of CVs to ZEVs as a strategy to reduce vehicle emissions, Canada has the responsibility and motive to weigh the performance of ZEVs in terms of their coal costs and benefits in comparison to CVs to ensure they align with the goal of their vehicle emissions reductions policies.

1.2. Objectives and Expected Outcomes

The primary objective of supporting and promoting the Zero-Emission vehicles policy in Canada is to reduce GHG emissions in the transport sector by encouraging the adoption of EVs, FCVs, and PHEVs. The study achieves this by conducting a CBA that compares the social costs and benefits of ZEVs with CVs in terms of ownership cost and environmental cost as a strategy to show that ZEV promotion is an optimal vehicle emissions reduction policy, and that the government should do more to promote ZEVs. The study involves two scenarios, and the first involves the ownership and

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environmental cost of having CVs in the transport sector. The second involves the ownership and environmental cost of having ZEVs on the road as an alternative to CVS—the government's overall opinion. Hence, the CBA compares the two scenarios by looking at the ownership and environmental costs of two cars in the same category: an EV, the car that falls under the ZEVs category, and a conventional car with a combustion engine. This involves looking at their production and sales data, aggregated environmental costs linked to their lifetime emissions data, fuel costs, maintenance costs, servicing costs, mileage costs, and overall performance data to compare their financial and environmental benefits. With all these factors considered, the study outlines the net benefits of promoting ZEVs by outlining their long-term viability in terms of ownership cost and overall environmental social benefit.

2. Case Background

2.1. Country Context

Figure 1 shows the transport sector in Canada is one of the highest sources of GHG emissions after oil and gas. This is because the transport sector is energy-intensive; for instance, in 2019, the transport sector consumed 23% of the 12,305 petajoules (PJ) total energy consumption behind the industry sector, which accounted for 52%of energy demand. High energy demand resulted in RPPs being the main energy source. In 2019, RPP demand stood at 4953 PJ, with a large percentage allocated to the transport sector. As a high consumer of oil and refined products globally, the Canadian transport sector in 2019 consumed 1,268 liters of gasoline and 855 liters of diesel per capita. Overall, RPP emits a large percentage of GHGs. For example, according to a 2018 report, the transport sector in Canada emitted 185.9 Megatonnes of Carbon dioxide, with 82.8% of this emission coming from heavy-duty trucks, light trucks, and cars [4]. This reality has resulted in EVs emerging as a promising solution in the transport sector as they can help reduce the reliance on RPPs. Canada was among the 13 countries that "signed the Electric Vehicles Initiative (EVI) under the Clean Energy Ministerial intending to accelerate the global deployment of EVs and to serve as a platform for knowledge-sharing on policies and programs that support EV deployment" [1]. Hence, the Canadian government has been at the forefront of promoting and supporting ZEV adoption in the transport sector. This is a strategy to reduce GHG emissions. The government has achieved this by enacting a zero-emission vehicles policy that introduces "a new federal purchase incentive of up to $5,000 for electric battery or hydrogen fuel cell vehicles with a manufacturer's suggested retail price of less than $45,000" [1].

2.2. Transport Sector GHG Emission Issues

Like other countries in the world, Canada is concerned about GHG emissions from the transport sector due to the negative impacts associated with them. For instance, global warming and climate change are by-products of GHGs. GHGs trap heat in the atmosphere and create a"greenhouse effect"[5]. This is a serious problem today as climate change and global warming are associated with various negative environmental issues. For instance, they cause "increases in temperature, rising sea levels, changes in precipitation patterns, droughts, floods, heat waves, and hurricanes" [5]. Additionally, GHGs are also linked to health-related problems. For example, each year in Canada, about 21,000 premature deaths are attributed to air pollution caused by GHGs [6]. Hence, since about 10 million people, which represents approximately 32%of the Canadian population, live in traffic-related exposure zones, GHG emissions are a serious issue that the Canadian government is trying to mitigate by promoting a shift from CVs to ZEVs through the zero-emission vehicle policy [6,7].

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3. Methodology

The paper employs relevant scholarly sources and government reports that perform a cost-benefit analysis of zero-emission vehicles. The paper also summarizes evidence from different sources on the methods and conclusions of cost-benefit analysis and cost-effectiveness of ZEVs and CVs. Finally, the paper employs comparative analysis to outline the environmental viability of zero-emission vehicle policy. A specific model of each type of vehicle was chosen to facilitate a direct comparison between the cost of ownership and emissions of ZEVs and CVs. The ZEV model was the electric 2022 Chevrolet Bolt, while the CV model was the gas 2022 Toyota Corolla Hatchback, as shown in Figure 2.

Electric 2022 Chevrolet Bolt   Gas 2022 Toyota Corolla Hatchback

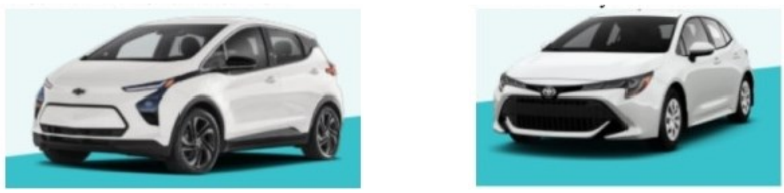

Figure 2: The ZEV and CV model chosen for analysis
(Source From: https://www.chevroletoffers.ca and www.toyota.ca)

The two cars fall in the same light category and were selected for their popularity in the Canadian market. The cars are mid-size with a 5-passenger capacity. Hence, this helped ensure the cars were in the same category and were typically used in the same manner while also simplifying the analysis and readability of graphs. According to Wosk, the 2022 Chevrolet Bolt retails at $38,198, while the 2022 Toyota Corolla Hatchback retails at $21,450 in British Colombia. The price includes the rebates given by the provincial and federal governments. For instance, the retail price of the 2022 Chevrolet Bolt base modes includes the $5,000 federal government rebate and $3,000 provincial rebate in British Colombia [8].

3.1. Cost Benefit Analysis

For the paper to determine the viability of the zero-emission vehicles policy as a GHG emission reduction policy, it employs the use of CBA that compares the social costs and social benefits of ZEVs and CVs as a strategy to outline the net benefit of ZEVs in terms of ownership cost and environmental impact. The CBA was the best methodology for the study because it helped calculate the NSB of each type of vehicle by deducting their social costs (C)from their social benefits (B). This helps us to examine whether ZEVs are optimal for reducing vehicle emissions. The evaluation also made it possible to include assumptions of fuel and car costs because of their volatility. It also embodies two main scenarios. Scenario 1: 2022 Toyota Corolla Hatchback Cost and Environmental Impact Evaluation (Without Project Scenario); Scenario 2: 2022 Chevrolet Bolt Cost and Environmental Impact Evaluation (With Project Scenario). The two scenarios create a framework that helps us quantify, compare, and identify ZEVs' costs and benefits in relation to CVs. This helps determine the promotion of ZEVs as an optimal vehicle emission reduction policy in Canada. The paper uses CBA because it encompasses quantitative and qualitative features. For instance, it used the Fleet Procurement Analysis Tool by Atlas Public Policy, as employed by Wosk, to obtain data needed to establish the quantitative factors associated with the total costs of ownership of the vehicles. The CBA also uses qualitative factors to rate ZEVs by comparing them to CVs. In the computation of car ownership of the 2022 Toyota Corolla Hatchback and 2022 Chevrolet Bolt, the CBA examines various factors such as the cost of the car (depreciation)(CC), Car operation cost (COC), Car utilization cost (CUC), and Car Fuel cost (CFC). As outlined in the Fleet Procurement Analysis Tool, the COC includes insurance, taxes, and other costs include to make the vehicle roadworthy per Canadian law. Likewise, the CUC includes costs like maintenance costs and repair costs. On the other hand, the computation of environmental costs of the 2022 Toyota Corolla Hatchback and 2022 Chevrolet Bolt involves outlining their greenhouse gas emission cost (GHGEC), the vehicle overall performance cost (VOPC), and the climate change cost (CCC)of each vehicle per ton of COz equivalent. According to Stickler (2021), GHGEC includes the COz emissions associated with the manufacturing stage of the vehicles.

The total ownership cost and the total environmental cost of each vehicle help outline the NSB of owning ZEVs in relation to CVs in terms of their cost and GHGs, respectively.

3.2. Without Project Scenario

The section evaluates the ownership costs and environmental impact of CVs. The CV car, The 2022 Toyota Corolla Hatchback gas variant, is under consideration, as shown in Figure 2.

3.2.1. 2022 Toyota Corolla Hatchback Ownership Cost

The process involves capturing the vehicle's CC, COC, CUC, and CFC. The computation follows the formula: Cost of 2022 Toyota Corolla Hatchback(Ccv)=CC+COC+CUC+CFC.

3.2.2. 2022 Toyota Corolla Hatchback Environmental Cost

The process captures the vehicle's GHGEC, VOPC, and CCC. The computation follows the formula: The environmental cost of the 2022 Toyota Corolla Hatchback (Ecv) =GHGEC +VOPC +CCC.

The GHGEC includes the COz emissions of manufacturing and assembling the body-interior and gasoline engine transmission. Overall, this scenario will help quantify CVs' ownership costs and environmental impact.

3.3. With Project Scenario

The section calculates ZEVs' ownership costs and environmental impact, focusing on EVs. The car under consideration is the 2022 Chevrolet Bolt, an electric variant shown in Figure 2.

3.3.1. The 2022 Chevrolet Bolt's Ownership Cost

The process captures the vehicle's CC, COC, CUC, and CFC. The computation follows the formula: Cost of 2022 Chevrolet Bolt (CzEv)=CC+COC+CUC+CFC.

However, the ownership cost of ZEVs factors in the federal and provincial government incentives or rebates as benefits that are redacted from the cost, which in a province like British Colombia are $5,000 and $3,000 for the federal and provincial governments, respectively [8].

3.3.2. The 2022 Chevrolet Bolt's Environmental Cost

The process captures the vehicle's GHGEC, VOPC, and CCC. The computation follows the formula: The environmental cost of the 2022 Chevrolet Bolt (EzEv)=GHGEC+VOPC+CCC.

The GHGEC includes the CO_2 emissions associated with manufacturing and assembling the body-interior, the inverter, the motor, and lithium-ion batteries, estimated to emit 177kg of CO_2 per kWh of capacity [6].

Overall, this scenario will help to quantify the ownership costs and the environmental impact associated with ZEVs.

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3.4. Valuing Benefits and Costs

The process involves valuing the NSB of ZEVs compared to CVs regarding ownership cost and environmental impact.

3.4.1. Valuing ownership Costs

In the case of the 2022 Toyota Corolla Hatchback and the 2022 Chevrolet Bolt, this includes deducting the Hatchback's ownership cost from Bolt's ownership cost. The computation follows the formula: Ownership NSBzEv=CzEV-Ccv.

3.4.2. Valuing environmental Costs

The process involves deducting the Hatchback's environmental cost from Bolt's environmental cost. The computation follows the formula: Environmental NSBzEV =EzEV-Ecv.

The two formulas help calculate the net present benefit of ZEVs compared to CVs as a strategy to outline the viability of zero-emissions vehicle policy in Canada.

3.5. General Assumptions

The study encompasses several assumptions captured in the True Cost report by Wosk (2022), as shown in Table 1.

Table 1: Summary of Key Assumptions

Average retail prices for regular gasoline from April 2021 to March 2022	\$1.45/1
Average prices for residential electricity in 2021	13.9c/kWh
Annual vehicle mileage (Ownership cost)	20,000 kilometres (Annual vehicle mileage)
Expected vehicle ownership in years	8 [As used by Wosk (2022)]
Annual vehicle mileage (Ownership cost)	15,000 kilometres (Annual vehicle mileage)
Expected vehicle ownership in years	13 [As used by Stickler (2021)]
Canadian average EV purchase incentives based on provincial rebates plus federal incentives as of March 21, 2022.	British Colombia (\$5,000+\$3,000 = \$8,000)
Carbon price per tonne in 2022	\$50
Climate change emission estimate	120 g CO2/km
The 2018 FE of gasoline	2.157 kg CO2/1
Gasoline Consumption	5.9 liters per 100 km

4. Economic Payoff

Using the equations and the assumptions outlined in the Methodology sections, it is possible to calculate the economic payoff of adopting ZEVs in relation to CVs in terms of ownership and environmental costs. This involves identifying the overall net present value of promoting ZEVs.

4.1. Net Present Value

The Net Present Value of promoting ZEVs involves first calculating the ownership and environmental costs of the 2022 Toyota Corolla Hatchback as outlined in the Without project scenario in the methodology. Second, it involves calculating the ownership cost and environmental cost of the 2022

Chevrolet Bolt as outlined in the project scenario in the methodology. Finally, it involves finding the NSB of ZEVs in relation to CVs in terms of ownership cost and environmental impact.

From the True Cost report, a dataset can be created that reflects the ownership of the 2022 Toyota Corolla Hatchback and 2022 Chevrolet Bolt, as shown in Table 2.

Table 2: The data of ownership cost per kilometer ($/km)

Costs per kilometer	2022 Chevrolet Bolt	2022 Toyota Corolla Hatchback
Cost of the Car (CC)	0.14	0.11
Car operation cost (COC)	0.04	0.07
Car utilization cost (CUC)	0.08	0.07
Car fuel cost (CFC)	0.03	0.12

4.1.1. Without Project Scenario

a. The car ownership cost: From Table 2, the total ownership cost of a 2022 Toyota Corolla Hatchback per kilometer can be calculated. Ccv=cc+C0c+CUC+CFC and Ccv=0.11+0.07+0.07+0.12=0.37. Hence, the ownership cost of a 2022 Toyota Corolla Hatchback per kilometer is $0.37/km. Table 2 can also help outline the difference between the costs involved in the ownership of a 2022 Toyota Corolla Hatchback, as shown in Figure 3.

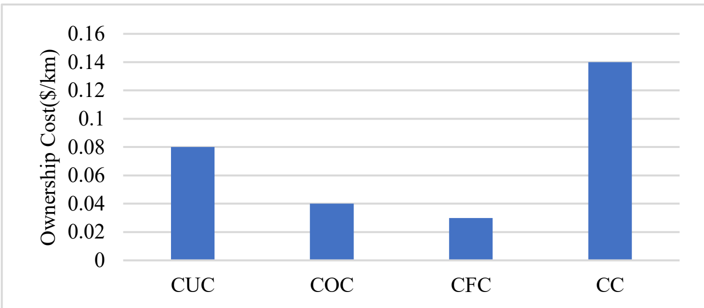

Figure 3: Ownership cost of 2022 Toyota Corolla Hatchback per Kilometer
(Source From: www.toyota.ca)

b. Environmental cost: The equation for calculating the environmental cost is as Ecv =GHGEC+VOPC+CCC. The GHGEC includes the cost involved in the manufacturing stage, which, according to Stickler (2021), includes 4,219 kg of COz in manufacturing and assembling the vehicle's body-interior and the cost of assembling the gasoline engine transmission, which stands at 1,274 kg of CO_2. Hence, GHGEC=4,219+1,274=5,493kg of CO_2

Stickler (2021) notes that the VOPC involves costs in operations like coolants, oil change, tire replacement, and 12 V battery, and it stands at 487 kg of COz, while the CCC for 195,0000 kilometers covered in 13 years stands at 48,216 kg of CO_2. Ecv=5,493+487+48,216=54,196. Hence, Ecv =54,196 kg of CO2 or 54.2 tonnes.

4.1.2. With Project Scenario

a. The car ownership cost: From Table 2, the total ownership cost of a 2022 Chevrolet Bolt per kilometer could be calculated as (CzEv)=CC+COC+CUC+CFC and (CzEv)=0.14+0.04+0.08+0.03=0.29. Hence, the ownership cost of a 2022 Chevrolet Bolt per kilometer is $0.29/km. Table 2 can also help outline the difference between the costs of owning a 2022 Chevrolet Bolt, as shown in Figure 4.

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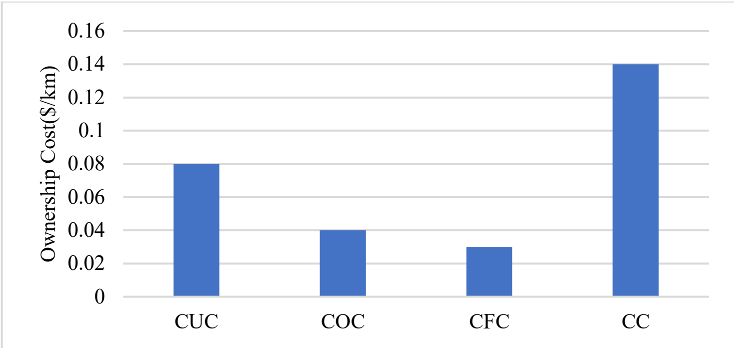

Figure 4: Ownership cost of 2022 Chevrolet Bolt per Kilometer
(Source From: https://media.chevrolet.com)

b. Environmental cost: For EVs, the GHGEC includes the cost involved in the manufacturing stage, which, according to Stickler, includes 4,219 kg of COzin manufacturing and assembling the vehicle's body-interior including parts like suspensions, brakes, exterior and interior panels, seats and dashboards. The manufacturing also includes the costs of emissions from the motor and inverter, which stand at 641 and 1,070 kg of COz, respectively [6]. The cost also captures the costs of emissions from lithium-ion batteries, which stand at 177kg per kWh of capacity. Hence, for a 2022 Chevrolet Bolt with 65 kWh energy capacity, the emission cost is 177×65=11,505kg of CO_2. Therefore, the total GHGEC is 4,219+641+1,070+11,505=17,435kg of CO_2 [9].

The VOPC of the 2022 Chevrolet Bolt includes the COz cost of operation, like tire replacement, and stands at approximately 458kg of COz for an electric car [10]. Strickler's article also outlines that the CCC of an EV for 13 years covering 195,000 kilometers is approximately 8,785 kg of COz.Therefore, EzEv=17,435+458 +8,785=26,678. Hence, EzEv=26,678 kg of COz or 26.7 tonnes kg of COz.

4.1.3. Valuation

From the without project and with project calculation of the 2022 Toyota Corolla Hatchback and 2022 Chevrolet Bolt ownership cost and environmental impact, it is possible to calculate the NPV of promoting zero-emissions vehicles as a GHG reduction policy. An analysis can be conducted to outline the nuances of the 2022 Chevrolet Bolt's Net Social Benefit (NSB) in comparison to the 2022 Toyota Corolla Hatchback, focusing on aspects of ownership and environmental impact.

a. The NSB of owning a 2022 Chevrolet Bolt: NSBzEv=CzEv-Ccv and NSBzEv=0.29-0.37=-0.08 S/km. This result means that the NSB of the 2022 Chevrolet Bolt, compared to the 2022 Toyota Corolla Hatchback, is $0.08 per kilometer. It reduces the ownership costs by $0.08 per kilometer.

b. The environmental NSB of a 2022 Chevrolet Bolt: NSBzEy=EzEv-Ecv. To calculate this, this study can start by creating a table that compares the environmental costs of the 2022 Chevrolet Bolt to the 2022 Toyota Corolla Hatchback, as shown in Table 3.

Table 3: Environmental costs of an electric and gas Hyundai Kona

Costs / Types of cars	GHGEC	VOPC	CCC	Total Cost
ZEV(Bolt)	17.435 kg	458 kg	8.785 kg	26,678 kg of CO_2
CV(Corolla)	5,493 kg	487 kg	48.216 kg	54,196 kg of CO_2

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Therefore, from the table, the NSB could be calculated as follows: NSBzEv=26,678-54,196=-27,518 kg of CO_2or-27.5 tonnes of CO_2.

Overall, this conclusion shows that ZEVs reduce the environmental cost caused by CVs by 27.5 tonnes of CO_2, this conclusion is also supported by fleet procurement analysis.

The 2021 Chevrolet Bolt EV emitted 0.005 kg of COz per kilometer, while the 2021 Toyota Corolla emitted 0.219 kg per kilometer. Overall, the comparison of the 2022 Chevrolet Bolt EV and the 2022 Toyota Corolla shows an NPV of promoting ZEVs in Canada as their promotion helps reduce the environmental cost associated with CVs by 27.5 tonnes of COz. Additionally, the study shows an NPV of owning a ZEV as it reduces the ownership cost by $0.08 per kilometer.

4.2. Sensitivity Analysis

The independent variables that represent uncertainty when calculating the NSB of ZEVs are the rebates offered by the provincial and federal governments. The provincial and federal governments provide incentives to people who buy ZEVs, as outlined by Wosk; it is easy to obtain the impact of different incentives in different provinces, as shown in Table 4.

Table 4: Ownership Cost NSB of ZEV per Province

Provinces	Federal Incentives	Provincial Incentives	Total Incentives	Bolt retail cost
New Brunswick	$5,000	$5,000	$10,000	$36,198
Nova Scotia	$5,000	$3.000	$8,000	$38.198
Prince Edward Island	$5,000	$5,000	$10,000	$36,198
Newfoundland and Labrador	$5,000	$2,500	$7,500	$38,698
Quebec	$5,000	$8,000	$13,000	$33,198
Ontario	$5,000		$5,000	$41,198
Manitoba	$5,000		$5,000	$41,198
Nunavut	$5,000		$5,000	$41,198
Saskatchewan	$5,000		$5,000	$41,198
Alberta	$5,000		$5,000	$41,198
Northwest Territories	$5,000		$5,000	$41,198
Yukon	$5,000	$5,000	$10,000	$36.198
British Columbia	$5,000	$3,000	$8,000	$38,198

Different retail prices in various provinces influence NSB. For example, Quebec has the highest ownership cost NSB because of its $13,000 rebates. However, there is a challenge in provinces that fail to offer rebates. This might affect the province's influence on motivating people to shift to ZEVs. For instance, this might result in ZEVs having different ownership costs NSB, as shown in Table 5.

Table 5: The Difference in Ownership Cost NSB of ZEVs

Provinces	Retail Price of Bolt	Ownership cost of ZEVs	Cost NSB of ZEVs
New Brunswick	36,198	0.274816	0.09518
Nova Scotia	38,198	0.29	-0.08
Prince Edward Island	36,198	0.274816	-0.09518
Newfoundland and Labrador	38,698	0.293796	-0.0762

Table 5: (continued).

Quebec	33.198	0.25204	-0.11796
Ontario	41,198	0.312776	0.05722
Manitoba	41,198	0312776	0.05722
Nunavut	41,198	0.312776	0.05722
Saskatchewan	41,198	0.312776	-0.05722
Alberta	41.198	0.312776	0.05722
Northwest Territories	41,198	0.312776	0.05722
Yukon	36,198	0.274816	0.09518
British Columbia	38,198	0.29	-0.08

From Table 5, provinces that offer higher rebates, such as Quebec, have the highest ownership cost NSB. The 2022 Chevrolet Bolt reduces ownership costs by $0.11796 per kilometer compared to the 2022 Toyota Corolla Hatchback. Although all the incentives provide rebates offered to provide a viable ownership NSB of buying the 2022 Chevrolet Bolt, Quebec's rebates show that more rebates particularly provincial rebates, are needed to make ZEVs cheaper both from the perspective of the retail price and overall ownership cost in 8 years.

5. Conclusion and Policy Implications

5.1. General Findings

The study's primary objective was to determine whether promoting a zero-emission vehicle policy in Canada is an optimal strategy to reduce GHG emissions in the transport sector. The study examined this by conducting a CBA that compares the social costs and benefits of ZEVs with CVs in terms of ownership and environmental costs. The valuations of the NPV of owning a ZEV focusing on the 2022 Chevrolet Bolt show an NSB of owning a 2022 Chevrolet Bolt compared to CVs represented by the 2022 Toyota Corolla Hatchback. This is because when ownership costs of the two vehicles are considered factors in the cost of the car(depreciation)(CC), Car operation cost (COC), Car utilization cost (CUC), and Car Fuel cost (CFC), owning a 2022 Chevrolet Bolt reduces the cost per kilometer by $0.08.Additionally, when the environmental cost NPV is measured considering their greenhouse gas emission cost (GHGEC), the vehicle overall performance cost (VOPC), and the climate change cost (CCC), the 2022 Chevrolet Bolt reduces the environmental impact by 27.5 tonnes of COz.Hence, the CBA shows that ZEV promotion is an optimal GHG reduction policy because it decreases the overall environmental impact of CVs in the transport sector. Through the ownership NSB, the CBA also shows that ZEVs have ownership cost benefits. When various factors associated with owning, maintaining, and using a vehicle are considered, ZEVs outperform CVs.Hence, the government can continue pushing the policy and addressing the cost barrier associated with adopting ZEVs in the Canadian public by demonstrating that owning ZEVs is a significant investment as they perform the same purpose as CVs but are significantly cheaper.

However, the CBA findings show that although ZEVs have less environmental impact when compared to CVs, they still emit some GHGs, particularly during their manufacturing process. As shown in Table 5, the GHGEC of Bolt is 17,435 kgs, more than that of the Corolla, which stands at 5,493 kgs. Bolt's environmental impact computations show that most GHGEC comes from emissions associated with lithium-ion batteries used in ZEVs, which are 177kg per kWh of capacity. Therefore, although ZEVs promise to reduce the environmental impact associated with CVs in the transport sector, the study shows that the government needs to adopt funding for innovative battery technology that lowers GHGEC as part of its ZEVs promotion campaign. The move can help them move closer to their vision of net-zero emissions by 2050. Additionally, as shown in the sensitivity analysis, the study states that the incentives offered by the federal and provincial governments play a crucial role in the promotion of ZEV adoption in Canada as they help bring down the retail price and the overall ownership cost. Hence, the government should continue offering rebates as they contribute to making ZEVs attractive as an investment for most Canadians who buy cars primarily based on their performance and cost. The incentives help offer low-cost solutions to owning a ZEV, making it a viable alternative for consumers and the transportation sector.

5.2. Constraints

Some constraints to the study stemmed from the assumptions adopted to simplify the analysis and development of data needed to understand the viability of promoting zero-emission vehicles as a GHG reduction policy in the transport sector. One of these constraints is that because of the difference in electricity costs, ZEV incentives, and fuel costs in different provinces in Canada, the study had to focus on British Colombia as a strategy to offer a more detailed understanding of ZEVs in terms of ownership cost and environmental impact when compared to CVs. Second, fuel and residential electricity prices in Canada and British Colombia were also a constraint. Hence, the study has found an average retail price for regular gasoline from April 2021 to March 2022 of approximately $1.45/1. In addition, in the transport sector, the study shows positive analysis in the adoption of ZEVs and suggests that the government, both federal and provincial, should move forward with promoting ZEVs.

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