Comparative Economic Analysis of Conventional and Plug-in Battery Electric Vehicles in Canada

by

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A project paper submitted to the
School of Graduate and Postdoctoral Studies in partial
fulfillment of the requirements for the degree of

Master of Engineering in Electrical and Computer Engineering

Department of Electrical, Computer, and Software Engineering
University of Ontario Institute of Technology (Ontario Tech University)
Oshawa, Ontario, Canada
December 2022

PROJECT REPORT REVIEW INFORMATION

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Master of Engineering in Electrical and Computer Engineering

Project Report title: Comparative Economic Analysis of Conventional and Plug-in Battery Electric Vehicles in Canada

The project paper was approved on December 10, 2022, by the following review committee:

Review Committee:

Research Supervisor	Dr. Walid Morsi Ibrahim
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The above review committee determined that the project paper is acceptable in form and content and that a satisfactory knowledge of the field was covered by the work submitted. A copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

Conventional vehicles typically use gasoline for their internal combustion engines (ICEs). On the other hand, plug-in battery electric vehicles (PBEVs) use electricity to charge their batteries, so they do not need gasoline. With the soaring gasoline prices in Canada and around the world, the interest in electric vehicles from the public and the government has increased. However, given the wide range in prices of PBEVs, the high maintenance cost of conventional vehicles and the volatility in gasoline prices, there is a need for a comparative economic analysis to address the following two main questions: (1) What should be the minimum ownership period of a PBEV to be economical than a conventional vehicle? (2) At what gasoline prices do the PBEVs become more economical than conventional vehicles? The work in this project addresses these questions to assist customers in making the correct decision when they intend to purchase a new vehicle. The results have shown that the longer the ownership period is, the PBEVs become more economical compared to conventional vehicles. The work in this report has shown that the total ownership cost savings may reach $88,482 over 15 years.

Key Terms— Economics, electric vehicles, Internal Combustion Engine vehicles.

AUTHOR’S DECLARATION

I hereby declare that this project paper consists of my original work. This is a true copy of the work, including any required final revisions, as accepted by my committee.

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ACKNOWLEDGEMENTS

This work would not have the spirit or been completed without the invaluable academic and educational support and belief in me as a writer and researcher by Dr. Walid Morsi Ibrahim. Dr. Walid was crucial in leading the team before, during, and after the project. The author is grateful to Canada's Natural Sciences and Engineering Research Council for financially supporting this work.

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LIST OF ABBREVIATIONS AND SYMBOLS

ICEVs	Internal Combustion engine vehicles
PBEVs	Plug-in Battery Electric vehicles
BEVs	Battery Electric vehicles
EVs	Electric Vehicles
HEVs	Hybrid Electric vehicles
PHEVs	plug-in hybrid electric vehicles
TOC	Total Ownership Cost
TCO	Total Cost of Ownership
NRCan	Natural Resource Canada
kWh	Kilowatt hour (Energy Unit)
GDP	Gross Domestic Product
MPC	Passenger mobility per capita
Km	Kilometer
$	Dollar
TOU	Time of use
GHG	Greenhouse gas
AWD	All wheel drive
FWD	Front wheel drive

Chapter 1 INTRODUCTION

1.1 Background

Conventional vehicles typically rely on gasoline as the fuel source for their internal combustion engines (ICE). However, such gasoline is derived from fossil fuels, which contributes significantly to greenhouse gas (GHG) emissions [1]. In several Canadian jurisdictions, the governments have launched several incentive programs to increase the adoption of plug-in battery electric vehicles (PBEVs) to reduce GHG emissions [2]. For example, in Canada, the Go Electric program in British Columbia offers up to $4,000 CAD when purchasing a PBEV, while in Quebec, the rebate is up to $7,000 CAD [2]. Furthermore, the soaring gasoline prices have motivated the public to consider PBEVs as an alternative to conventional ICE vehicles. However, many factors must be considered before deciding to switch from a traditional vehicle to a PBEV; hence, a comparative economic analysis is needed to help the public make such a decision.

1.2 Problem Statement

Unlike other Canadian provinces, in Ontario, Canada, there is currently no provincial rebate program. Hence, there is a need for a comparative economic analysis to help the public make the right decision when they want to switch from conventional to PBEV. The comparative economic analysis presented in this project report aims to address the following questions:

- What should be the minimum ownership period of a PBEV to be more economical than a conventional vehicle?
- What would be the total ownership cost savings?
- At what gasoline prices do the PBEVs become more economical than conventional

vehicles?

1.3 Contribution

The analysis has been performed over the different ownership structures (numerous ownership durations) and various gasoline prices to answer the above-stated questions using fleet procurement analysis tool [3]. This analysis considered different vehicle models and manufacturers for comparison. Cash flow analysis has also been presented to show how much an EV and an ICE would have value at the end of ownership duration.

The following paper has been accepted for publication:

Muhammad M. Rehman and Walid G. Morsi, “Comparative Economic Analysis of Conventional and Plug-in Battery Electric Vehicles in Canada,” Accepted for publications in the *IEEE Electrical Power and Energy Conference (EPEC)*, 2022.

1.4 Report Organization

The material presented in this report is organized as follows: chapter 2 presents the work related to this topic, followed by the Methodology in Chapter 3. In chapter 4, the results are described. Chapter 5 states the conclusion of the report. In the end, relevant references are stated.

Chapter 2 RELATED WORK

In the literature, few studies have tried to study the economics of electric vehicles. Costa et al. in [1] presented an economic payback comparison between ICE vehicles and EVs for European countries. The main objective of this study was to present a detailed analysis of the economic consequences of adopting EVs. The study considered Gross Domestic Product (GDP) and passenger mobility per capita (MPC), electricity and fuel costs, and prices of vehicles for each European country to examine the economic viability of using BEVs. This study did not consider some factors such as driving style, climate conditions, and state incentives and assumed that maintenance cost is the same for ICEVs and BEVs. The analysis in this study found BEVs to be more economical than ICEVs, even with the above assumption. The study concluded that PBEVs might be more economical in a timeframe of about ten years, and some countries started to give benefits at the acquisition time, e.g., Denmark and Spain European union must consider the incentives to make BEVs' acquisition cost affordable.

Graditi et al. in [4] proposed a model to calculate the unitary Cost of electric vehicles (EVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and ICE vehicles in Italy. The techno-economic model determines the Cost using MATLAB by considering battery data (quantity, type, structure), vehicle attributes (size of the gas tank; speed, temperature, autonomy at constant speed), and costs. The study concluded that the state incentive plays a significant role in the economics of electric vehicles by reducing the gap between the Cost of BEVs and ICEVs and concluded that EVs have low competitiveness on ICEVs. The research aimed to analyze the come with a new model that considers environmental effects too. The work in [5] was carried out to analyze the effect of user preference in the electric vehicle consumption market. The study introduced a game-theoretic model economic analysis to consider user preferences in terms of cost perimeters (time, money, battery health, and the users' sensitivities to each of them) in EVs' adoption. The main contribution to this research was to consider the utility function that includes both time and money instead of considering only money to provide market penetration analysis by providing two market competition scenarios, i.e., 1. Competition between gasoline and electric energy provider, and 2. Competition between two electric energy providers. The study concluded that user preferences significantly affect energy providers' prices and profits. Freire et al. in [6] presented an integrated energy, greenhouse gas and life cycle cost analysis for EVs in Portugal. They calculated the Cost per km for two types of EV technologies (BEVs and PHEVs) and two ICE technologies (gasoline and diesel) in two types of passenger cars (Compact and subcompact) using annual cost formula and two interest rates (5% and 10%) and two electricity prices. Also, 20,000 km annual mileage and ten years life cycle period has been considered in this analysis. The analysis showed that the BEV's uniform annual Cost is still more significant with higher rates (such as 10%). The disparity between acquisition and running costs is smaller for interest rates below 5%, but the overall Cost per mile for BEVs is still significantly greater than for ICE passenger cars. In the end, the study concluded that in terms of economics, EVs are not competitive due to their high sticker price despite the low running Cost.

The study in [7] aimed to identify monetary factors involved in total ownership cost, calculated by constructing a model and comparing EVs' Total Ownership Cost (TOC) with ICEVs in the Indonesian context. In this analysis, TOC calculation is done by considering three ownership periods (5, 10, and 16) and three scenarios of annual mileages (10,000, 18,000, and 25,000) for BEV, PHEV, HEV, and ICEV. The study resulted that at medium and high annual mileage, HEVs are the best choices as compared to other vehicles, while ICEVs are more competitive in case of low annual mileage. Additionally, with moderate and high ownership periods, HEVs are more economical due to low TOC. On the other hand, PHEVs and BEVs need high annual mileage, normal-high electricity prices, and low-to-moderate ownership periods. In the end, it is concluded that longer ownership and high annual driven kilometre are the factors that increase the competitiveness of HEVs, PHEVs, and BEVs over conventional ICEVs. Higher fuel prices play a role in the competitiveness of a BEV over PHEV and HEV.

ABAS et al. in [8] conducted a techno-economic analysis (Life cycle cost analysis) to check the feasibility of EVs in Brunei. This study considered three vehicles in comparison, i.e., HEV and ICEs, and BEVs and their all-related Cost from acquisition to disposal (acquisition, operating, maintenance costs and salvage value). Sensitivity analysis also has been done in the respective study among acquisition cost, interest rate, annual distance travelled, costs of electricity and gasoline, and battery prices. The local data from research papers, technical information from manufacturers and subject-matter experts, and updated market prices have been used to explore the Bruneian market. The conclusion was that EVs are still expensive due to acquisition cost, which is a large part of their total ownership costs. And proposed, to be BEVs more economical than HEV and ICEs, the government subsidy and gasoline price should be significant, around USD$4100 and USD$0.70/L respectively. The research in [9] compared conventional and ecological vehicles' life cycle costs in the European EU context over three consumers-based scenarios A, B, and C of annual mileages (15000, 20000,25000 km). Five types of vehicles (gasoline, diesel, and ecological ones are EV, HEV and natural gas-powered vehicles). Moreover, the lifespan of 10 years has been considered. The researchers analyzed the data as per European standards and came up with the cost/km for each vehicle. The comparison concluded that Natural gas cars are always cheaper for all annual mileage segments, whereas EVs are cheaper with higher annual mileage.

The study in [10] presented the techno-economic model for TCO analysis of electric and diesel vehicles in the French (France) environment. The authors considered real driving cycles (urban, extra-urban, and highway trips). They found that the total cost of ownership of the considered electric vehicle is less than for the equivalent diesel car by almost 1000€ over five years. Moreover, it is found that with real driving cycles, TCO is less than with standard-defined driving cycles. This study concluded that Economic factors strongly impact the TCO of EVs compared to the TCO of ICEVs. Government subsidization, ownership length, and vehicle depreciation are the main factor contributing to TCO. The stated future development in this study can be done by introducing charging infrastructure to charge the EVs. LeBeau et al. in [11] conducted an economic analysis of EVs for Flanders, Belgium, by studying the Total Cost of ownership for small, medium, and premium car segments. They came up with the total cost of ownership by considering all vehicle-related costs (purchase cost, registration tax, vehicle road tax, maintenance, tires and technical control cost, insurance cost, battery leasing cost, battery replacement cost and fuel or electricity cost), seven years ownership period and 15000km annual mileage. The study concluded that EVs are not economical without leasing or contract battery replacement despite their low running costs.

Clean Energy Canada published a report, "*The True Cost,*" in April 2022 [12], in which a number of popular vehicles were studied considering a fixed number of years for ownership and fixed gasoline prices. The study considered an annual mileage of 20,000km, eight years ownership period, and 55% and 45% city and highway driving style. The total cost of ownership is calculated by the vehicle's comparison tool, "fleet procurement analysis tool" and the vehicle's performance data has been considered from Natural Resource Canada. The report concluded that EVs are cheaper than gasoline vehicles, except the Ford F-150 truck, as per the above assumption.

The above studies related to the economic viability of electric vehicles have demonstrated their studies for different countries. The study [1] considered European countries' context to provide economic payback analysis. And it is found to be an average of 10 years. Other studies are done to provide a generic view of whether EVs are economical or not. These studies considered a fixed ownership period and annual mileage. The study [7] compared vehicles at three different ownership periods and annual mileages and provided the result of EVs' status with respect to economics in the Indonesian context. Clean Energy Canada [12] presented an economic comparison between conventional ICE vehicles and electric vehicles by placing a fixed number of ownership years and a fixed gasoline price. There is a gap in getting clear on how much we should at least own the electric vehicle. And there is a lack of analysis of economic profitability by gasoline prices variability in Canadian specifications. This project addresses the above gap by analyzing the Cost per km and total Cost of ownership for a variety of ownership periods and by varying gasoline prices. This project will provide a statistical figure of ownership period and minimum gasoline price below which EVs are not significantly economical.

Chapter 3 METHODOLOGY

3.1 *Procedure*

The flow chart in Fig.1 shows the overall process flow of analysis. To make comparisons, the analysis method selection comes first, which resulted in the choice of the Microsoft excel based tool described in the later section. In the following step, data required by the tool were collected from various sources in Ontario, Canada. The exact figure depicts the inputs needed for the comparative economic analysis tool. The inputs are gasoline price, diesel, residential electricity prices, public charging prices, en route charging prices, vehicle manufacturer's suggested retail price (MSRP), the vehicle performance data, insurance cost, annual mileage, the driving style (city and highway), and the charging style (home, public, and en route). Next step, to compare the vehicles' costs using collected data, a simulation was done using the fleet procurement analysis tool. The final step was to analyze the results and get the specific mathematical figure to answer the question stated in the problem statement.

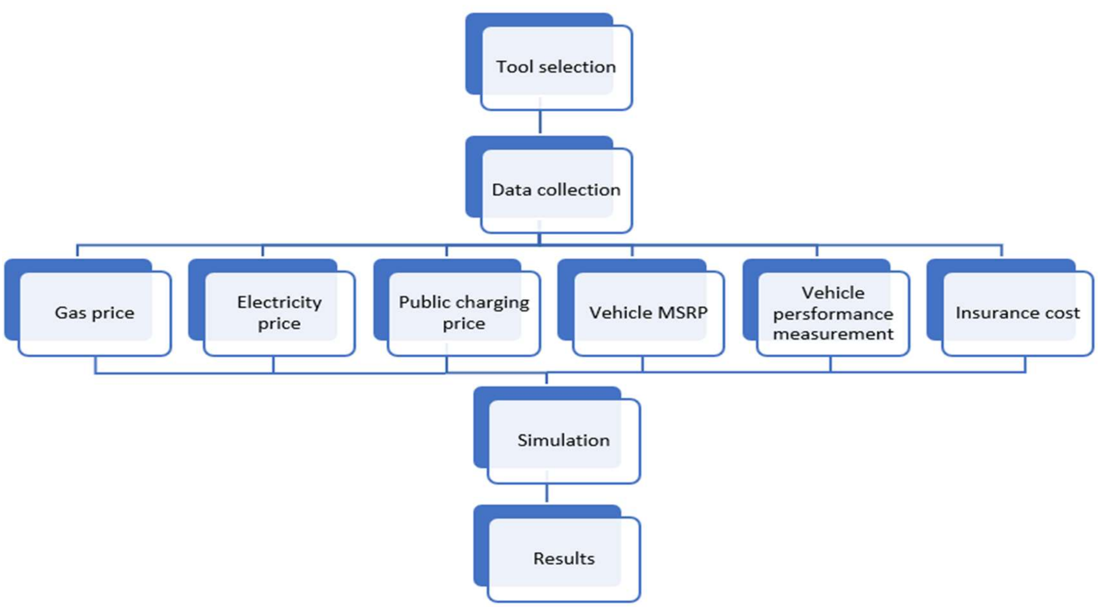

Fig. 3.1. Flow chart of the analysis process

3.2 *Comparative Economic Analysis tool description*

The Canadian version of the tool developed by Atlas Public Policy [13], named Fleet Procurement Analysis Tool, has been used to get the comparison results. This is a Microsoft Excel-based tool that provides economic feasibility information. It offers various procurement ownership structures, vehicle types (Low, medium, and heavy-duty), and procurement scenarios. The study considered all vehicle-related costs (e.g., purchase, fuel, maintenance and repair, insurance costs, Cost of downtime in EV charging, carbon price, relevant taxes and fees, Government Incentives, and charging infrastructure).

3.3 *Data Description and Data Analysis*

The average gasoline price in Ontario has been obtained from the Canadian Automobile Association (CAA) [14]. The average of the time-of-use (TOU) electricity prices (off-peak, mid-peak, and on-peak) regulated by the Ontario Energy Board [15] by 08 February 2022 has been considered in this work, which came out to be $0.122/kWh. Regarding the Public charging prices, the prices data were gathered by finding the individual price of 230 paid public charging stations via the “chargehub” [16] station locator for which the average price was calculated. To calculate the public charging price/kWh, this work considered 75kWh battery storage, level 2 charger rated 6.5kW. Table 1 shows a glimpse of the collected public chargers' data. Moreover, to obtain the Enroute charging price, the chosen rated power of the fast chargers was 150kW. As a result, the public charging and Enroute charging price are found to be $0.253/kWh and $0.12/kWh, respectively. The Cost of downtime of public charging as per “chargehub” is set to be $15/hr [16]. Additionally, the Cost of carbon in Canada in 2022 was $50/ton [17].

To find the threshold of gasoline price below which the ICE vehicles become more economical than the PBEVs, the gasoline prices of the previous five years have been considered in this work using [18]. The gasoline prices in Ontario over the five years are listed in Fig. 2. To determine the minimum ownership period, different ownership periods have been considered in this work ranging from 4 to 12 years. Moreover, a 7% interest rate in Canada has been set for calculation according to trading economics [19].

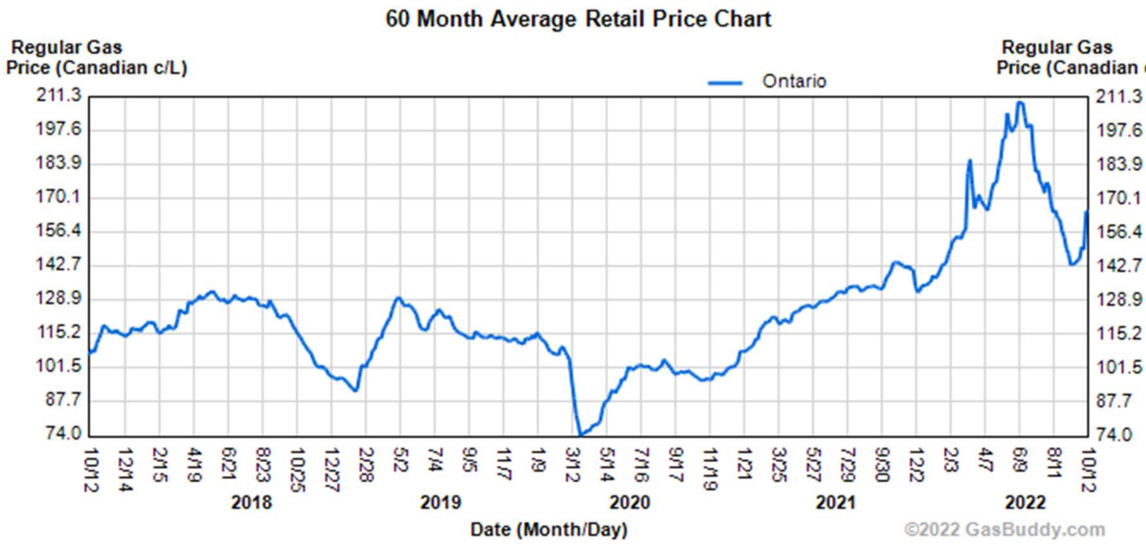

Fig.3.2. Historical prices of gasoline over the last five years in Ontario

TABLE 3.1 PUBLIC CHARGER PRICES IN ONTARIO ($/HR.)

Electricity prices for level 2 charger ($)	No of hours	Charger wattage (kW)
$2.00	1	6.5
$1.00	1	6.5
$1.50	1	6.5
$1.50	1	6.5
$1.50	1	6.5
$1.50	1	6.5
$1.50	1	6.2

$1.50	1	6.5
$1.50	1	6.5
$2.00	1	6.7
$1.00	1	6.7
$1.00	1	6.5
$1.00	1	6.5
$1.00	1	6.7
$2.00	1	7
$1.50	1	7.68
$1.50	1	7.2
$1.50	1	7.68
$2.50	1	7.2
$1.50	1	7.2
$1.50	1	6.2
$1.50	1	6.5
$2.00	1	6.5
$2.00	1	6.5
$1.50	1	6.2
$1.00	1	6.2
$2.50	1	6.5

Few assumptions have been made in this work regarding the driving style of the vehicle, its annual mileage, and the charging infrastructure style. The driving style is set to be 55% and 45% city and highway driving, respectively. The annual mileage has been assumed to be 30,000km. The charging mode is set to 80% home, 15% public, and 5% "en route" charging. The base ownership period has been kept for *nine years*.

Furthermore, the vehicle MSRP and the performance data were provided by one of the

Canadian vehicle information resources, “driving.ca” [20] and Natural Resource Canada (NRCan) [21]. The insurance cost has been obtained by averaging the insurance prices of individual cars in 12 cities of Ontario via an Insurance premium finder [22]. According to an assumed personal profile, i.e., 30 years of age, annual driven kilometre 30,000 with 60km daily to work or school, and 12 years of driving experience with no accident, the analysis was performed. The selected PBEVs and the conventional ICE vehicles' specifications are listed in tables 2 and 3, respectively.

Moreover, the government of Canada set incentives to adopt the conventional gas cars' transition to Electric cars. The Central Government of Canada and provincial governments published eligible vehicles for federal and provincial rebates, respectively. The province of Ontario does not have a provincial rebate program but rather than federal rebate program. The list of eligible vehicles under the zero-emission vehicle program can be found at Transport Canada [23].

In Simulation, maintenance and repair Cost also been included according to Canadian defaults in the simulation tool. Similarly, taxes and fees also have been considered.

TABLE 3.2. PLUG-IN BATTERY ELECTRIC VEHICLE SPECIFICATIONS

Name	**EPA fuel economy (Le/100km)**			**Range**	**MSRP**	**Incentives**	**Insurance Cost**
	Combined	City	Hwy	Km	$	$	$
2021 Chevrolet Bolt EV	2.0 (17.8 kWh/100 km)	1.9 (16.5kWh/100 km)	2.2 (19.5kWh/100 km)	417	50k	5k	2124

2021 Kia Soul EV(Limited)	2.1 (18.7 kWh/100 km)	1.9 (16.9kWh/100 km)	2.4 (21 kWh/100 km)	383	52k	5k	1992
2021 Hyundai KONA electric (Preferred)	2.0 (17.4 kWh/100 km)	1.8 (16.2kWh/100 km)	2.2 (19.3 kWh/100 km)	415	46k	5k	2107
2021 Volvo XC40 Recharge AWD	3.0 (26.6 kWh/100 km)	2.8 (24.5kWh/100 km)	3.3 (29.2 kWh/100 km)	335	65k	-	1727
2021 Tesla Model 3(Long range AWD)	1.8 (15.6 kWh/100 km)	1.7 (14.9kWh/100 km)	1.9 (16.5 kWh/100 km)	568	64k	-	2411

TABLE 3.3. GASOLINE VEHICLES SPECIFICATIONS

Name	**EPA fuel economy (Le/100km)**			**MSRP**	**Incentives**	**Insurance Cost**
	Combined	City	Hwy	$	$	$
2021 Chevrolet Equinox AWD	8.8	9.4	8.0	35k	-	2218
2021 Kia Soul (GT-LINE Limited)	7.9	8.5	7.0	29k	-	2135
2021 Hyundai Kona (Preferred FWD)	7.9	8.6	7.0	23k	-	2097

2021 Volvo XC40 (T5 AWD Inscription)	9.4	10.7	7.7	49k	-	2517
2021 Toyota Camry (XLE V6)	8.4	9.5	7.0	42k	-	2056

A percentage increase has been calculated to determine how much the Cost will increase using conventional ICE vehicles in place of EVs. The percentage increase γ is computed from:

$$\gamma(\%) = \frac{\alpha - \beta}{|\beta|} \times 100 \qquad (1)$$

Where α is the total cost of ownership of ICE vehicles and β is the total cost of ownership of PBEV, respectively.

Chapter 4 RESULTS AND DISCUSSION

4.1 Results

This section presents the results of the comparative economic analysis. The results of each comparison have been presented in such a way that tables 4 and 5 show the total ownership cost of PBEV versus ICE Vehicles at a constant high and low gasoline price with varying ownership periods, respectively. Secondly, table 6 lists the total ownership cost of PBEV versus ICE Vehicles at a constant ownership duration with the varying lowest price. Then, vehicle cost per km at various ownership years at a constant high and low gasoline price, and fourth vehicle cost per km at varying lowest prices at constant ownership of years have been presented. Fifth, Cash flows comparison throughout ownership years are shown. In the second last, the economic percentage at a high and low gasoline price in case of varying ownership periods have been presented. The last section of results gives information about economic percentage increase at constant ownership with varying lowest gasoline prices, followed by the net amount of cash flows at the end of various ownership years. The baseline vehicles represent PBEVs, and the Comparison vehicle represents conventional ICE vehicles.

4.1.1 *Total Ownership Costs over the Different ownership durations*

TABLE 4.1. TOCS AT A CONSTANT HIGH GASOLINE PRICE ($1.66/L) AND VARIOUS OWNERSHIP YEARS

	Vehicle types	**Total Ownership Years Costs ($)**				
		4years	**5 years**	**9 years**	**12 years**	**15 years**
Comparison 1	2021 Chevrolet Bolt EV	54,695	66,738	114,480	151,746	193,670
	2021 Chevrolet Equinox AWD	58,375	74,301	148,938	211,495	282,122

Comparison 2	2021 Kia Soul EV(Limited)	56,258	68,243	115,640	152,463	193,778
	2021 Kia Soul (GT-LINE Limited)	55,349	70,603	141,743	201,301	268,865
Comparison 3	2021 Hyundai KONA electric Preferred	52,495	64,482	111,226	147,721	189,052
	2021 Hyundai Kona (Preferred FWD)	54,713	69,949	139,815	198,092	264,492
Comparison 4	2021 Volvo XC40 Recharge AWD	71,799	84,460	135,759	175,367	218,824
	2021 Volvo XC40 (T5 AWD Inscription)	60,232	76,290	152,190	215,946	287,687
Comparison 5	2021 Tesla Model 3(Long range AWD)	62,590	74,717	125,510	165,844	210,812
	2021 Toyota Camry (XLE V6)	59,455	75,538	151,575	215,812	288,604

TABLE 4.2. TOCS AT A CONSTANT HIGH GASOLINE PRICE ($0.74/L) AND VARIOUS OWNERSHIP YEARS

	Vehicle types	**Total Ownership years' Cost ($)**				
		12 years	**9 years**	**8 years**	**7 years**	**5 years**
Comparison 1	2021 Chevrolet Bolt EV	151,746	114,492	102,640	90,851	66,738
	2021 Chevrolet Equinox AWD	178,551	124,402	107,789	91,762	61,197
Comparison 2	2021 Kia Soul EV(Limited)	152,463	115,640	103,899	92,205	68,243
	2021 Kia Soul (GT-LINE Limited)	171,906	119,841	103,874	88,453	58,911
Comparison 3	2021 Hyundai KONA electric (Preferred)	147,713	111,226	99,659	88,151	64,477

	2021 Hyundai Kona (Preferred FWD)	168,490	117,758	102,221	87,190	58,175
Comparison 4	2021 Volvo XC40 Recharge AWD	175,367	135,759	122,997	110,280	84,460
	2021 Volvo XC40 (T5 AWD Inscription)	180,822	126,019	109,213	93,029	62,319
Comparison 5	2021 Tesla Model 3(Long range AWD)	165,844	125,510	112,690	100,023	74,171
	2021 Toyota Camry (XLE V6)	184,351	128,133	110,943	94,402	63,024

TABLE 4.3. TOCS AT A CONSTANT OWNERSHIP PERIOD (9 YEARS) AND VARIOUS LOWEST GASOLINE PRICES

	Vehicle types	**Total Ownership cost ($) at various lowest prices**		
		$0.50/L	**$0.60/L**	**$0.65/L**
Comparison 1	2021 Chevrolet Bolt EV	114,492	114,492	114,492
	2021 Chevrolet Equinox AWD	117,998	120,667	122,001
Comparison 2	2021 Kia Soul EV(Limited)	115,640	115,640	115,640
	2021 Kia Soul (GT-LINE Limited)	114,127	116,508	117,698
Comparison 3	2021 Hyundai KONA electric (Preferred)	111,226	111,226	111,226
	2021 Hyundai Kona (Preferred FWD)	112,004	114,402	115,601
Comparison 4	2021 Volvo XC40 Recharge AWD	135,759	135,759	135,759
	2021 Volvo XC40 (T5 AWD Inscription)	119,192	122,036	123,459
Comparison 5	2021 Tesla Model 3(Long range AWD)	125,510	125,510	125,510
	2021 Toyota Camry (XLE V6)	122,018	124,566	125,840

4.1.2 *Comparisons at Constant High Gasoline Prices (1.66$/L) and varying Ownership period*

This section of results shows a comparison of vehicle cost/km of five different groups of vehicles for various ownership duration at a fixed high gasoline price. The analysis of these results will give a minimum ownership period at the current high gasoline price.

4.1.2.1 *Comparaison 1 (2021 Chevrolet Bolt EV BEV vs 2021 Chevrolet Equinox ICE)*

Ownership period: 4 years

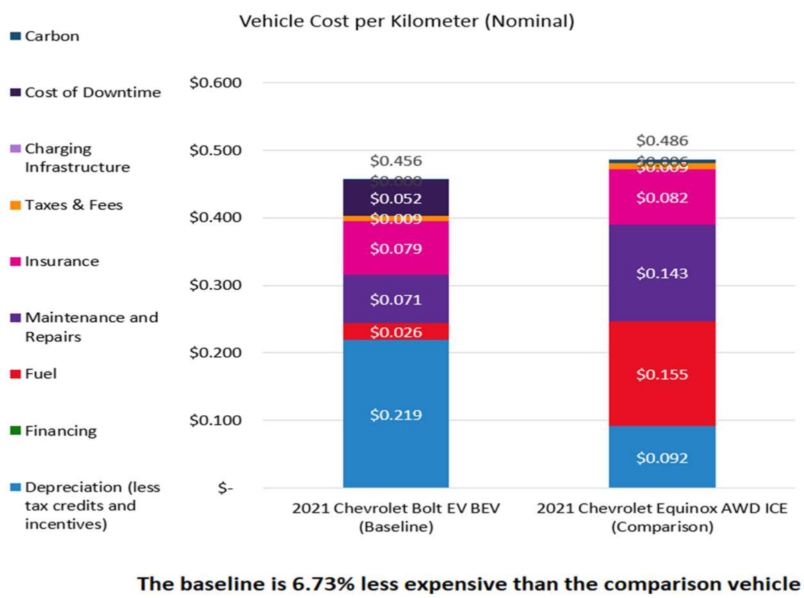

Fig.4.1. Vehicle Cost per km for ownership duration of 4 years at a high gasoline price in case of Comparison 1

Fig. 4.1 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV is slightly more than its equivalent PBEV for this significantly less period of ownership. The difference between EV's nominal cost/km and ICEV's nominal cost/km is considerably less. i.e., almost $0.030. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, also is significantly less, i.e.,6.73%.

Ownership period: 5 years

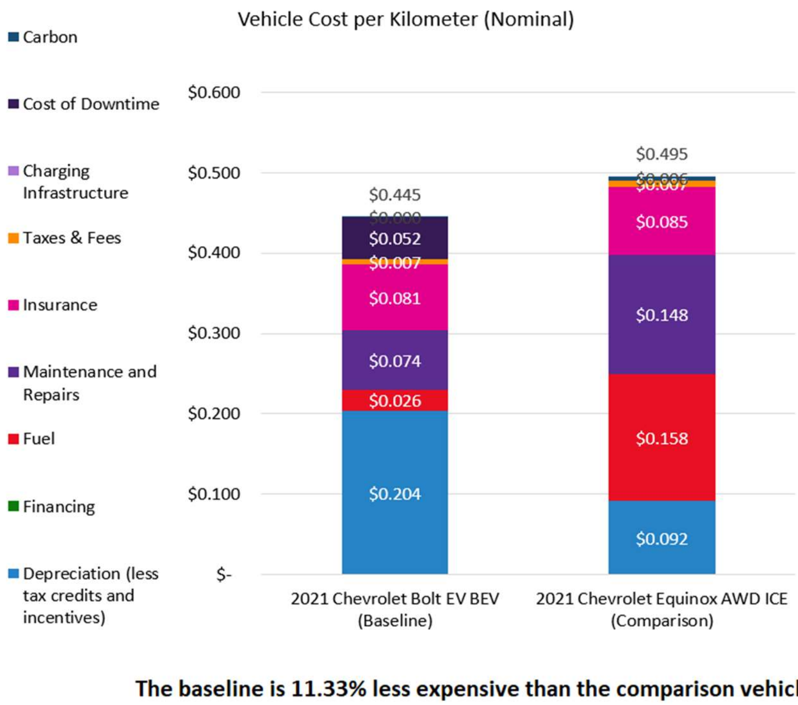

Fig.4.2. cost per km for ownership duration of 5 years at a high gas price in case of Comparison 1

Fig. 4.2 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV is more than its equivalent PBEV for the ownership of 5 years. The difference between EV's nominal cost/km and ICEV's nominal cost/km is significantly less. i.e., almost $0.050. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, also is less, i.e.,11.33%. The percentage difference has been increased with an increase in ownership.

Ownership period: 9 years

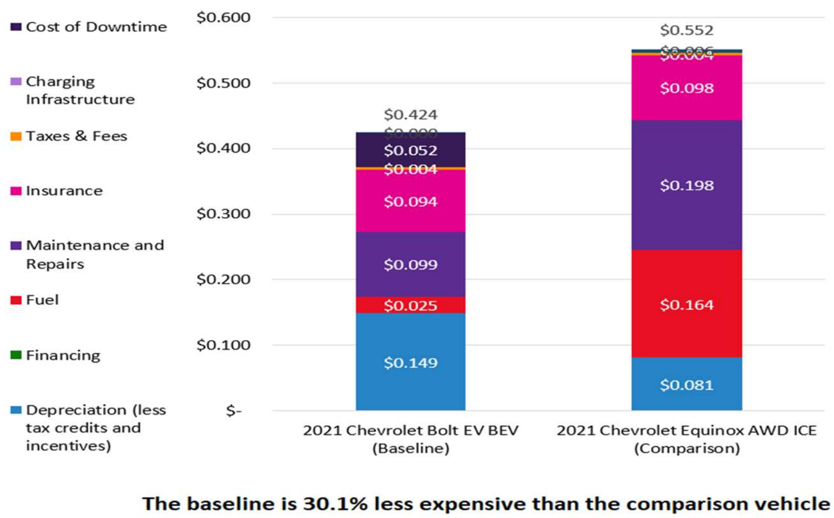

Fig.4.3. Cost per km for an ownership duration of 9 years at a high gasoline price in case of Comparison 1

Fig. 4.3 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV has been increased, whereas the cost/km of its equivalent PBEV is decreased for the ownership of 9 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, is significant, i.e., 30.1%. The percentage difference has been increased with an increase in ownership.

Ownership period: 12 years

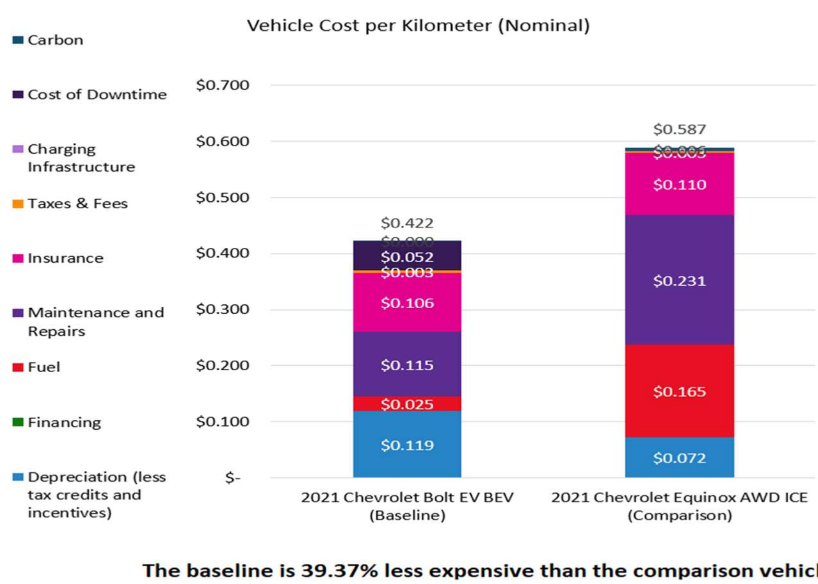

Fig.4.4.Cost per km for ownership duration of 12 years at a high gas price in case of Comparison 1

Fig. 4.4 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 12 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 39.37%. The percentage difference has been increased with an increase in ownership.

Ownership period: 15 years

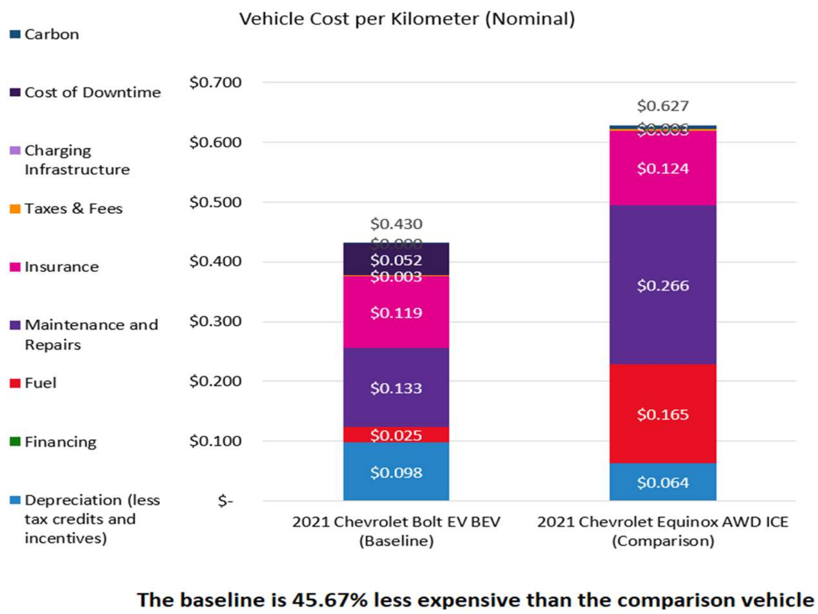

Fig.4.5. cost per km for ownership duration of 15 years at a high gas price in case of Comparison 1

Fig. 4.5 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 15 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 45.67%. The percentage difference has been increased with an increase in ownership.

4.1.2.2 *Comparison 2 (2021 Kia Soul EV BEV (180Ah) vs 2021 Kia Soul ICE)*

Ownership period: 4 years

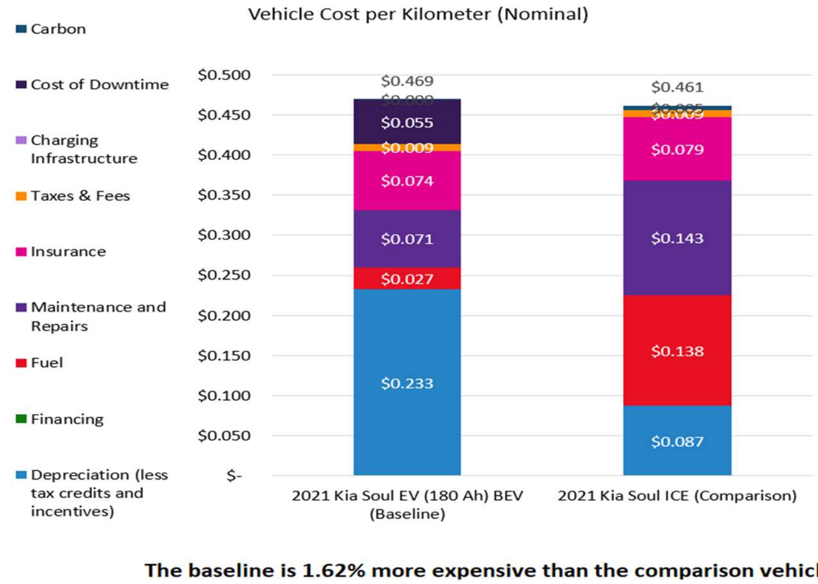

Fig.4.6. Cost per km for ownership duration of 4 years at a high gas price in case of Comparison 2

Fig. 4.6 shows that in the case of comparison 2, the nominal vehicle's cost/km of ICEV is slightly less than its equivalent PBEV for this very less period of ownership. In this case, Kia EV is more expensive than its equivalent ICE. However, EV is slightly costly, i.e., 1.62%.

Ownership period: 5 years

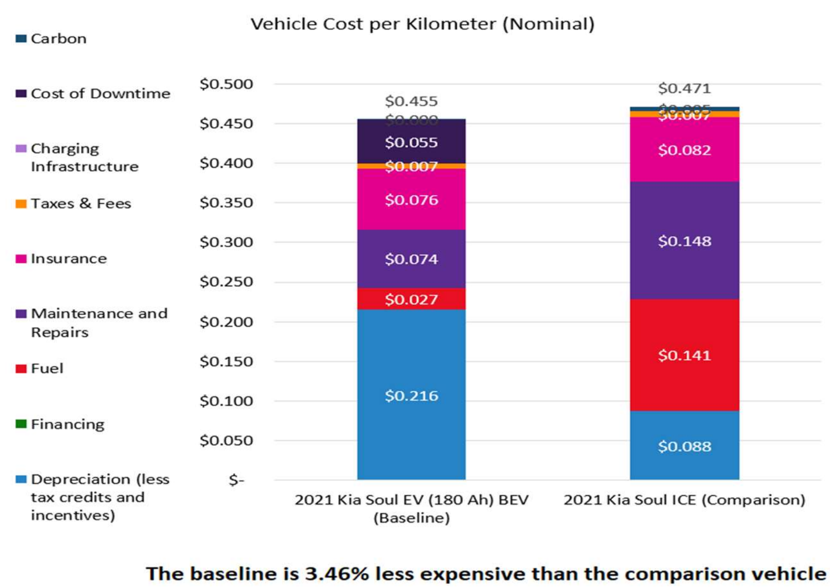

Fig.4.7. cost per km for ownership duration of 5 years at a high gas price in case of Comparison 2

Fig. 4.7 shows that in the case of comparison 2, the nominal vehicle's cost/km of ICEV is slightly more than its equivalent PBEV for the ownership of 5 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, is less, i.e., 3.46%. In this case, Kia EV turned out to be cheaper than Kia ICE. The percentage difference has been increased with an increase in ownership.

Ownership period: 9 years

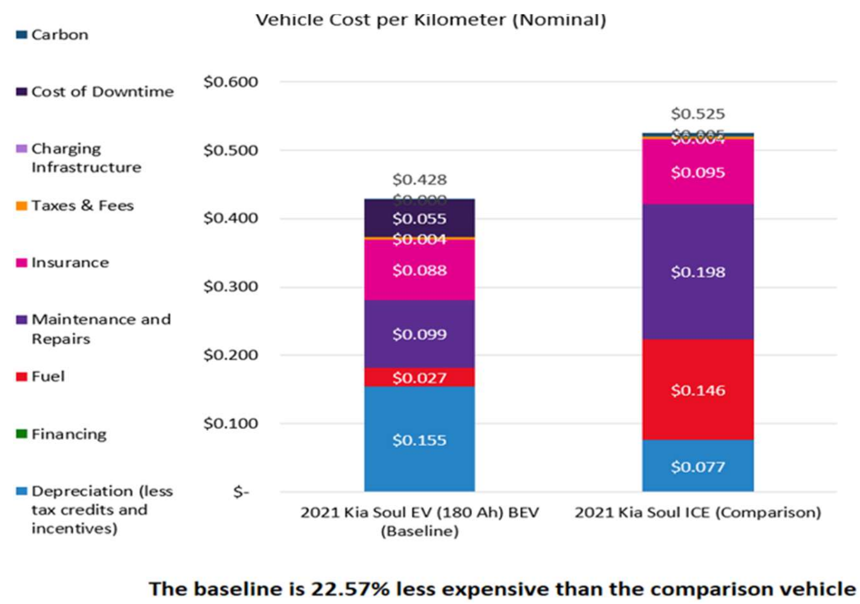

Fig.4.8. cost per km for ownership duration of 9 years at a high gas price in case of Comparison 2

Fig. 4.8 shows that in the case of comparison 2, the nominal vehicle's cost/km of ICEV has been increased, whereas the cost/km of its equivalent PBEV is decreased for the ownership of 9 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, is significant, i.e., 22.57%. The percentage difference has increased with an increase in ownership.

Ownership period: 12 years

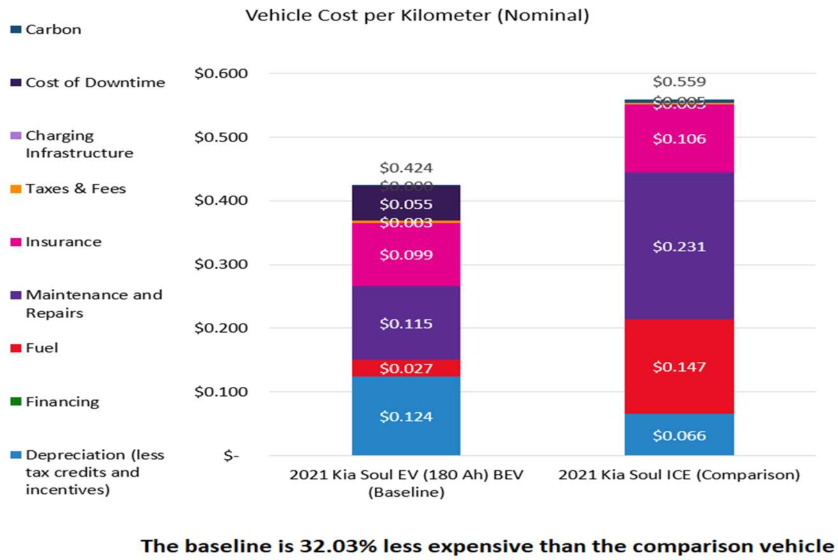

Fig.4.9. cost per km for ownership duration of 12 years at a high gas price in case of Comparison 2

Fig. 4.9 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 12 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 32.03%. The percentage difference has increased with an increase in ownership.

Ownership period: 15 years

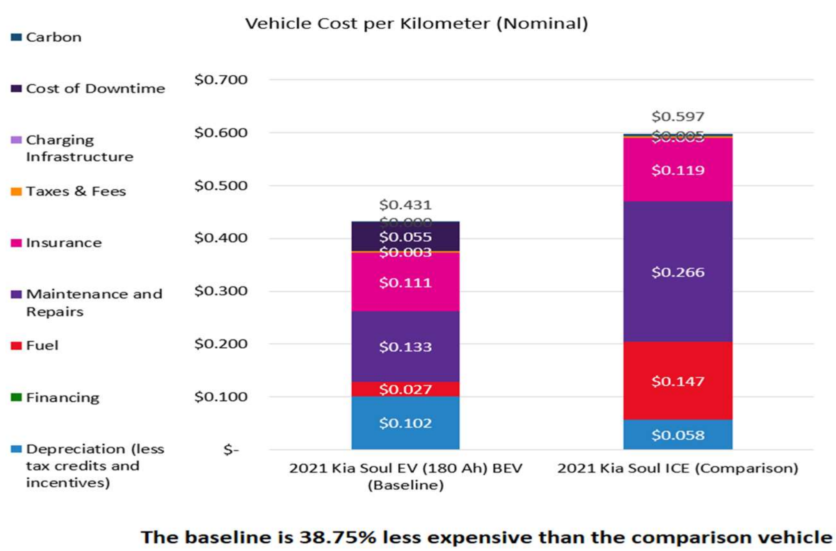

Fig.4.10.Cost per km for ownership duration of 15 years at a high gas price in case of Comparison 2

Fig. 4.10 shows that in the case of comparison 2, the nominal vehicle’s cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 15 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 45.67%. The percentage difference has increased with an increase in ownership.

4.1.2.3 *Comparison 3 (2021 Hyundai KONA electric vs 2021 Hyundai Kona ICE)*

Ownership period: 4 years

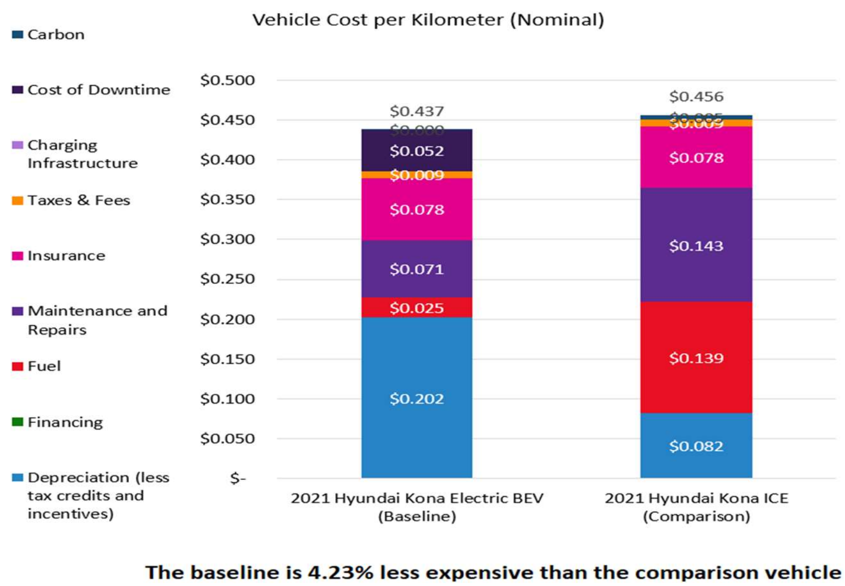

Fig.4.11. Cost per km for ownership duration of 4 years at a high gas price in case of Comparison 3

Fig. 4.11 shows that in the case of comparison 3, the nominal vehicle's cost/km of ICEV is slightly more than its equivalent PBEV for this significantly less period of ownership. The difference between EV's nominal cost/km and ICEV’s nominal cost/km is very less. i.e., almost $0.019. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, also is significantly less, i.e.,4.23%.

Ownership period: 5 years

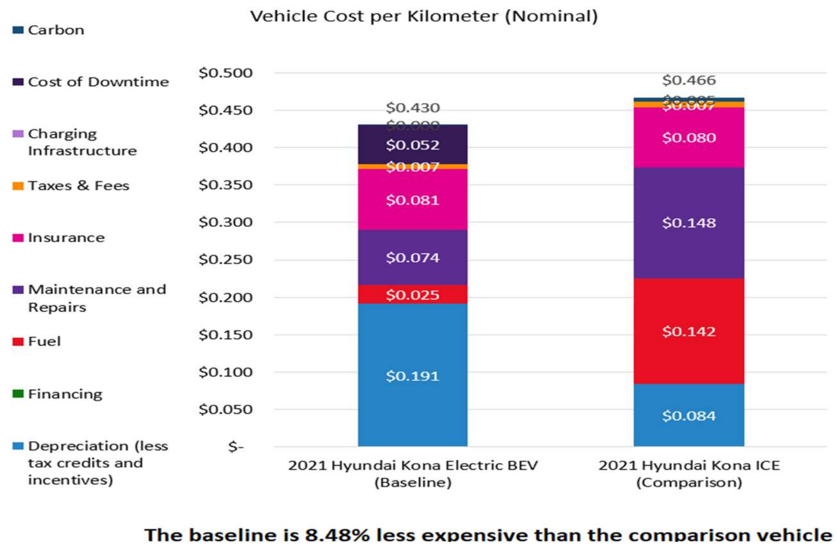

Fig.4.12. Cost per km for ownership duration of 5 years at a high gas price in case of Comparison 3

Fig. 4.12 shows that in the case of comparison 3, the nominal vehicle's cost/km of ICEV is more than its equivalent PBEV for the ownership of 5 years. The difference between EV's nominal cost/km and ICEV's nominal cost/km is very less. i.e., almost $0.036. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, also is less, i.e., 8.48%. The percentage difference has been increased with an increase in ownership.

Ownership period: 9 years

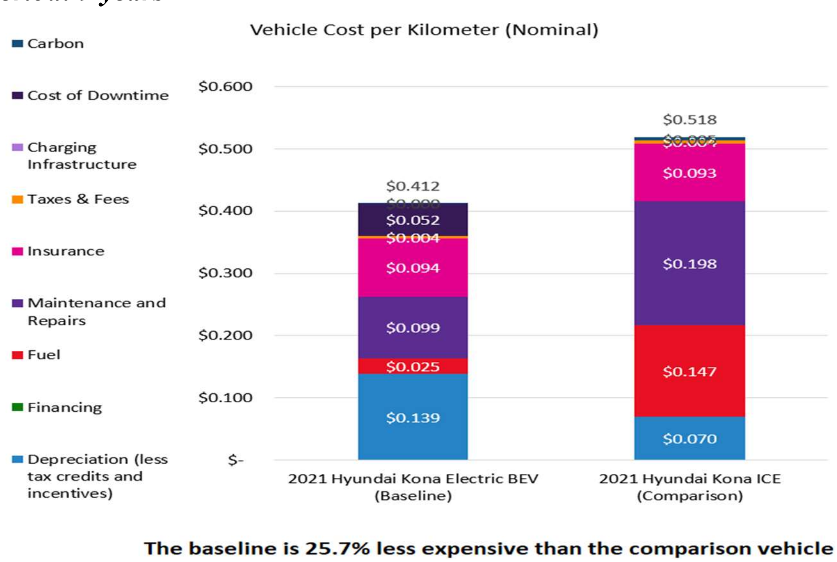

Fig.4.13.Cost per km for ownership duration of 9 years at a high gas price in case of Comparison 3

Fig. 4.13 shows that in the case of comparison 3, the nominal vehicle's cost/km of ICEV has been increased, whereas the cost/km of its equivalent PBEV is decreased for the ownership of 9 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, is significant, i.e., 25.7%. The percentage difference has been increased with an increase in ownership.

Ownership period: 12 years

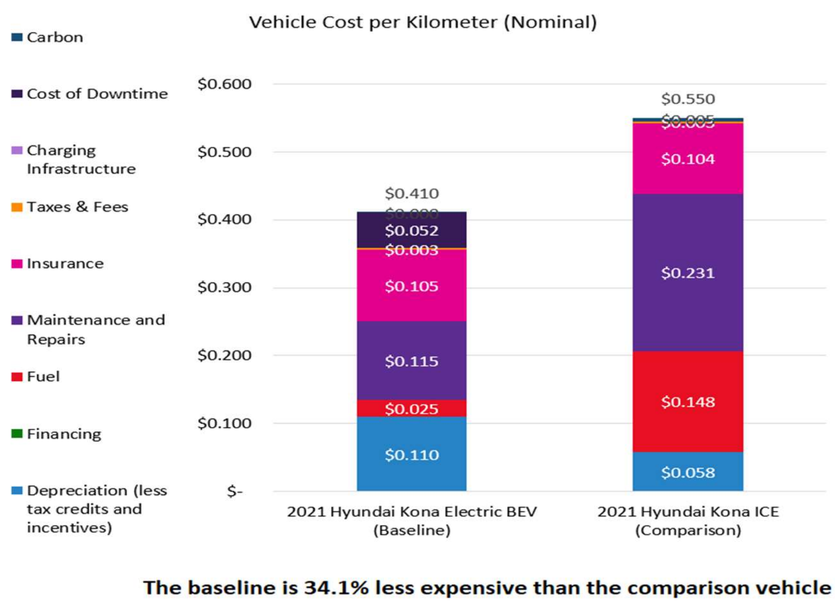

Fig.4.14.Cost per km for ownership duration of 12 years at a high gas price in case of Comparison 3

Fig. 4.14 shows that in the case of comparison 3, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 12 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 34.1%. The percentage difference has been increased with an increase in ownership.

Ownership period: 15 years

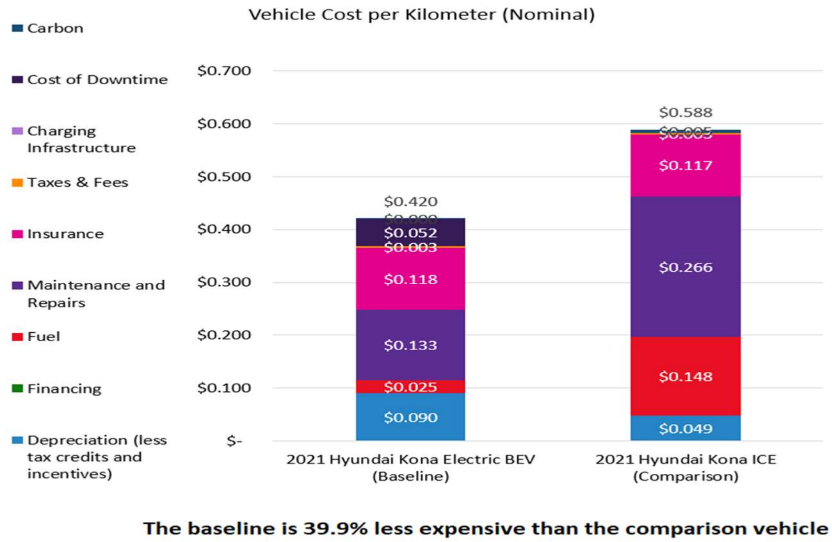

Fig.4.15. Cost per km for ownership duration of 15 years at a high gas price in case of Comparison 3

Fig. 4.15 shows that in the case of comparison 3, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 15 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 39.9%. The percentage difference has been increased with an increase in ownership.

4.1.2.4 *Comparison 4(2021 Volvo XC40 Recharge BEV vs 2021 Volvo XC40 ICE)*

Ownership period: 4 years

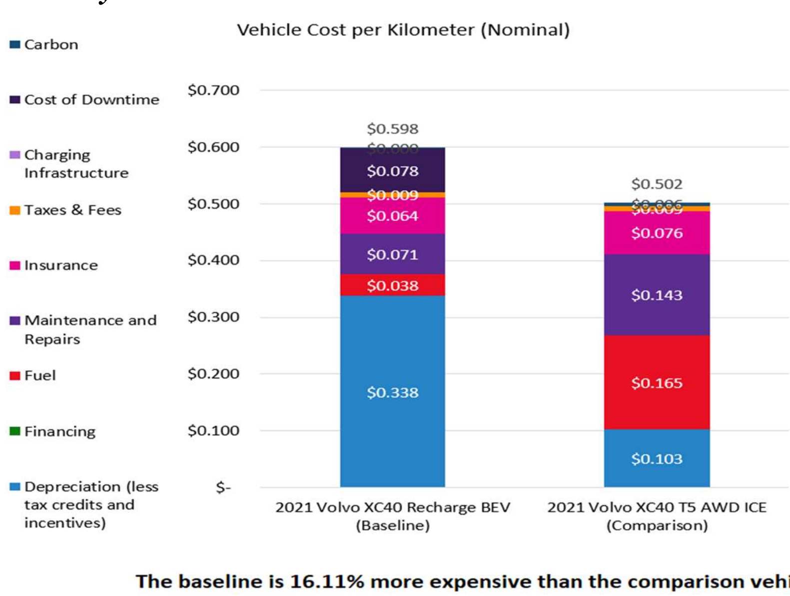

Fig.4.16. Cost per km for ownership duration of 4 years duration at high gas price in case of Comparison 4

Fig. 4.16 shows that in the case of comparison 4, the nominal vehicle's cost/km of ICEV is significantly less than its equivalent PBEV for this very less period of ownership. In this case, Volvo XC40 EV is more expensive than its equivalent ICE, i.e., 16.11% more expensive. The depreciation cost of the Volvo XC40 EV is much higher than Volvo XC40 ICE.

Ownership period:5 years

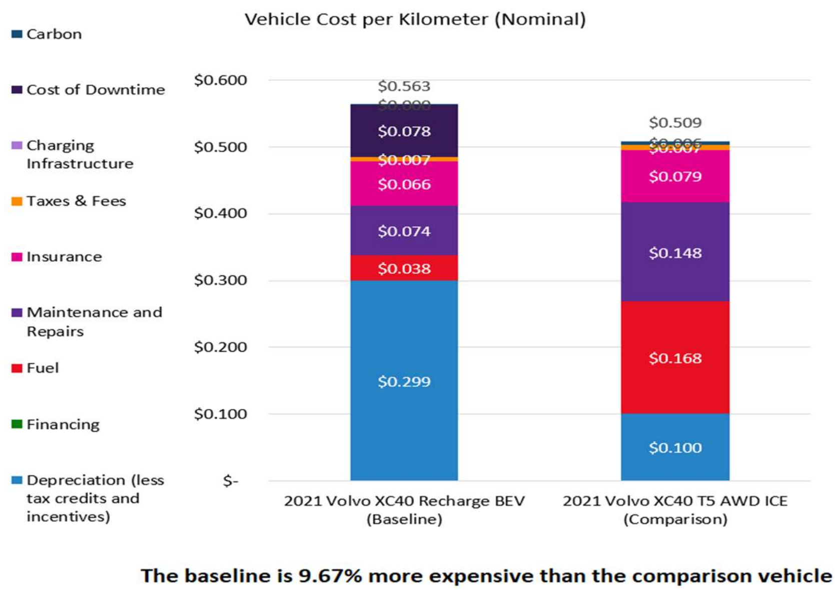

Fig.4.17. Cost per km for ownership duration of 5 years at a high gas price in case of Comparison 4

Fig. 4.17 shows that in the case of comparison 4, the nominal vehicle's cost/km of ICEV is significantly less than its equivalent PBEV for ownership of 5 years. In this case, Volvo XC40 EV is still more expensive than its equivalent ICE, i.e., 9.67% more expensive. With the increase in ownership years, the percentage increase is reduced. The depreciation cost of the Volvo XC40 EV is much higher than Volvo XC40 ICE.

Ownership period: 9 years

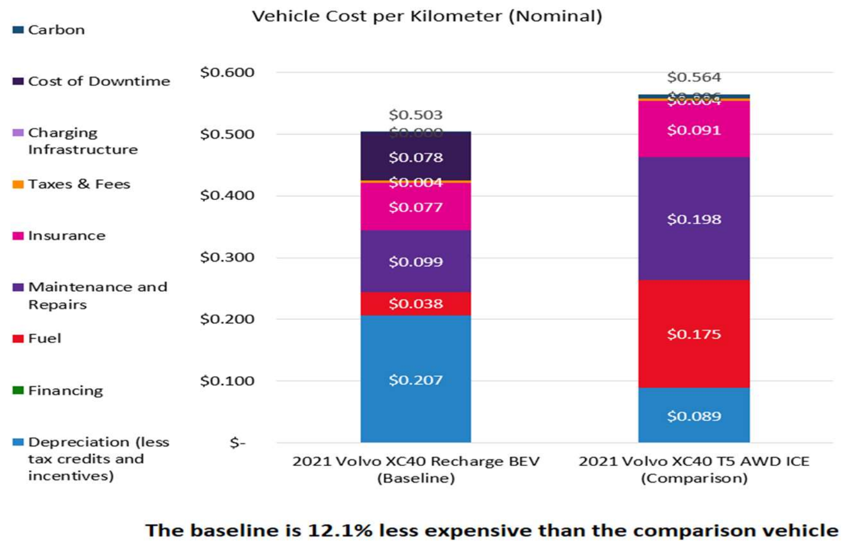

Fig.4.18. Cost per km for ownership duration of 9 years at a high gas price in case of Comparison 4

Fig. 4.18 shows that in comparison 4, the nominal vehicle's cost/km of ICEV has been increased, whereas the cost/km of its equivalent PBEV is decreased for the ownership of 9 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, turned out to be positive towards EV, i.e., 12.1%. The percentage difference has been increased with an increase in ownership. The depreciation cost of the Volvo XC40 EV is reduced due to the long ownership period.

Ownership period: 12 years

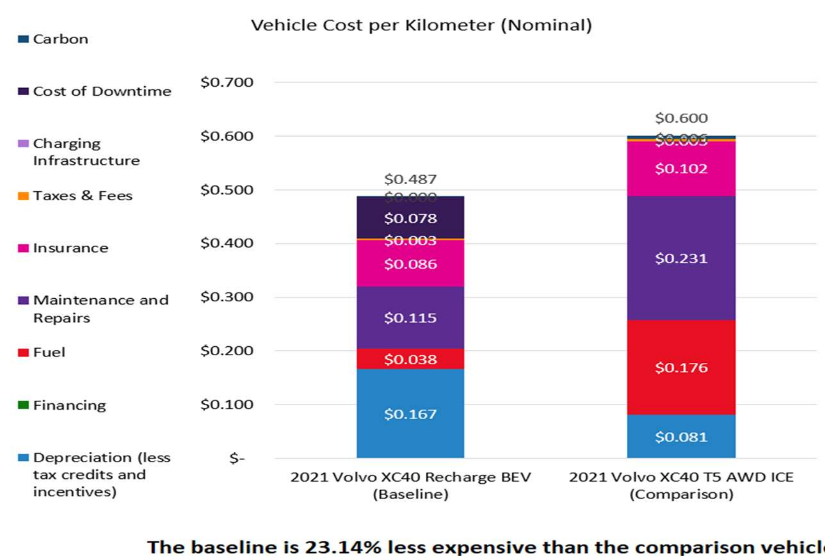

Fig.4.19. Cost per km for ownership duration of 12 years at a high gas price in case of Comparison 4

Fig. 4.19 shows that in the case of comparison 4, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 12 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes significant, i.e., 23.14%. The percentage difference has increased with an increase in ownership. The depreciation cost of the Volvo XC40 EV is reduced due to the long ownership period.

Ownership period: 15 years

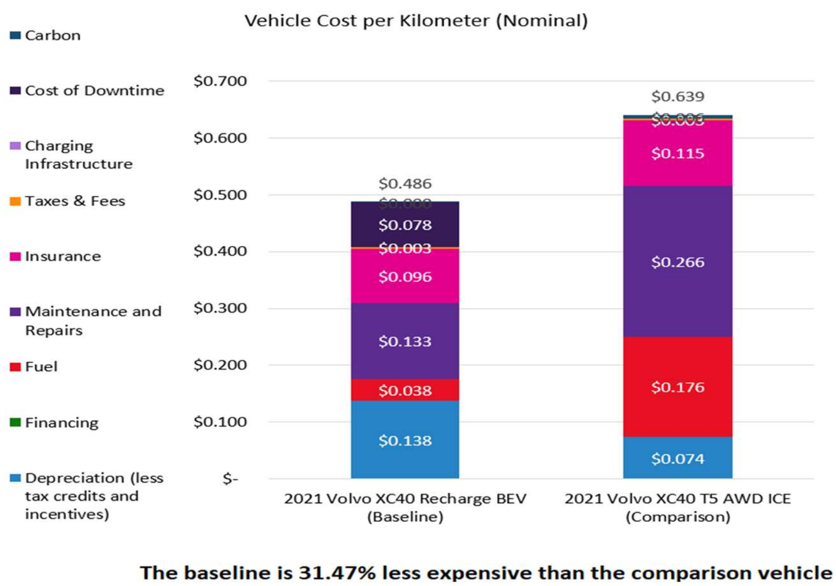

Fig.4.20. Cost per km for an ownership duration of 15 years at a high gas price in case of Comparison 4

Fig. 4.20 shows that in the case of comparison 4, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 15 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 31.47%. The percentage difference has increased with an increase in ownership. The depreciation cost of the Volvo XC40 EV is reduced due to the long ownership period.

4.1.2.5 *Comparison 5 (2021 Tesla Model 3 BEV (180Ah) vs 2021 Toyota Camry ICE)*

Ownership period: 4 years

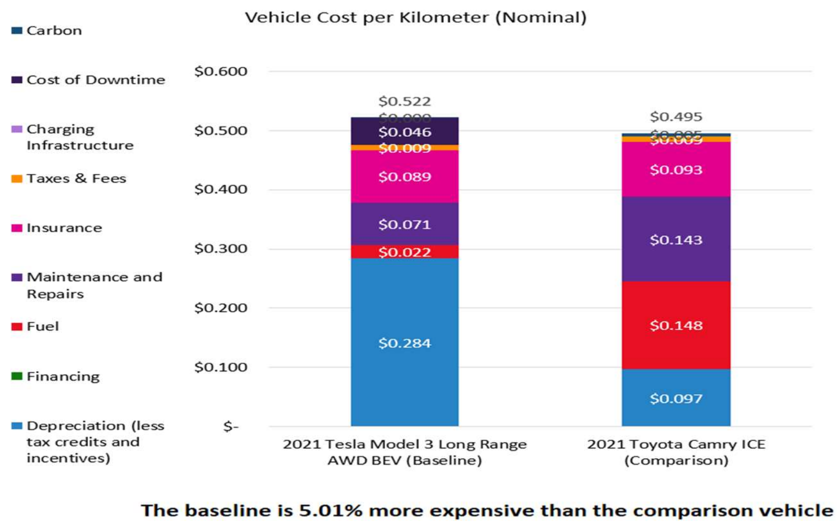

Fig.4.21. Cost per km for ownership duration of 4 years at a high gas price in case of Comparison 5

Fig. 4.21 shows that in the case of comparison 5, the nominal vehicle's cost/km of ICEV is less than its equivalent PBEV for this significantly less period of ownership. In this case, Tesla Model 3 EV is more expensive than its equivalent Toyota Camry ICE, i.e., 5.01% more expensive. The depreciation cost of the Tesla Model 3 EV is higher than Toyota Camry ICE.

Ownership period: 5 years

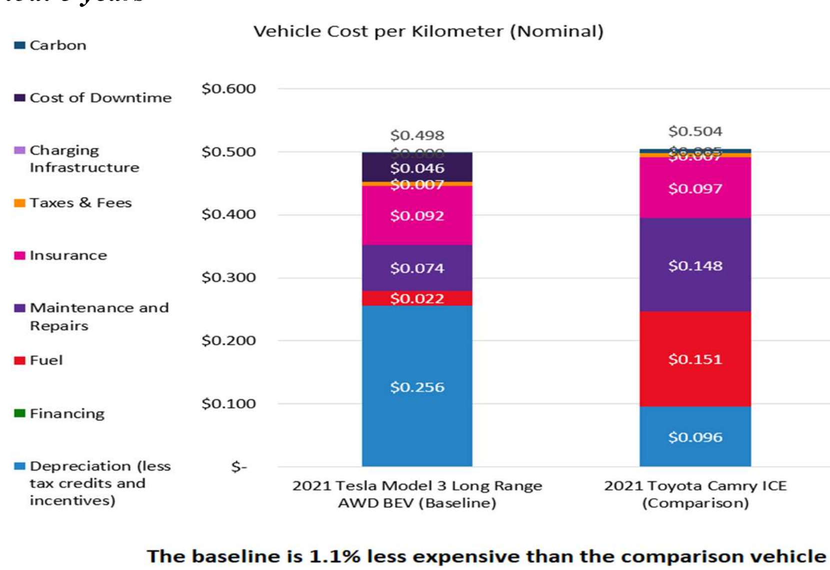

Fig.4.22. Cost per km for ownership duration of 5 years at a high gas price in case of Comparison 5

Fig. 4.22 shows that in the case of comparison 5, the nominal vehicle's cost/km of ICEV is slightly more than its equivalent PBEV for ownership of 5 years. In this case, Tesla Model 3 EV is still almost equal to its equivalent Toyota Camry ICE, i.e., 1.1 % less expensive. With the increase in ownership years, the percentage increase turned from negative to positive toward EV. The depreciation cost of the Tesla Model 3 is still higher than Toyota Camry ICE.

Ownership period: 9 years

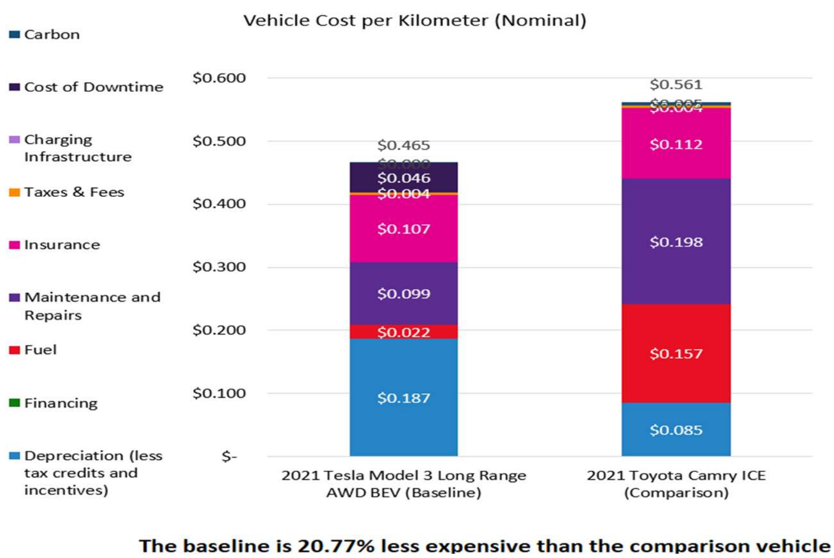

Fig.4.23. Cost per km for ownership duration of 9 years at a high gas price in case of Comparison 5

Fig. 4.23 shows that in the case of comparison 5, the nominal vehicle's cost/km of ICEV has been increased, whereas the cost/km of its equivalent PBEV is decreased for the ownership of 9 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, turned to significant towards EV, i.e., 20.77%. The percentage difference has increased with an increase in ownership. The depreciation cost of the Tesla Model 3 EV is reduced due to the long ownership period.

Ownership period: 12 years

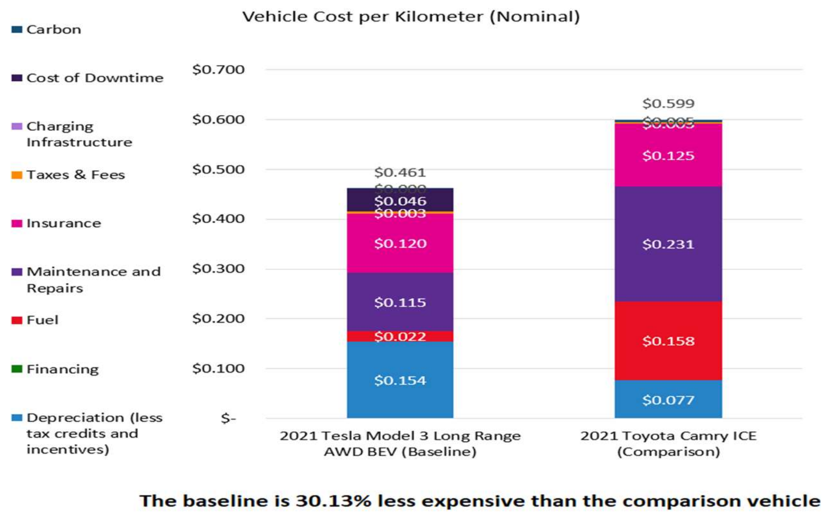

Fig.4.24. Cost per km for ownership duration of 12 years at a high gas price in case of Comparison 5

Fig. 4.24 shows that in the case of comparison 5, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 12 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes significant, i.e., 30.13%. The percentage difference has increased with an increase in ownership. The depreciation cost of the Volvo XC40 EV is reduced due to the long ownership period.

Ownership period: 15 years

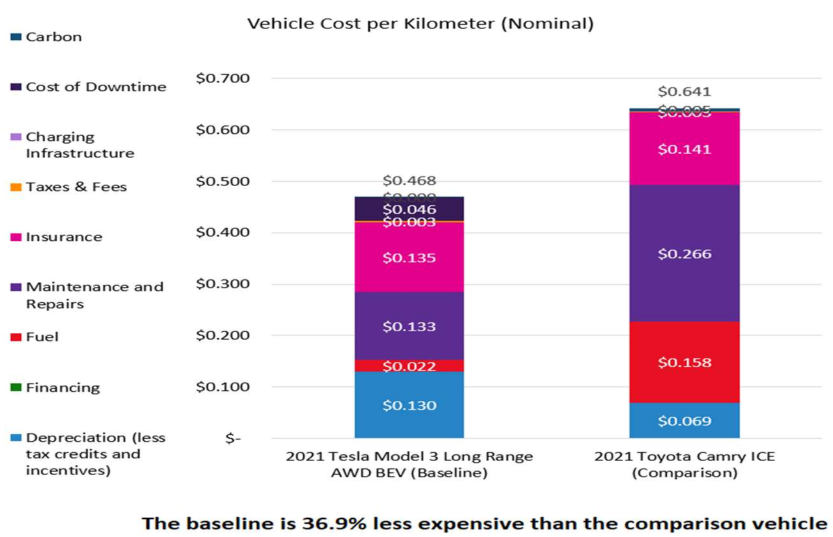

Fig.4.25. Cost per km for ownership duration of 15 years at a high gas price in case of Comparison 5

Fig. 4.25 shows that in the case of comparison 5, the nominal vehicle's cost/km of ICEV is significantly more than its equivalent PBEV for the ownership of 15 years. The percentage increase, which is a percentage increase in TOC with the use of traditional ICE, becomes more significant, i.e., 36.9%. The percentage difference has increased with an increase in ownership. The depreciation cost of the Volvo XC40 EV is reduced due to the long ownership period.

4.1.2.6 *Economic status of Electric vehicles at High Gasoline price($1.66/L)*

The following table shows economic percentages and status of electric vehicles 9 years and above. The positive values of percentages represent the Electric vehicles are cheaper than their equivalent ICEs and vice versa.

TABLE 4.4. ECONOMIC STATUS AT A CONSTANT HIGH GASOLINE PRICE ($1.66/L) AND VARIOUS OWNERSHIP YEARS

Electric Vehicle's Models	**Beneficence percentages (%) of Electric vehicles of at gasoline price of $1.66/L over different ownership periods ("Positive" = economical and "negative" = non-economical)**			
	9 years	**12 years**	**15 years**	**Economical Status at 9 years and above**
2021 Chevrolet Bolt EV	30.1	39.37	45.67	Most economical
2021 Hyundai KONA electric	25.7	34.1	39.9	Economical
2021 Kia Soul EV(Limited)	22.57	32.03	38.75	Economical
2021 Tesla Model 3	20.77	30.13	36.9	Less economical
2021 Volvo XC40 Recharge	12.1	23.14	31.47	Least Economical

4.1.3 Comparisons at Constant Low Gasoline Prices (0.74$/L) and varying Ownership period

This section presents the Economic percentages and vehicles' cost per kilometre at the lowest gasoline price in Ontario over the last five years with varying ownership periods (starting with the higher and then low and so on). The analysis of these results will give a minimum ownership period at a low gasoline price.

4.1.3.1 *Comparaison 1(2021 Chevrolet Bolt BEV vs 2021 Chevrolet Equinox ICE)*

Ownership period: 12 years

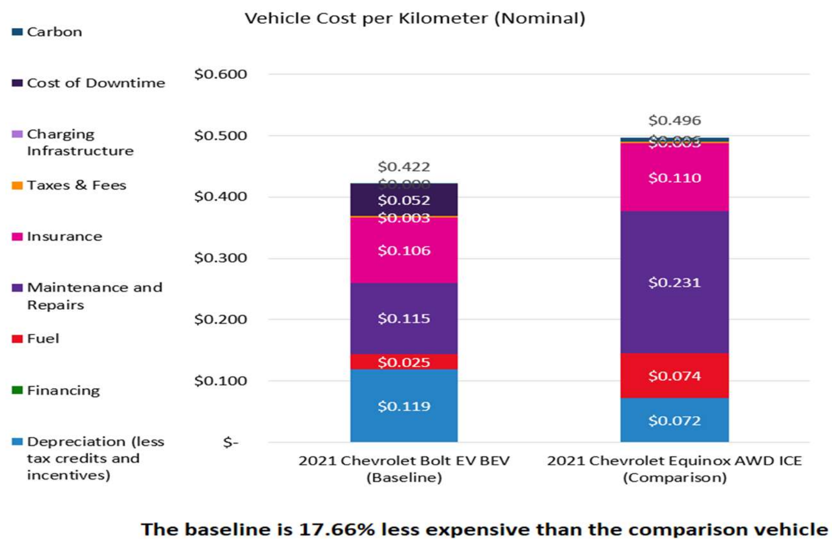

Fig.4.26. Cost per km for ownership duration of 12 years at a low gas price in case of Comparison 1

Fig. 4.26 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV is considerably more than its equivalent PBEV for this 12 years' ownership. Even with the low gasoline price for ICEV, Chevrolet Bolt EV is cheaper than Chevrolet Equinox ICE. However, the percentage increase is less than in the case of the current high gasoline price, i.e.,17.66%. Maintenance and repair costs contribute to making ICEV expensive at the low gasoline price.

Ownership period: 9 years

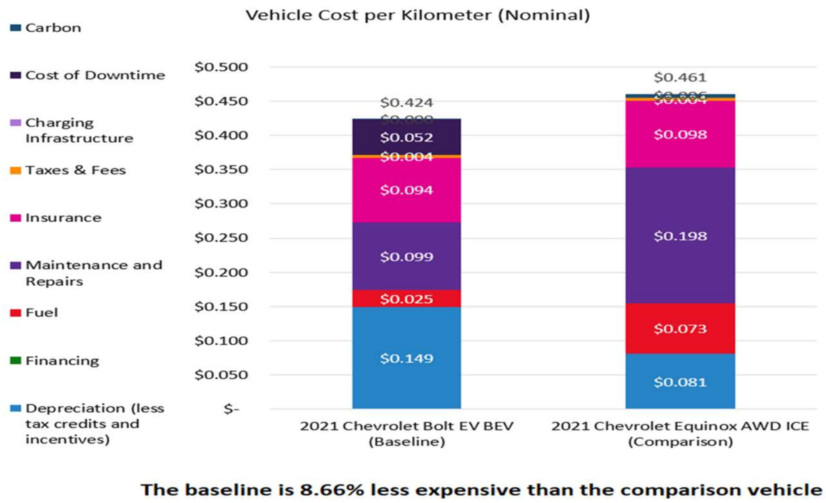

Fig.4.27. Cost per km for ownership duration of 9 years at a low gas price in case of Comparison 1

Fig. 4.27 shows, in the case of comparison 1, the nominal vehicle's cost/km of ICEV is considerably more than its equivalent PBEV for this nine years' ownership. The percentage increase becomes less with the decrease in ownership period, i.e.,8.66%, due to an increase in depreciation cost. Maintenance and repair costs contribute to making ICEV expensive at the low gasoline price.

Ownership period: 8 years

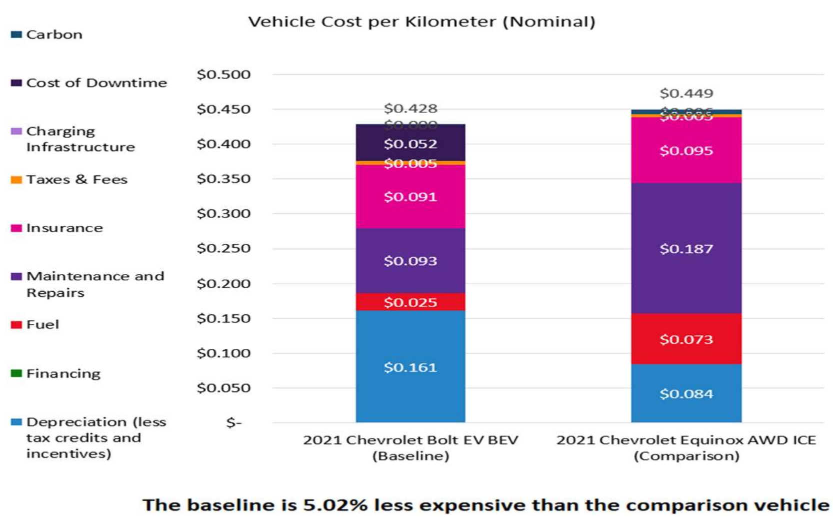

Fig.4.28. Cost per km for ownership duration of 8 years at a low gas price in case of Comparison 1

Fig. 4.28 shows, in the case of comparison 1, the nominal vehicle's cost/km of ICEV is more than its equivalent PBEV for eight years of ownership. The percentage increase becomes less with the decrease in ownership period, i.e., 5.02%. Maintenance and repair costs contribute to making ICEV expensive at the low gasoline price.

Ownership period: 7 years

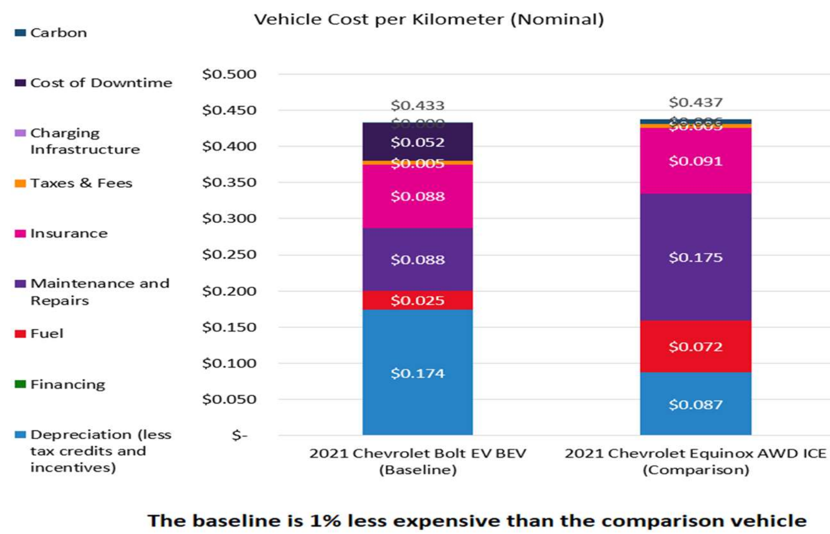

Fig.4.29. Cost per km for ownership duration of 7 years at a low gas price in case of Comparison 1

Fig. 4.29 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV is almost equal to its equivalent PBEV for seven years of ownership. The percentage increase gets more decrease with the decrease in ownership period, i.e., 1%. In this case, EV is only 1% less expensive, and its cost becomes balanced.

Ownership period: 5 years

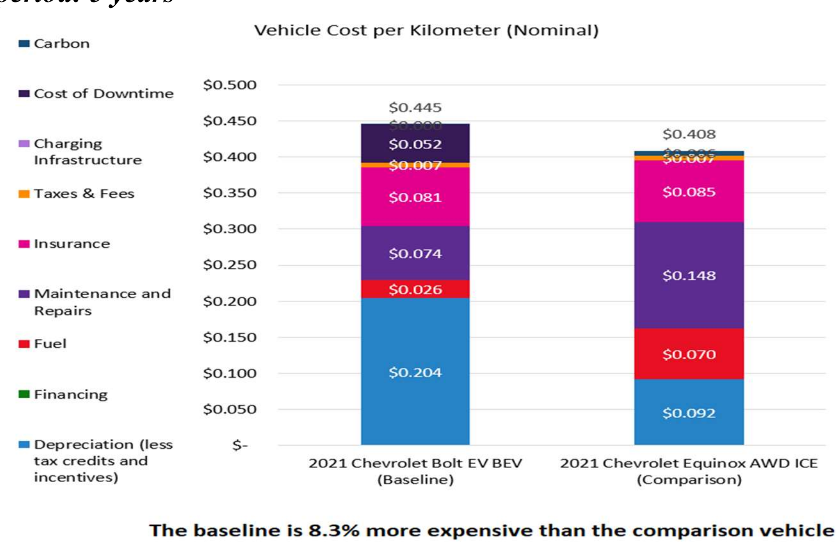

Fig.4.30. Cost per km for an ownership duration of 5 years at a low gas price in case of Comparison 1

Fig. 4.30 shows that in the case of comparison 1, the nominal vehicle's cost/km of ICEV turned to less than its equivalent PBEV for five years of ownership. The percentage increase turned out to be negative for PBEV, and PBEV became expensive, i.e., -8.3 %, due increase in depreciation cost with lowering ownership years.

4.1.3.2 *Comparison 2 (2021 Kia Soul BEV (180Ah) vs 2021 Kia Soul ICE)*

Ownership period: 12 years

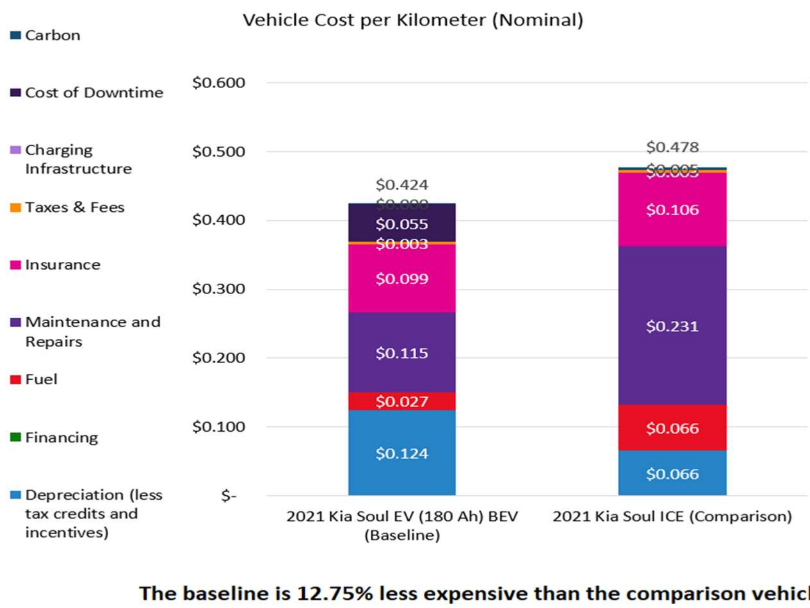

Fig.4.31. Cost per km for ownership duration of 12 years at a low gas price in case of Comparison 2

Fig. 4.31 shows, in the case of comparison 2, the nominal vehicle's cost/km of ICEV is considerably more than its equivalent PBEV for this 12 years' ownership. Even with the low gasoline price for ICEV, Kia Soul EV is cheaper than Kia Soul ICE. However, the percentage increase is less than in the case of the current high gasoline price, i.e.,12.75%. Maintenance and repair costs contribute to making ICEV expensive at the low gasoline price.

Ownership period: 9 years

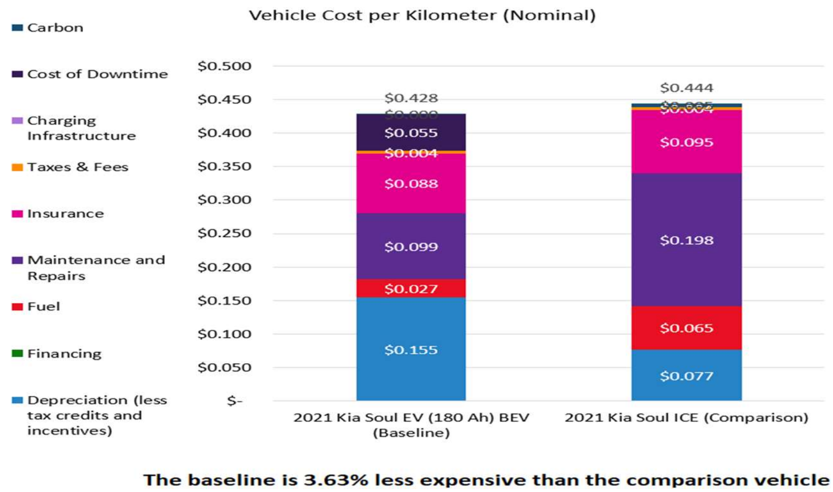

Fig.4.32. Cost per km for ownership duration of 9 years at a low gas price in case of Comparison 2

Fig. 4.32 shows that in the case of comparison 2, the nominal vehicle's cost/km of ICEV is slightly more than its equivalent PBEV for this ownership of nine years. The percentage increase becomes less with the decrease in ownership period, i.e., 3.63%, due to an increase in depreciation cost. Maintenance and repair costs contribute to making ICEV expensive at the low gasoline price.

Ownership period: 8 years

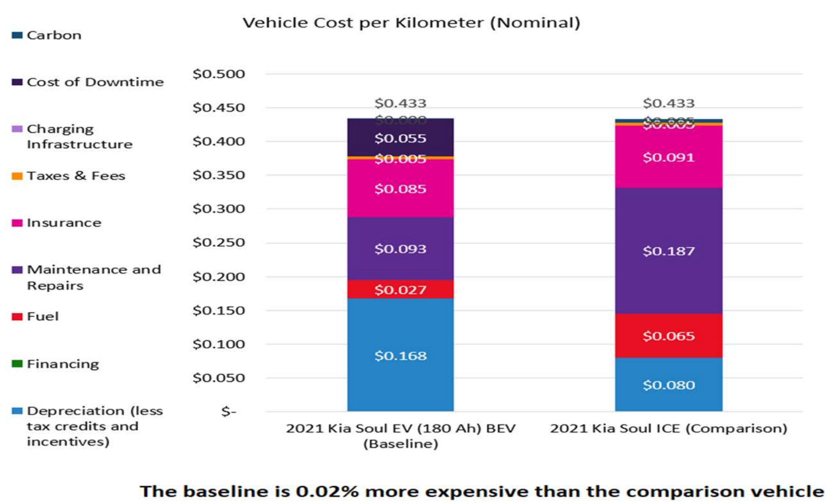

Fig.4.33. Cost per km for ownership duration of 8 years at a low gas price in case of Comparison 2

Fig. 4.33 shows that in comparison 2, the nominal vehicle's cost/km of ICEV becomes equal to its equivalent PBEV for ownership of eight years. Kia Soul EV will not be beneficial at a low gasoline price and eight years of ownership. The percentage increase became almost zero, and Kia EV turned towards expansiveness.

Ownership period: 7 years

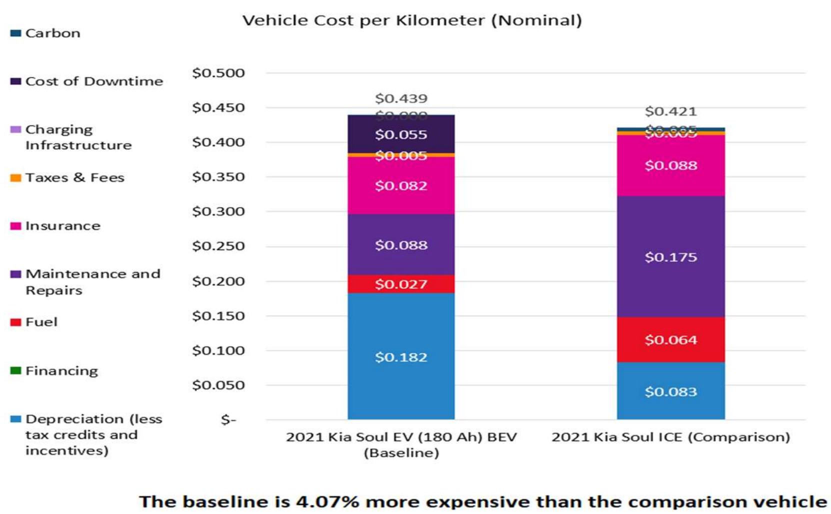

Fig.4.34. Cost per km for ownership duration of 7 years at a low gas price in case of Comparison 2

Fig. 4.34 shows, in the case of comparison 2, the nominal vehicle's cost/km of ICEV turned to less than its equivalent PBEV for seven years of ownership. At a low gasoline price and seven years ownership period, Kia Soul EV is more expensive. The percentage increase becomes negative to EV, i.e., 4.07%.

Ownership period: 5 years

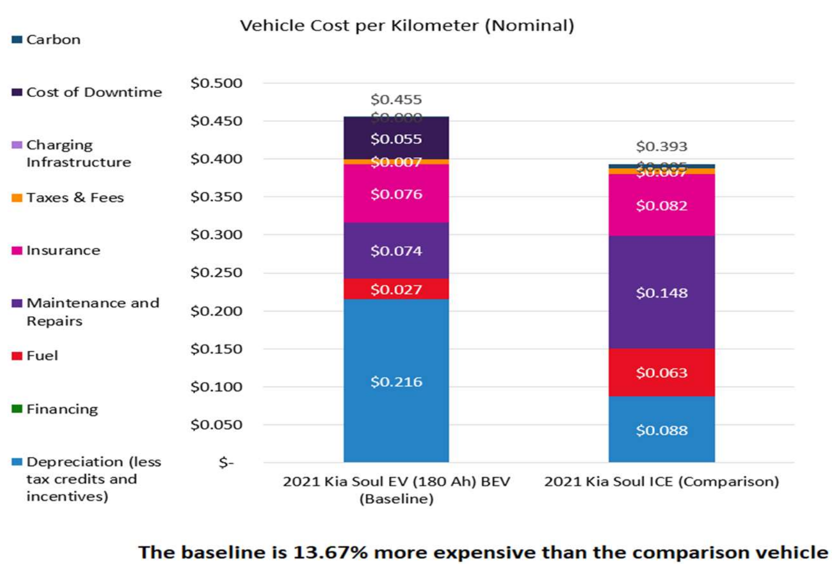

Fig.4.35. Cost per km for ownership duration of 5 years at a low gas price in case of Comparison 2

Fig. 4.35 shows that in comparison 2, the nominal vehicle's cost/km of ICEV is significantly less than its equivalent PBEV for five years' ownership. At a low gasoline price and five years ownership period, Kia Soul EV is more expensive. The percentage increase becomes negative to EV, i.e., -13.67%. The less ownership duration will; the more expensive EV will be.

4.1.3.3 *Comparison 3 (2021 Hyundai KONA electric vs 2021 Hyundai Kona ICE)*

Ownership period: 12 years

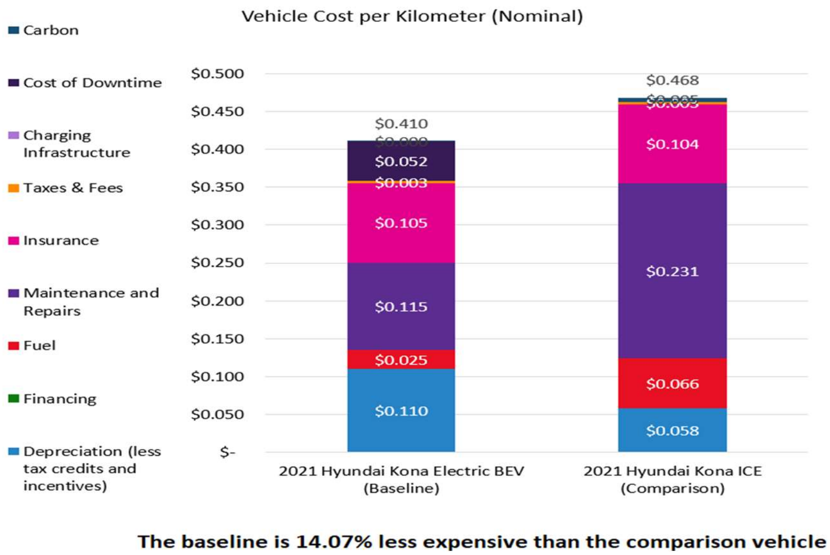

Fig.4.36. Cost per km for ownership duration of 12 years at a low gas price in case of Comparison 3

Fig. 4.36 shows that in the case of comparison 3, the nominal vehicle's cost/km of ICEV is considerably more than its equivalent PBEV for this 12 years' ownership. Even with the low gasoline price for ICEV, Hyundai Kona EV is cheaper than Hyundai Kona ICE. However, the percentage increase is less than in the case of the current high gasoline price, i.e.,14.07%. Maintenance and repair costs contribute to making ICEV expensive at the low gasoline price.

Ownership period: 9 years

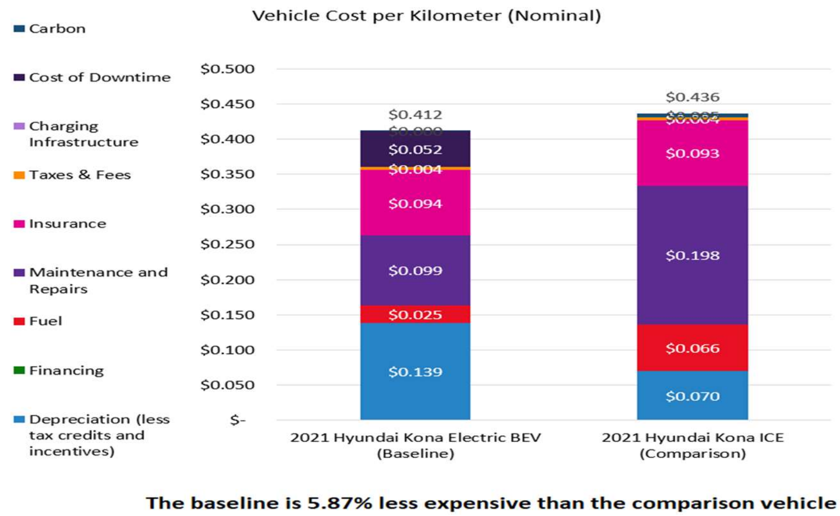

Fig.4.37. Cost per km for ownership duration of 9 years at a low gas price in case of Comparison 3

Fig. 4.37 shows that in the case of comparison 3, the nominal vehicle's cost/km of the Hyundai Kona ICEV is slightly more than its equivalent PBEV for this nine years' ownership. The percentage increase of Hyundai ICE is reduced to 5.87% with the decrease in owning period.

Ownership period: 8 years

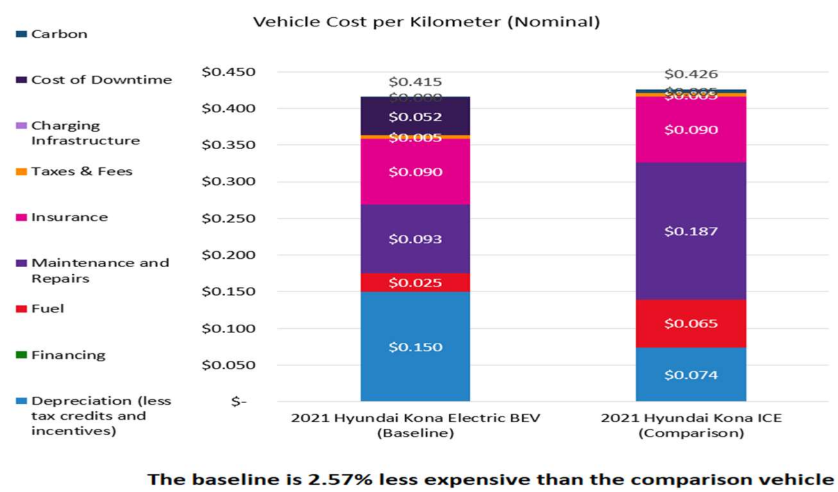

Fig.4.38. Cost per km for ownership duration of 8 years at a low gas price in case of Comparison 3

Fig. 4.38 shows that in comparison 3, the nominal vehicle's cost/km of the Hyundai Kona ICEV is slightly more than its equivalent PBEV for this ownership of eight years. The percentage increase of Hyundai ICE is reduced to 2.57% with the decrease in owning period.

Ownership period: 7 years

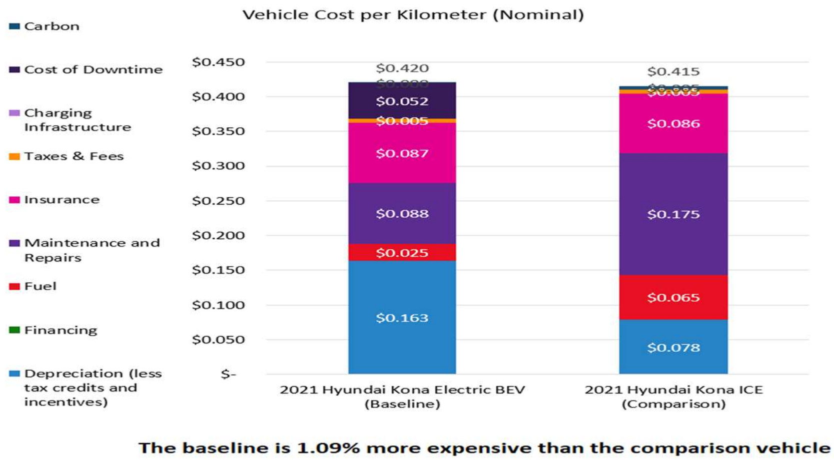

Fig.4.39. Cost per km for ownership duration of 7 years at a low gas price in case of Comparison 3

Fig. 4.39 shows that in comparison 3, the nominal vehicle's cost/km of the Hyundai Kona ICEV is slightly less than its equivalent PBEV for this ownership of seven years. Hyundai Kona electric has become expensive at this ownership period and low gasoline price. The percentage increase of Hyundai ICE is reduced to -1.09% with the decrease in owning period, which represents the cheapness of Hyundai ICEV at this point.

Ownership period: 5 years

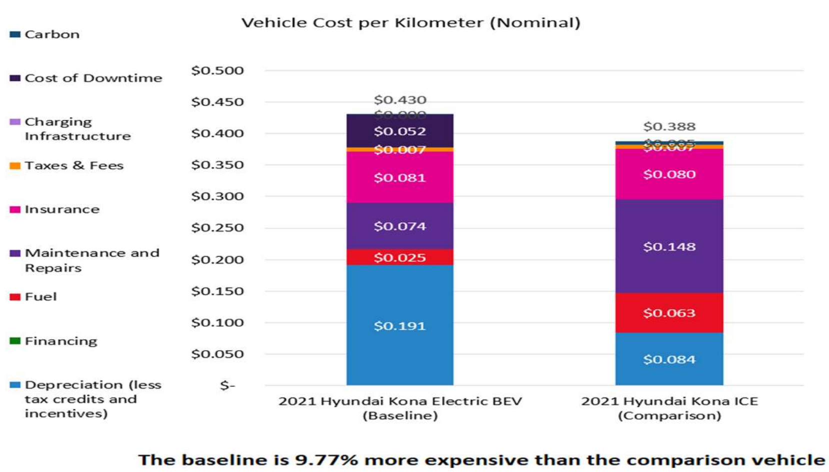

Fig.4.40. Cost km for ownership duration of 5 years at a low gas price in case of Comparison 3

Fig. 4.40 shows that in comparison 3, the nominal vehicle's cost/km of the Hyundai Kona ICEV is less than its equivalent PBEV for this ownership of five years. Hyundai Kona electric has become more expensive at this ownership period and low gasoline price.

The percentage increase of Hyundai ICE is reduced to -9.77% with the decrease in owning period, which represents more expensiveness of the Hyundai Kona EV.

4.1.3.4 *Comparison 4 (2021 Volvo XC40 Recharge BEV vs 2021 Volvo XC40 ICE)*

Ownership period: 12 years

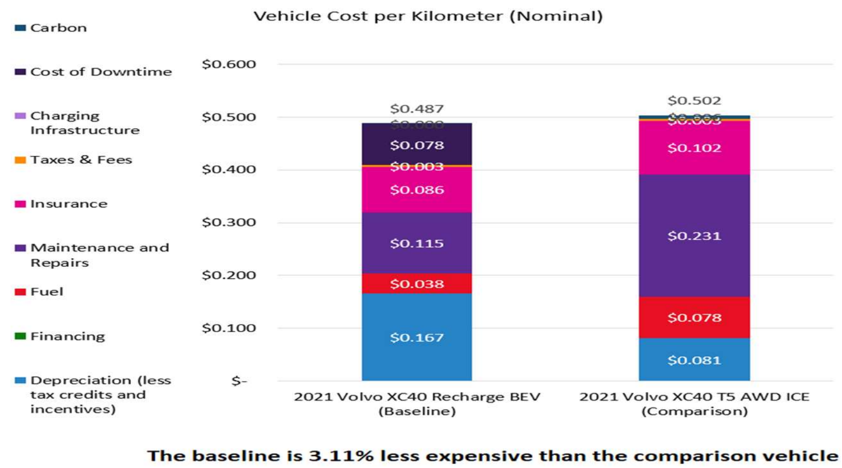

Fig.4.41. Cost per km for ownership duration of 12 years at a low gas price in case of Comparison 4

Fig. 4.41 shows that in the case of comparison 4, the nominal vehicle's cost/km of ICEV is slightly more than its equivalent PBEV for this 12 years' ownership. The percentage increase in the case of Volvo XC40 EV and ICEV is less as compared to other EV vehicles at this consideration, i.e., the XC40 EV is only 3.11% less expensive than XC40 ICEV.

Ownership period: 9 years

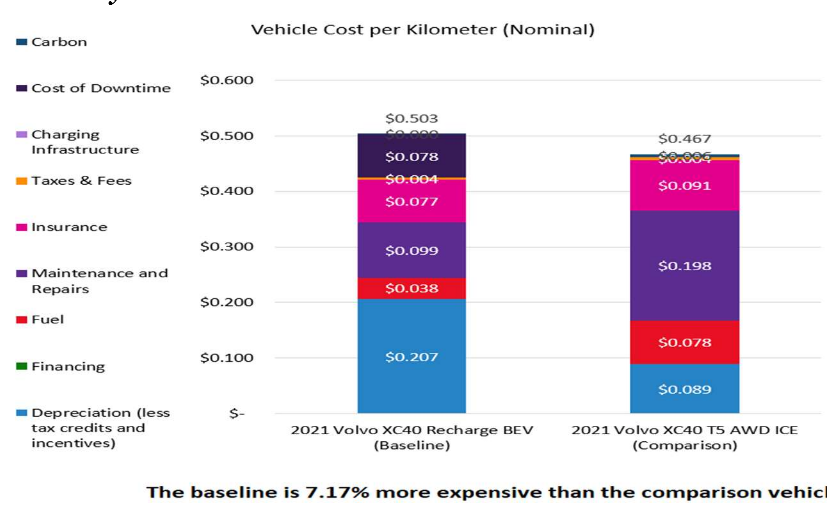

Fig.4.42. Cost per km for ownership duration of 9 years at a low gas price in case of Comparison 4

Fig. 4.42 shows that in comparison 4, the nominal vehicle's cost/km of ICEV is less than its equivalent PBEV for the ownership of nine years. At this ownership period and low gasoline price, Volvo EV become expensive with a percentage increase of -7.17%.

Ownership period: 8 years

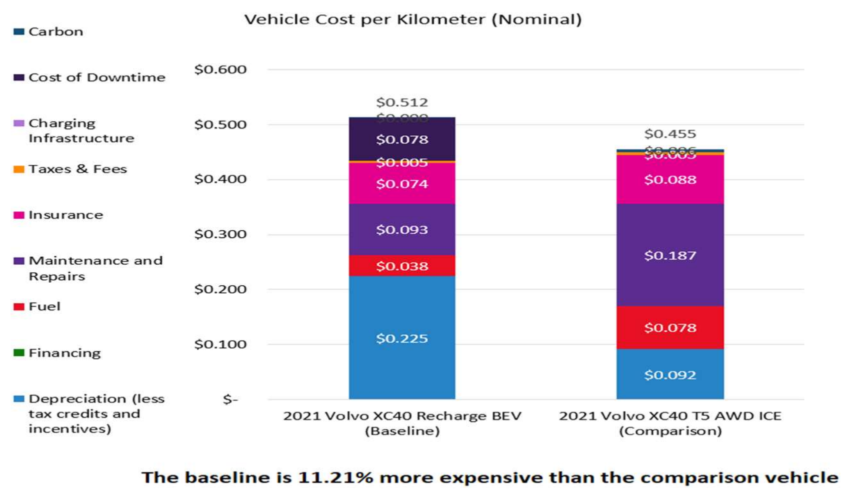

Fig.4.43. Cost per km for ownership duration of 8 years at a low gas price in case of Comparison 4

Fig. 4.43 shows that in comparison 4, the nominal vehicle's cost/km of ICEV is significantly less than its equivalent PBEV for the ownership of eight years. At this ownership period and low gasoline price, Volvo EV become more expensive with a percentage increase of -11.21%.

Ownership period: 7 years

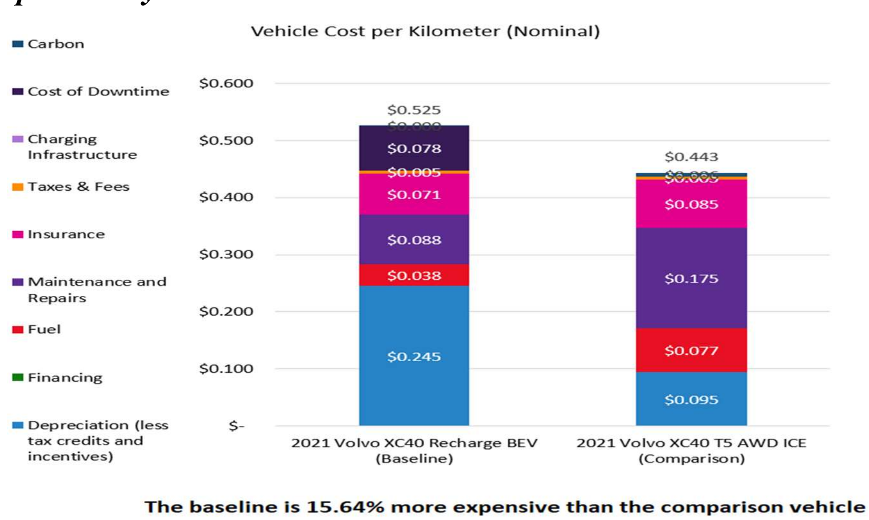

Fig. 4.44. Cost per km for ownership duration of 7 years at a low gas price in case of Comparison 4

Fig. 4.44 shows that in comparison 4, the nominal vehicle's cost/km of ICEV is significantly less than its equivalent PBEV for the ownership of seven years. At this ownership period and low gasoline price, Volvo EV become more expensive with a percentage increase of -15.64%.

Ownership period: 5 years

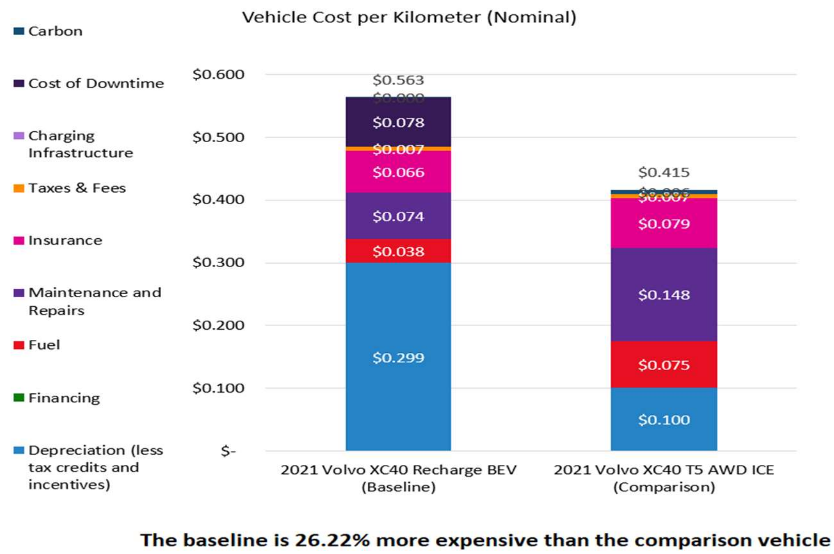

Fig.4.45. Cost per km for ownership duration of 5 years at a low gas price in case of Comparison 4

Fig. 4.45 shows that in the case of comparison 4, the nominal vehicle's cost/km of ICEV is significantly less than its equivalent PBEV for ownership of five years. At this ownership period and low gasoline price, Volvo EV become more expensive with a percentage increase of -26.22%. As there is a decrease in ownership years, the Economic viability of electric vehicle versions becomes negative.

4.1.3.5 *Comparison 5 (2021 Tesla Model 3 BEV (180Ah) vs 2021 Toyota Camry ICE)*

Ownership period: 12 years

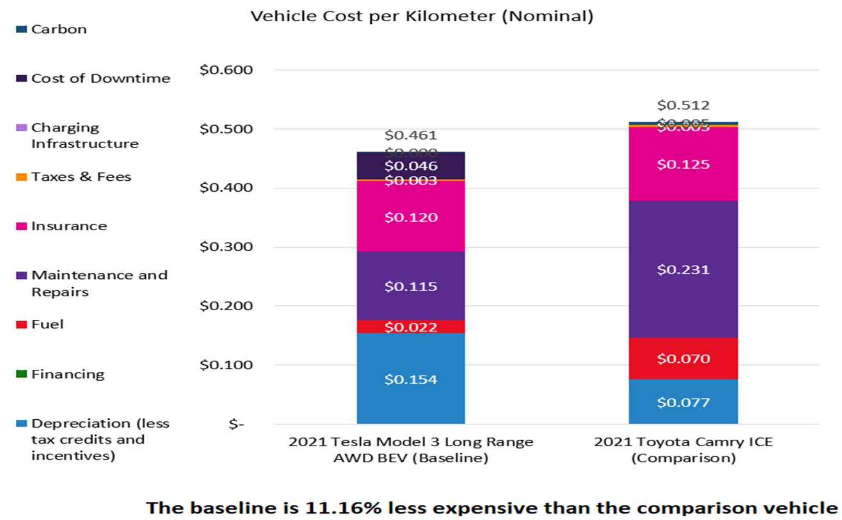

Fig.4.46. Cost per km for ownership duration of 12 years at a low gas price in case of Comparison 5

Fig. 4.46 shows that in the case of comparison 5, the nominal vehicle's cost/km of ICEV is considerably more than its equivalent PBEV for this 12 years' ownership. Even with the low gasoline price for ICEV, Tesla Model 3 EV is cheaper than Toyota Camry ICE. However, the percentage increase is less than in the case of the current high gasoline price, i.e.,11.16%. Maintenance and repair costs contribute to making ICEV expensive at the low gasoline price.

Ownership period: 9 years

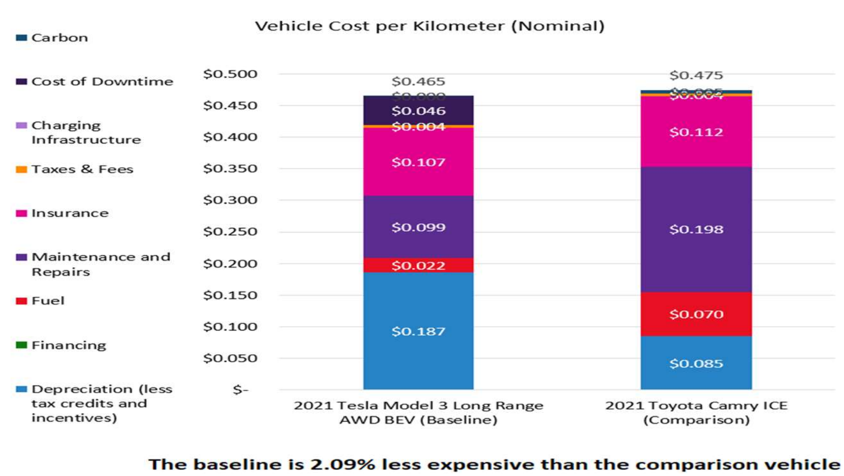

Fig.4.47. Cost per km for ownership duration of 9 years at a low gas price in case of Comparison 5

Fig. 4.47 shows that in comparison 5, the nominal vehicle's cost/km of Toyota Camry ICE is slightly more than its equivalent PBEV for this nine years' ownership. Tesla Model 3 is only 2.09% less expensive than the Toyota Camry, with the ownership of 9 years and a gasoline price of $0.74/L.

Ownership period: 8 years

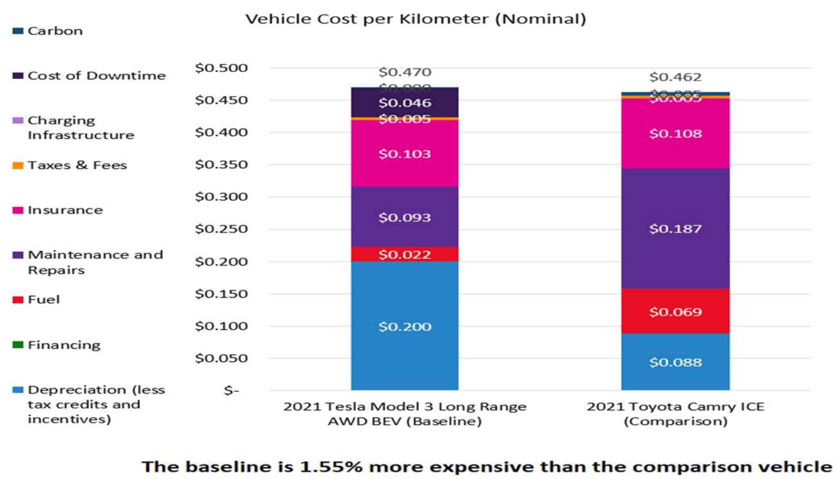

Fig.4.48. Cost per km for ownership duration of 8 years at a low gas price in case of Comparison 5

Fig. 4.48 shows that in the case of comparison 5, the nominal vehicle's cost/km of Toyota Camry ICE is slightly less than its equivalent PBEV for this ownership of eight years. At this point, Tesla Model 3 is become more expensive than Toyota Camry by 1.55%.

Ownership period: 7 years

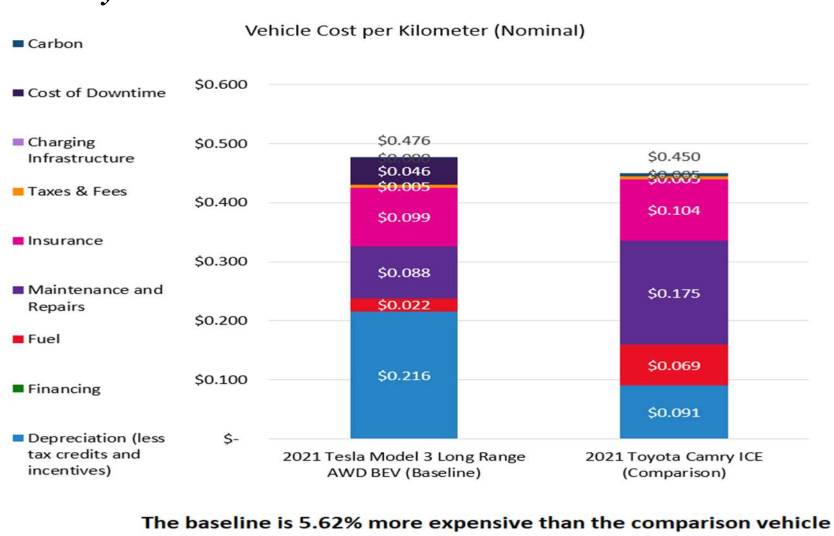

Fig.4.49. Cost per km for ownership duration of 7 years at a low gas price in case of Comparison 5

Fig. 4.49 shows that in the case of comparison 5, the nominal vehicle's cost/km of Toyota Camry ICE is less than its equivalent PBEV for this seven years' ownership. The percentage of expensiveness has increased with decreasing ownership years. At this point, Tesla Model 3 is become more expensive than Toyota Camry by 5.62%.

Ownership period: 5 years

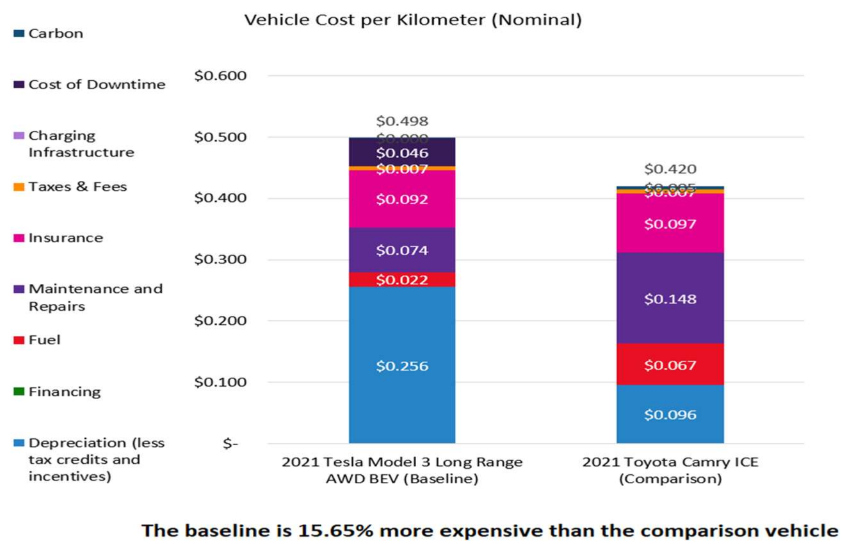

Fig.4.50. Cost per km for an ownership duration of 5 years at a low gas price in case of Comparison 5

Fig. 4.50 shows that in the case of comparison 5, the nominal vehicle's cost/km of Toyota Camry ICE is less than its equivalent PBEV for this ownership of five years. The percentage of expensiveness has been more increased with decreasing ownership years. At this point, Tesla Model 3 is become more expensive than Toyota Camry by 15.65%

4.1.3.6 *Economic status of Electric vehicles at Low Gasoline price($0.74/L)*

The following table shows economic percentages and status of electric vehicles 8 years and above. The positive values of percentages represent the Electric vehicles are cheaper than their equivalent ICEs and vice versa.

TABLE 4.5. ECONOMIC STATUS AT A CONSTANT LOW GASOLINE PRICE ($0.74/L) AND VARIOUS OWNERSHIP YEARS

Electric Vehicle's Models	**Beneficence percentages (%) of Electric vehicles of at gasoline price of $0.74/L over different ownership periods ("Positive" = economical and "negative" = non-economical)**			
	12 years	**9 years**	**8 years**	**Economical Status at 8 years and above**
2021 Chevrolet Bolt EV	17.66	8.66	5.02	Most economical
2021 Hyundai KONA electric (Preferred)	14.07	5.87	2.57	Economical
2021 Kia Soul EV(Limited)	12.75	3.63	-0.02	Economical
2021 Tesla Model 3	11.16	2.09	-1.55	Less economical
2021 Volvo XC40 Recharge	3.11	-7.17	-11.21	Least Economical

4.1.4 *Comparisons at Constant Ownership period (9 years) and varying Lowest gas price*

This results section presents the economic viability of five groups of vehicles over different low gasoline prices and a nine-year base ownership period. The evaluation of these results will show us the minimum threshold of gasoline prices below which PBEVs are not economical at the medium ownership period.

4.1.4.1 *Comparaison 1(2021 Chevrolet Bolt EV BEV vs 2021 Chevrolet Equinox ICE)*

Lowest Gas Price (0.50$/L)

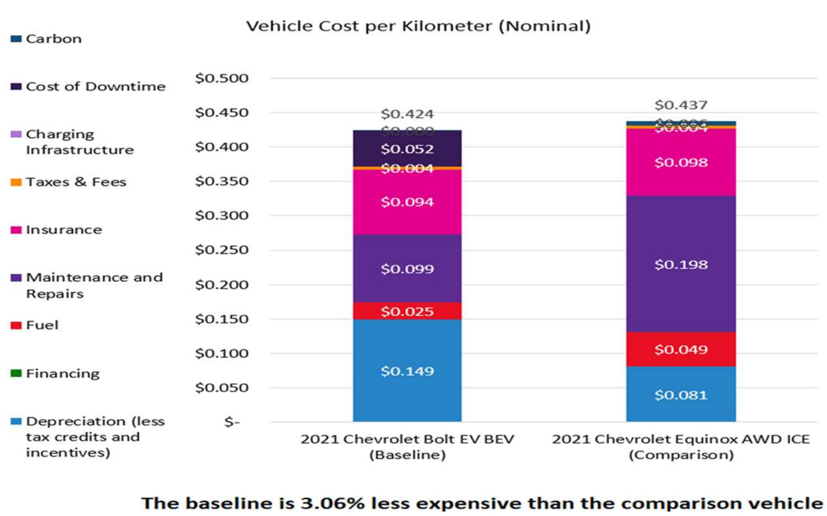

Fig.4.51. Cost per km for the lowest gas price ($0.50/l) at nine years' ownership for comparison 1

Fig 4.51 presents PBEV and ICEV's Cost per kilometre in case of comparison one at the very lowest gasoline price of $0.50/L. At this lowest price of gasoline, Chevrolet BOLT EV is still cheaper than its equivalent ICEV. However, its percentage is less, i.e., 3.06%.

Lower Gas Price (0.60$/L)

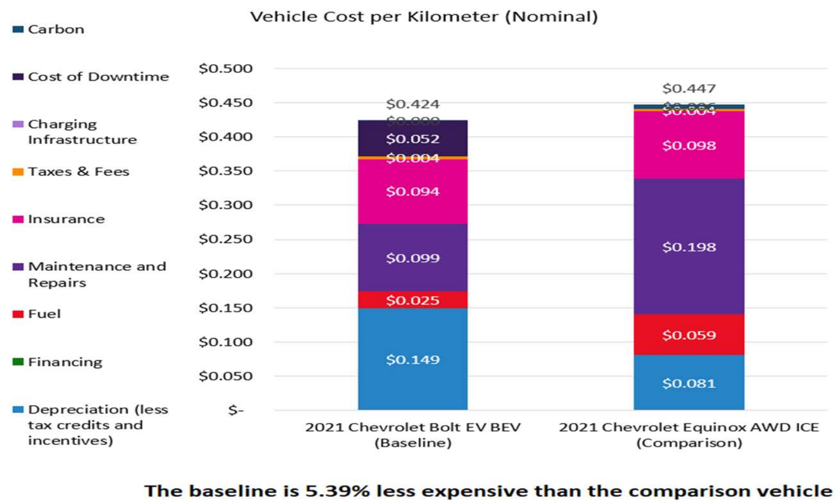

Fig.4.52. Cost per km for the lower gas price ($0.60/l) at nine years' ownership for comparison 1

Fig 4.52 presents PBEV and ICEV's Cost per kilometre in case of comparison one at the low gasoline price of $0.60/L. At this second low price of gasoline, Chevrolet BOLT EV is still cheaper than its equivalent ICEV, but it is more than the $0.50/L case. The percentage of cheapness is increased by increasing gasoline prices.

Low Gas Price (0.65$/L)

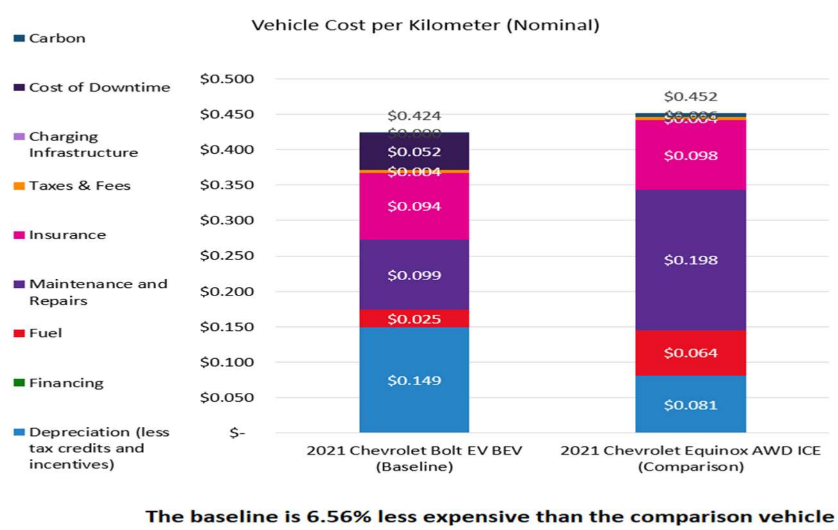

Fig.4.53. Cost per km for the lower gas price ($0.65/l) at nine years' ownership for comparison 1

Fig 4.53 presents PBEV and ICEV's Cost per kilometre in case of comparison one at the low gasoline price of $0.65/L. At this low price of gasoline, Chevrolet BOLT EV is cheaper than its equivalent ICEV but more than the $0.60/L case. The percentage of cheapness is increased by increasing gasoline prices.

4.1.4.2 *Comparison 2 (2021 Kia Soul EV BEV (180Ah) vs 2021 Kia Soul ICE)*

Lowest Gas Price (0.50$/L)

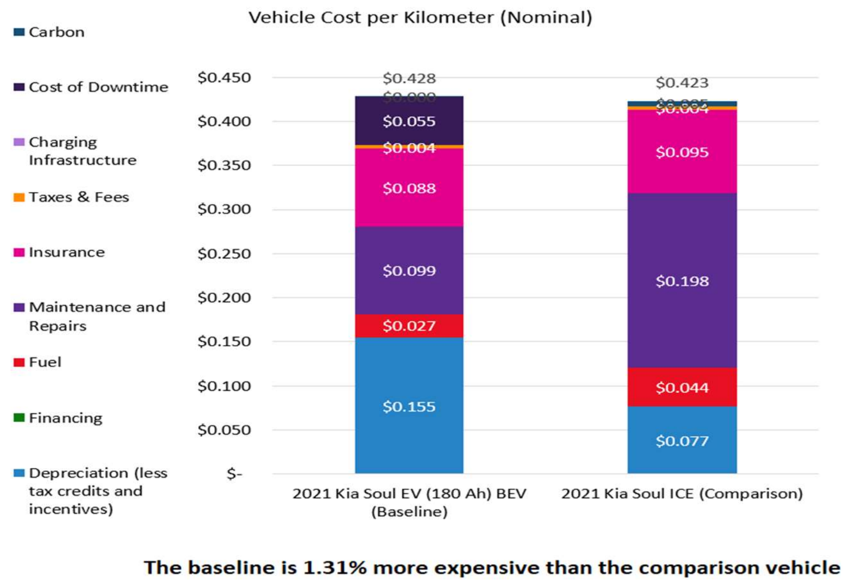

Fig.4.54. Cost per km for the lowest gas price ($0.50/l) at nine years' ownership for comparison 2

Fig 4.54 presents PBEV and ICEV's Cost per kilometre in the case of comparison two at the very lowest gasoline price of $0.50/L. At this lowest price of gasoline, Kia Soul EV is more expensive than its equivalent ICEV. However, its percentage is less, i.e., 1.31%.

Lower Gas Price (0.60$/L)

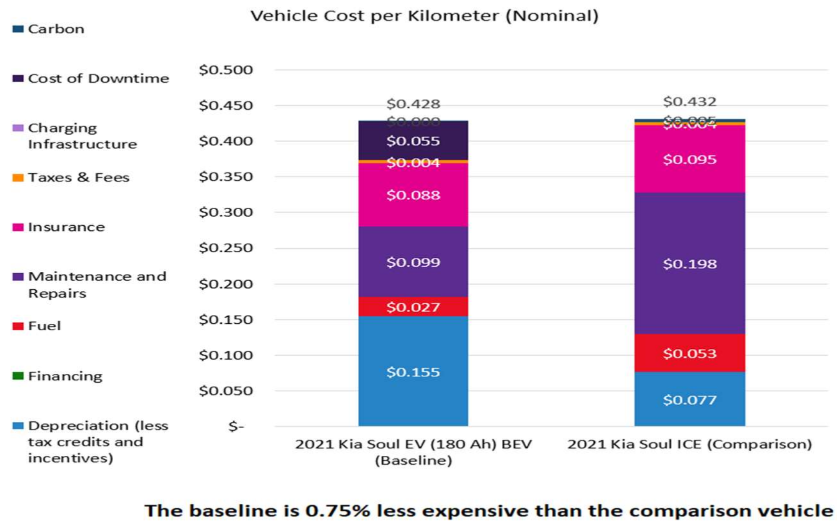

Fig.4.55. Cost per km for the lower gas price ($0.60/l) at nine years' ownership for comparison 2

Fig 4.55 presents PBEV and ICEV's Cost per kilometre in case of comparison two at the low gasoline price of $0.60/L. At this second low price of gasoline, Kia Soul EV becomes cheaper than its equivalent ICEV, but the percentage is significantly less. The TOC of Kia Soul EV and Kia Soul ICEV is almost equal at this gasoline price.

Low Gas Price (0.65$/L)

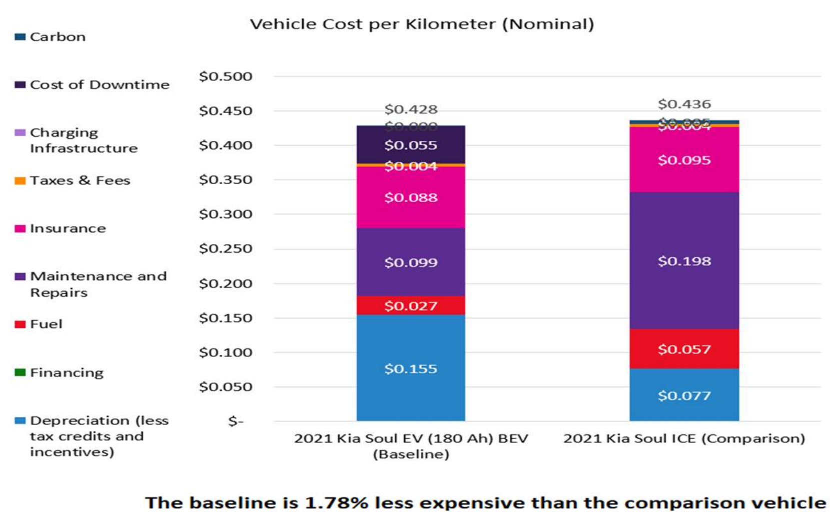

Fig.4.56. Cost per km for the lower gas price ($0.65/l) at nine years' ownership for comparison 2

Fig 4.56 presents PBEV and ICEV's Cost per kilometre in case of comparison two at the low gasoline price of $0.65/L. At this low price of gasoline, Kia Soul EV is still cheaper than its equivalent ICEV, but it is more than the $0.60/L case. The percentage of cheapness is increased by increasing gasoline prices. For the case of the Kia comparison, the percentage increase is very low due to the high initial cost of the Kia EV.

4.1.4.3 *Comparison 3 (2021 Hyundai KONA electric vs 2021 Hyundai Kona (ICE)*

Lowest Gas Price (0.50$/L)

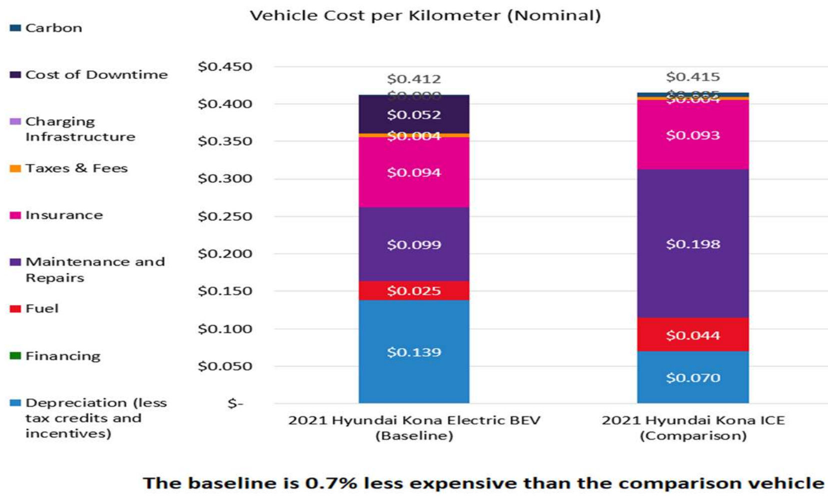

Fig.4.57. Cost per km for the lowest gas price ($0.50/l) at nine years' ownership for comparison 3

Fig 4.57 presents PBEV and ICEV's Cost per kilometre in case of comparison three at the very lowest gasoline price of $0.50/L. At this lowest price of gasoline, the cost/km of Hyundai Kona electric and ICE is almost equal. Hyundai Kona EV is only 0.7% less expensive than its gasoline version.

Lower Gas Price (0.60$/L)

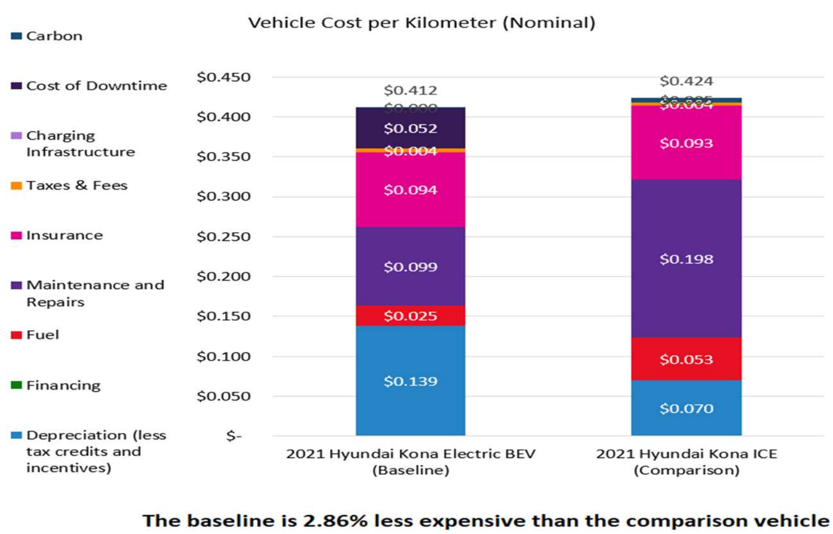

Fig.4.58. Cost per km for the lower gas price ($0.60/l) at nine years' ownership for comparison 3

Fig 4.58 presents PBEV and ICEV's Cost per kilometre in case of comparison three at the low gasoline price of $0.60/L. At this low price of gasoline, the cost/km of Hyundai Kona electric is slightly less than its equivalent. The percentage difference has been increased to 2.86%.

Low Gas Price (0.65$/L)

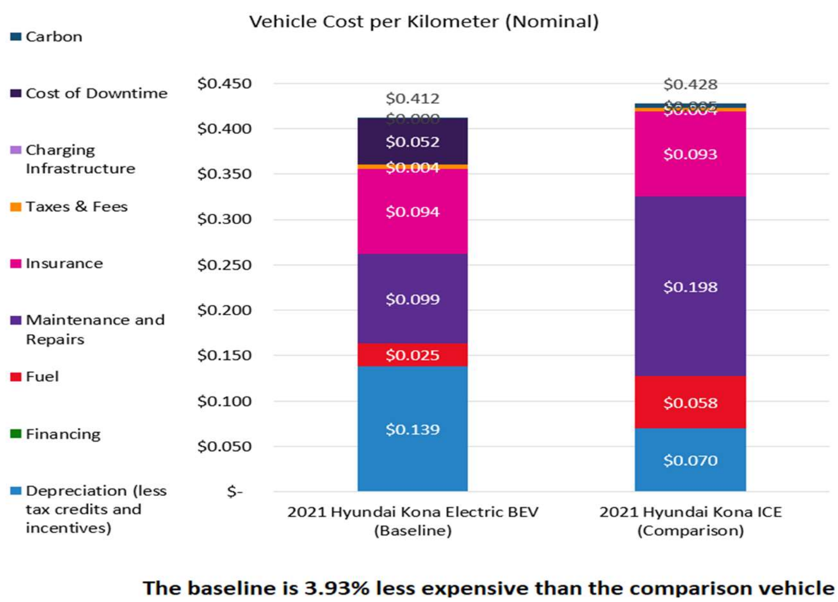

Fig.4.59. Cost per km for the lower gas price ($0.65/l) at nine years' ownership for comparison 3

Fig 4.59 presents PBEV and ICEV's Cost per kilometre in case of comparison three at the low gasoline price of $0.65/L. At this low price of gasoline, the cost/km of Hyundai Kona electric is less than its equivalent. The percentage difference has increased to 3.93%, which is more than the percentage at $0.60/L.

4.1.4.4 Comparison 4 (2021 Volvo XC40 Recharge BEV vs 2021 Volvo XC40 ICE*)*

Lowest Gas Price (0.50$/L)

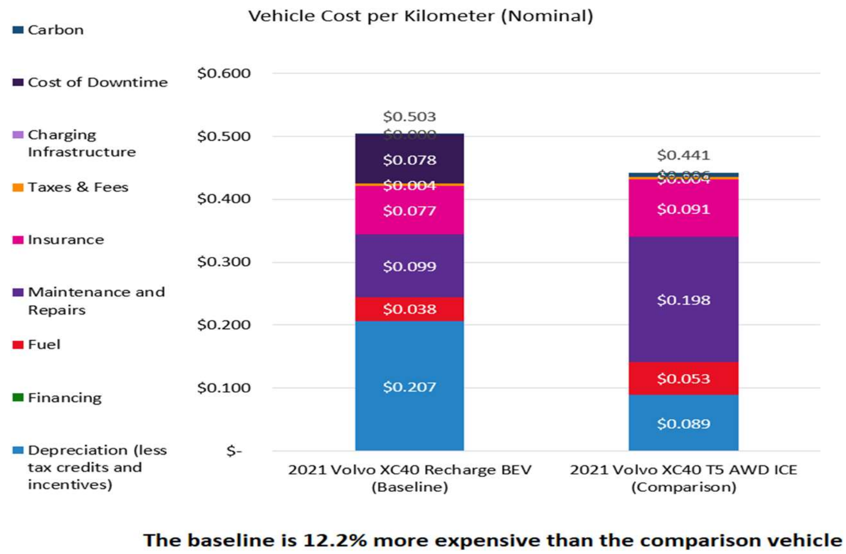

Fig.4.60. Cost per km for the lowest gas price ($0.50/l) at 9 years' ownership for comparison 4

Fig 4.60 presents PBEV and ICEV's Cost per kilometre in the case of comparison four at the very lowest gasoline price of $0.50/L. At this lowest price of gasoline, the cost/km of Volvo XC40 electric is more than Volvo XC40 gasoline. XC40 EV is 12.2% more expensive due to the high depreciation price. This low gasoline price is in favour of XC40 ICE.

Lower Gas Price (0.60$/L)

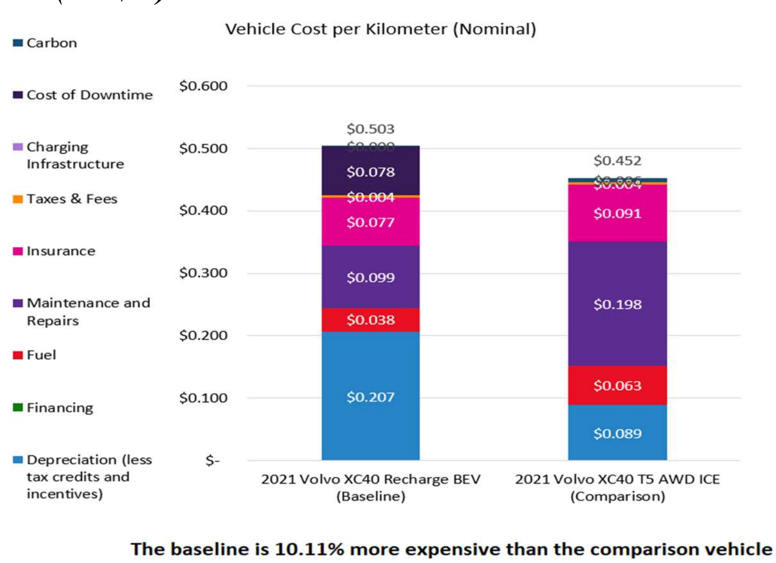

Fig.4.61. Cost per km for the lower gas price ($0.60/l) at nine years' ownership for comparison 4

Fig 4.61 presents PBEV and ICEV's Cost per kilometre in case of comparison four at a low gasoline price of $0.60/L. At this low price of gasoline, the cost/km of Volvo XC40 electric is considerably more than Volvo XC40 gasoline. XC40 EV is 10.11%. This gasoline price is also not favourable for the XC40 EV.

Low Gas Price (0.65$/L)

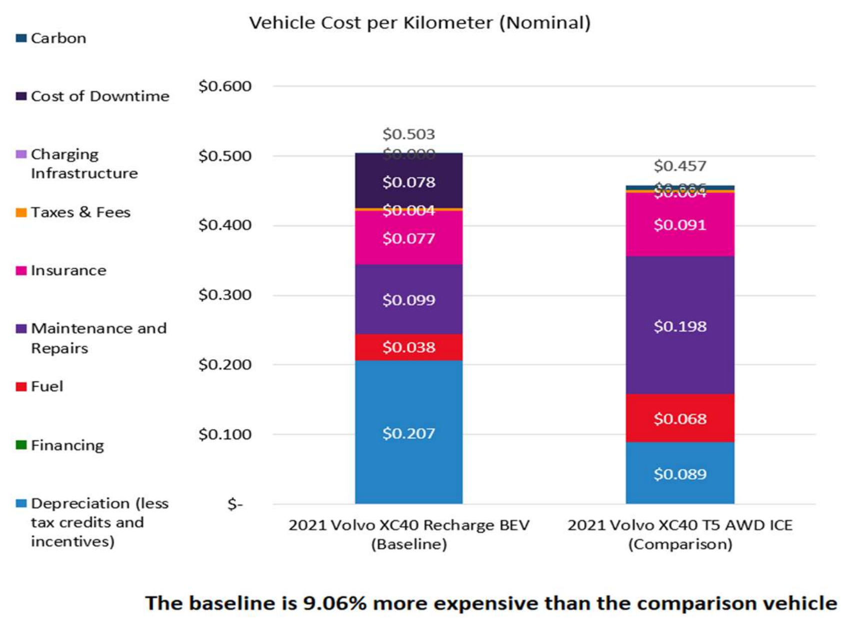

Fig.4.62. Cost per km for the lower gas price ($0.65/l) at nine years' ownership for comparison 4

Fig 4.62 presents PBEV and ICEV's Cost per kilometre in case of comparison four at a low gasoline price of $0.65/L. At this low price of gasoline, the cost/km of Volvo XC40 electric is considerably more than Volvo XC40 gasoline. XC40 EV is 9.06%. This gasoline price is also not favourable for the XC40 EV. Although, the expensiveness percentage is reduced.

4.1.4.5 *Comparison 5 (2021 Tesla Model 3 BEV (180Ah) vs 2021 Toyota Camry ICE)*

Lowest Gas Price (0.50$/L)

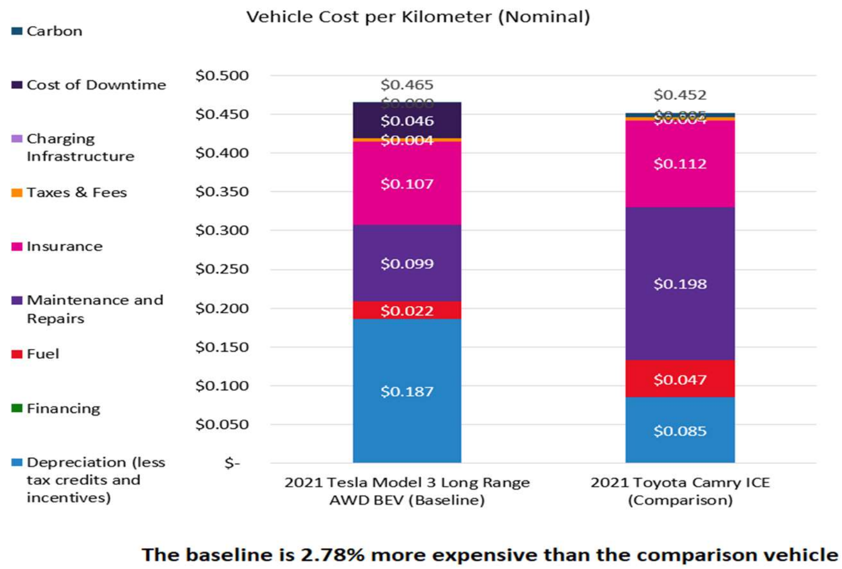

Fig.4.63. Cost per km for the lowest gas price ($0.50/l) at nine years' ownership for comparison 5

Fig 4.63 presents PBEV and ICEV's Cost per kilometre in case of comparison five at the very lowest gasoline price of $0.50/L. At this lowest price of gasoline, the cost/km of the Tesla Model 3 is slightly more than Toyota Camry ICE. Tesla Model 3 EV is 2.78% more expensive due to the high depreciation price.

Lower Gas Price (0.60$/L)

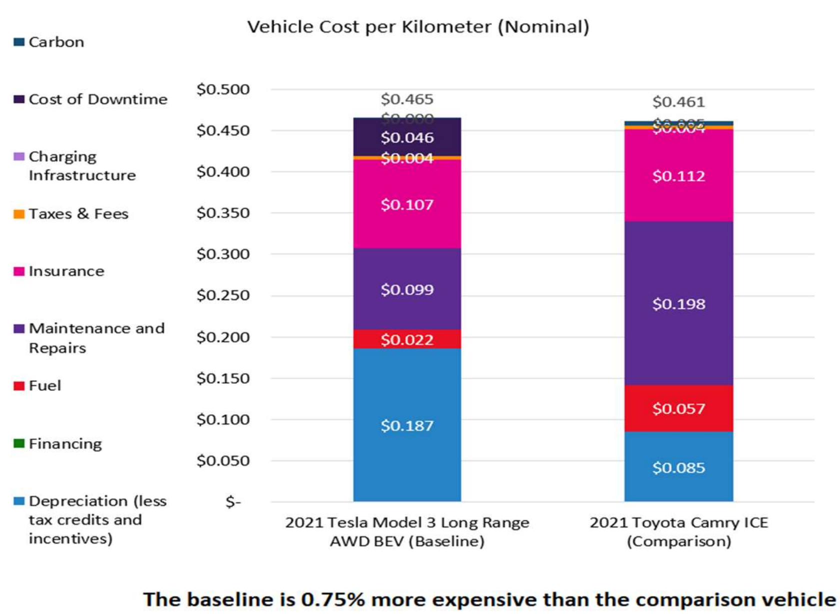

Fig.4.64. Cost per km for the lower gas price ($0.60/l) at nine years' ownership for comparison 5

Fig 4.64 presents PBEV and ICEV's Cost per kilometre in case of comparison five at a low gasoline price of $0.60/L. At this low price of gasoline, the cost/km of Tesla Model 3 approaches to be equal to the Toyota Camry ICE. Tesla Model 3 is 0.75% more expensive than Toyota Camry ICE. At this gasoline price, both vehicles are balanced with each other.

Low Gas Price (0.65$/L)

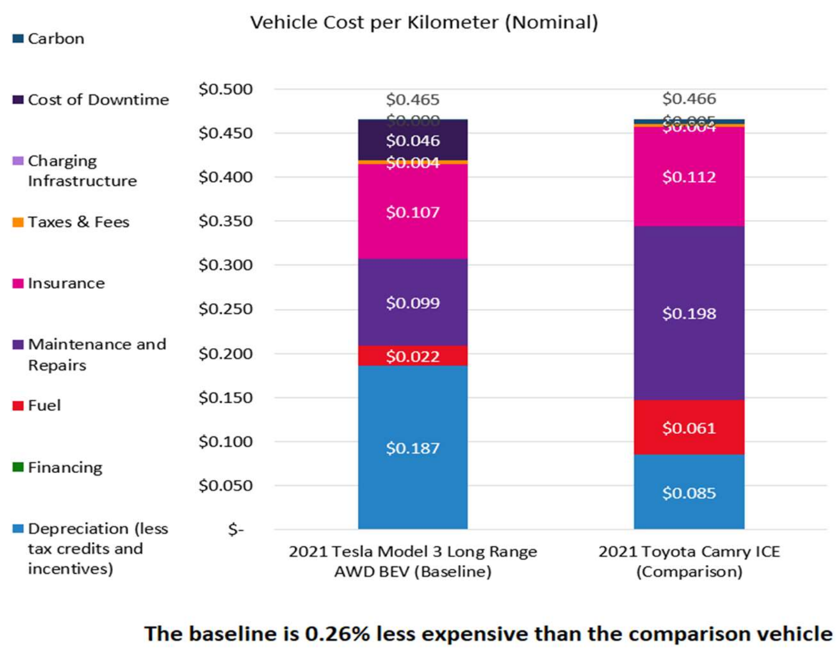

Fig.4.65. Cost per km for the lower gas price ($0.65/l) at nine years' ownership for comparison 5

Fig 4.65 presents PBEV and ICEV's Cost per kilometre in case of comparison five at a low gasoline price of $0.65/L. At this low price of gasoline, the cost/km of the Tesla Model 3 also approaches being equal to Toyota Camry ICE. However, Tesla Model 3 is 0.26% less expensive as compared to Toyota Camry ICE.

4.1.4.6 *Economic status of Electric vehicles according to Lowest Gasoline prices*

The following table shows economic percentages and status of electric vehicles over 9 years and three different low gasoline prices. The positive values of percentages represent the Electric vehicles are cheaper than their equivalent ICEs and vice versa.

TABLE 4.6. ECONOMIC STATUS AT A CONSTANT OWNERSHIP PERIOD AND VARIOUS LOW GASOLINE PRICES

Electric Vehicle's Models	**Beneficence percentages (%) of Electric vehicles of at various gasoline prices over 9-year ownership ("Positive" = economical and "negative" = non-economical)**			
	\$0.50/L	**\$0.60/L**	**\$0.65/L**	**Economical Status at low gasoline prices**
2021 Chevrolet Bolt EV	3.06	5.39	6.56	Economical
2021 Hyundai KONA electric	0.7	2.86	3.93	Less economical
2021 Kia Soul EV(Limited)	-1.31	0.75	1.78	Less economical
2021 Tesla Model 3	-2.78	-0.75	0.26	Non-economical
2021 Volvo XC40 Recharge	-12.2	-10.11	-9.06	Non-economical

4.1.5 *Cash Flow analysis of vehicle over various ownership periods at current high gas price*

This results section provides information about the annual cash flows throughout different ownership periods. Net cash flow is the sum of cash flow in and out. The positive cash flow of fleets at the end of the ownership period represents the vehicle's sale value. The vehicle will give enough capital upon its sale. In contrast, negative cash flow shows that the vehicle's value is less than operating costs, etc. The vehicles on negative cash flow at the end of the ownership period do not possess much more cost.

4.1.5.1 *Comparaison 1(2021 Chevrolet Bolt EV BEV vs 2021 Chevrolet Equinox ICE)*

Ownership period = 12 years

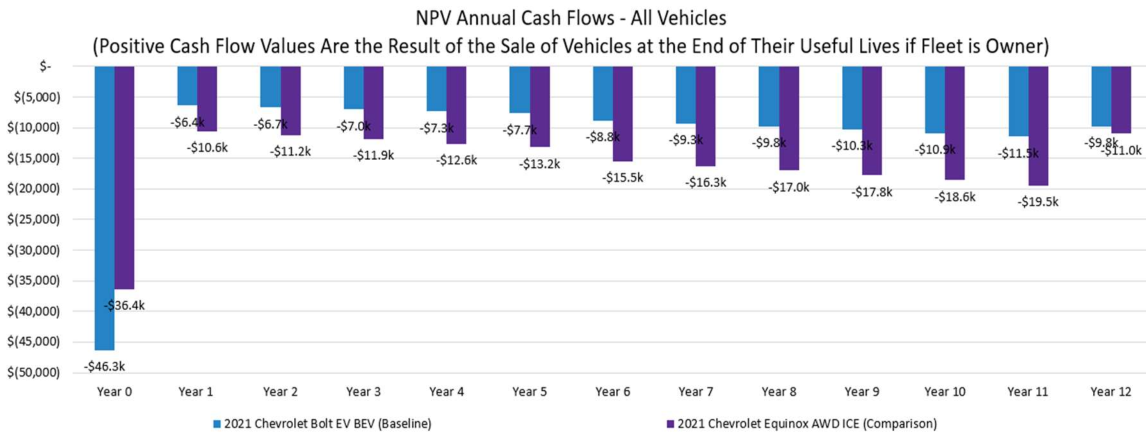

Fig.4.66. Cash flow chart over 12 years in the case of Chevrolet Bolt EV and Equinox ICE

Fig 4.66 shows that in the case of comparison 1, at the purchasing stage (years 0), the cash outflow for Chevrolet Bolt EV is more than Chevrolet Equinox ICE. Whereas, at the end of the ownership period, the cash outflow of Bolt EV is less compared to its opponent, which indicates the low operating Cost of EV compared to ICE. However, both vehicles have negative cash flow over the ownership of 12 years.

Ownership period = 9 years

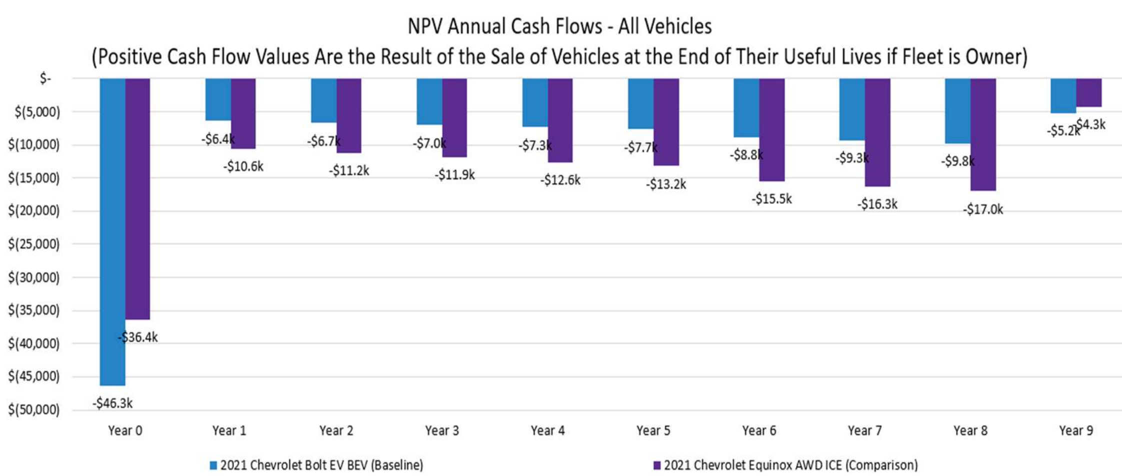

Fig.4.67. Cash flow chart over nine years in the case of Chevrolet Bolt EV and Equinox ICE

Fig 4.67 shows that in the case of comparison 1, at the purchasing stage (years 0), the cash outflow for Chevrolet Bolt EV is still more than Chevrolet Equinox ICE due to the high acquisition cost. Furthermore, in the 9th year of ownership, EV cash outflow is more. But still, both vehicles have negative cash flow over the ownership of 9 years.

Ownership period = 5 years

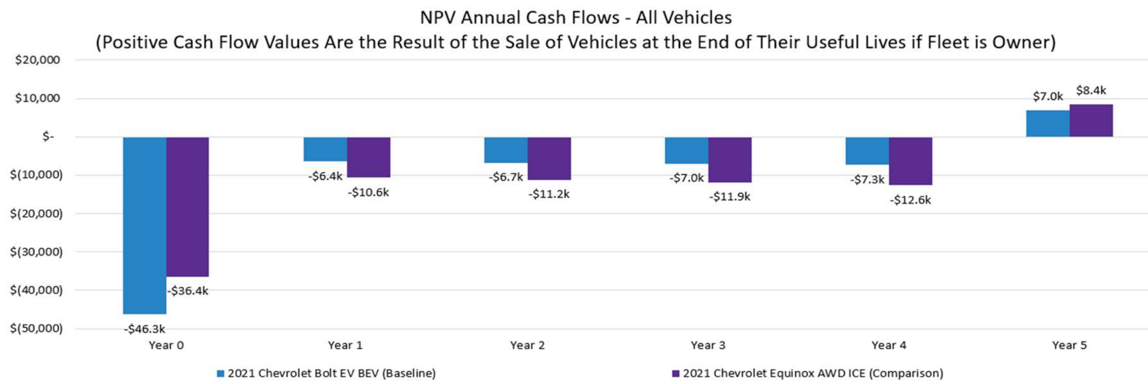

Fig. 4.68. Cash flow chart over five years in the case of Chevrolet Bolt EV and Equinox ICE

Fig 4.68 presents that in the case of comparison 1, at the purchasing stage (years 0), the cash outflow for Chevrolet Bolt EV is still more than Chevrolet Equinox ICE due to high acquisition cost. At the end of ownership of 5 years, both vehicles have positive cash flow, which means the vehicles have considerable value compared to higher years of ownership.

4.1.5.2 *Comparison 2 (2021 Kia Soul EV BEV (180Ah) vs 2021 Kia Soul ICE)*

Ownership period= 12 years

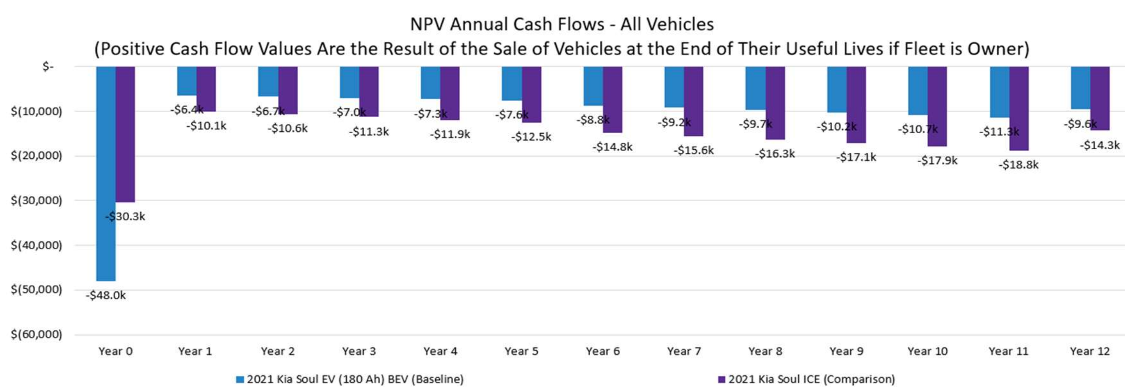

Fig.4.69. Cash flow chart over 12 years in the case of KIA Soul EV and Soul ICE

Fig 4.69 shows that in comparison 2, at the purchasing stage (years 0), the cash outflow for Kia soul EV is considerably more than Kia Soul ICE. Whereas, at the end of the ownership period, the cash outflow of Soul EV is less compared to its opponent, which indicates the low operating Cost of EV compared to ICE. But both vehicles have negative net cash flow over the ownership of 12 years.

Ownership period= 9 years

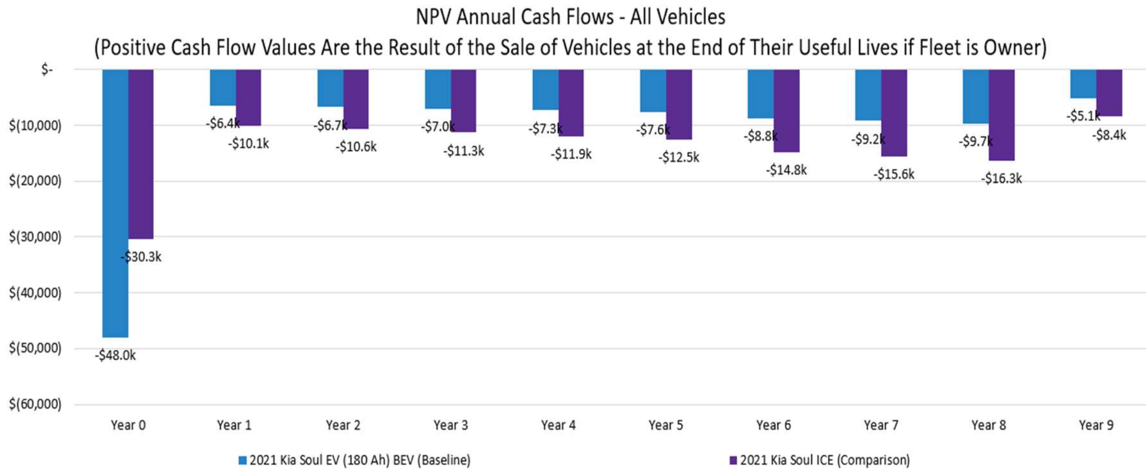

Fig.4.70. Cash flow chart over nine years in the case of KIA Soul EV and Soul ICE

Fig 4.70 shows, in the case of comparison 2, at the purchasing stage (years 0), the cash outflow for Kia Soul EV is still more than Kia Soul ICE due to the high acquisition cost of EV. At the end of the ownership period of 9 years, negative net cash flow is reduced, and it is higher for Kia Soul EV.

Ownership period= 5 years

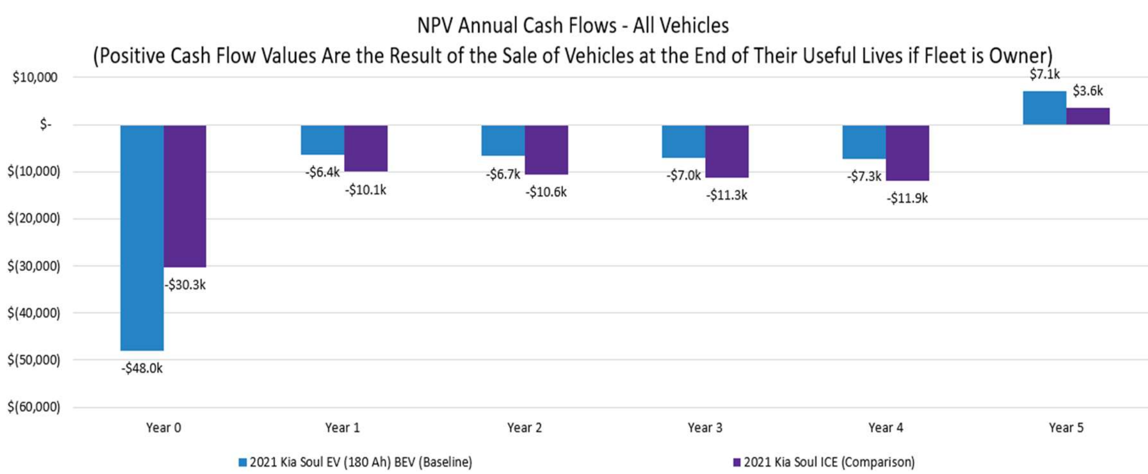

Fig.4.71. Cash flow chart over five years in the case of KIA Soul EV and Soul ICE

Fig 4.71 shows that in the case of comparison 2, at the purchasing stage (years 0), the cash outflow for Kia Soul EV is still more than Kia Soul ICE due to the high acquisition cost of EV. At the end of the ownership period of 5 years, the net cash flow is turned to positive, and it is higher for Kia Soul EV. Positive net cash flow represents the significant value of the vehicle at the end of the ownership period.

4.1.5.3 *Comparison 3 (2021 Hyundai KONA electric vs 2021 Hyundai Kona ICE)*

Ownership period = 12 years

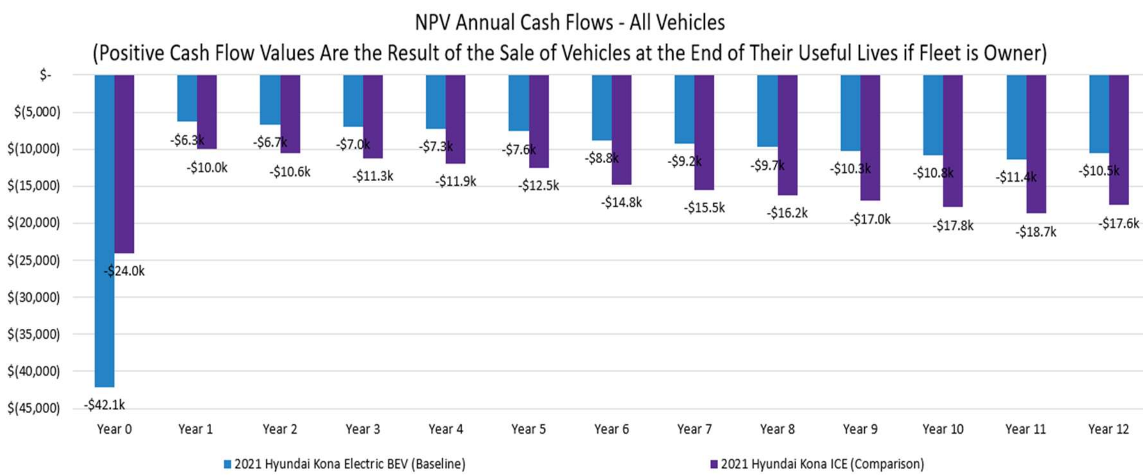

Fig.4.72. Cash flow chart over 12 years in the case of Hyundai Kona EV and Kona ICE

Fig 4.72 shows cash flow for comparison 3. It represents that at the purchasing stage (years 0), the cash outflow for Hyundai Kona EV is considerably more than Hyundai Kona ICE. Whereas, at the end of the ownership period, the cash outflow of Kona EV is less than its opponent, indicating the low operating Cost of EV compared to ICE. But both vehicles have negative net cash flow over the ownership of 12 years.

Ownership period = 9 years

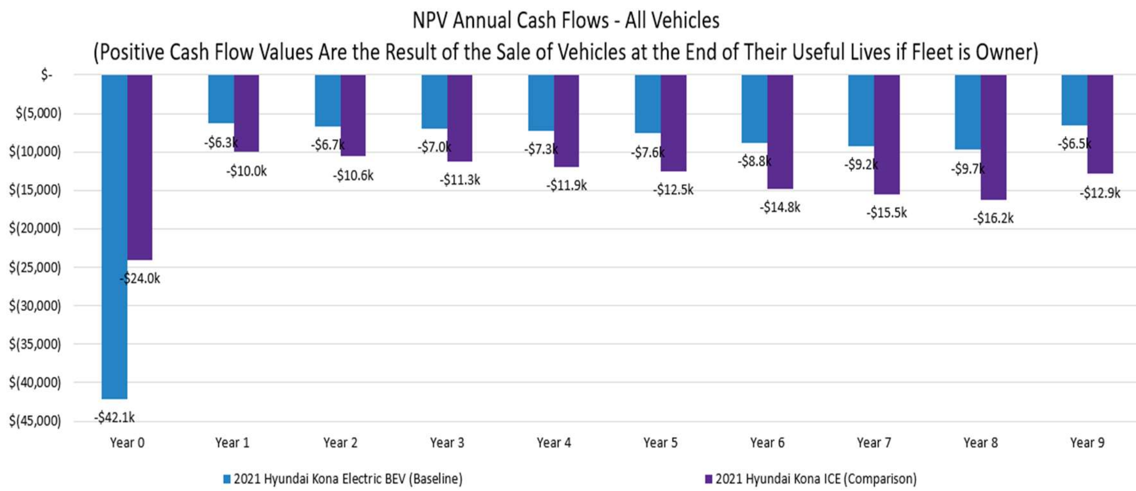

Fig.4.73. Cash flow chart over nine years in the case of Hyundai Kona EV and Kona ICE

Fig 4.73 shows cash flow for comparison 3. It represents that at the purchasing stage (years 0), the cash outflow for Hyundai Kona EV is considerably more than Hyundai Kona ICE. Whereas, at the end of the ownership period, the cash outflow of Kona EV is less compared to its opponent, which indicates the low operating Cost of EV compared to ICE. But both vehicles have negative net cash flow over the ownership of 9 years.

Ownership period = 5 years

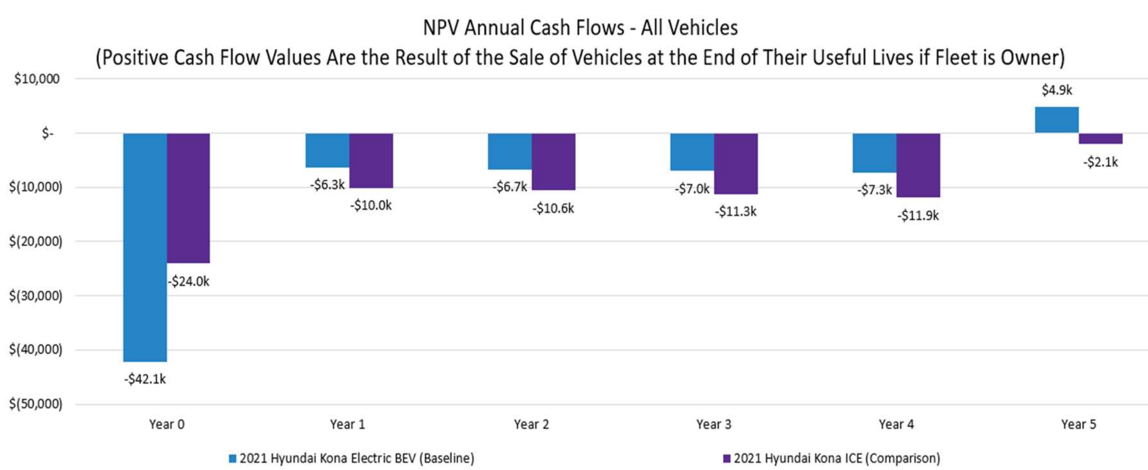

Fig.4.74. Cash flow chart over five years in the case of Hyundai Kona EV and Kona ICE

Fig 4.74 shows in case ownership of 5 years for comparison 3, at the purchasing stage (years 0), the cash outflow for Hyundai Kona EV is considerably more than Hyundai

Kona ICE. Whereas, at the end of the ownership period, Kona EV's cash outflow is very low compared to its opponent, so the net cash flow is positive, while for Hyundai Kona ICE, it is still negative. It represents that Hyundai Kona has more value as compared to the Hyundai Kona ICE at the end of ownership of five years.

4.1.5.4 *Comparison 4 (2021 Volvo XC40 Recharge BEV vs 2021 Volvo XC40 ICE)*

Ownership period = 12 years

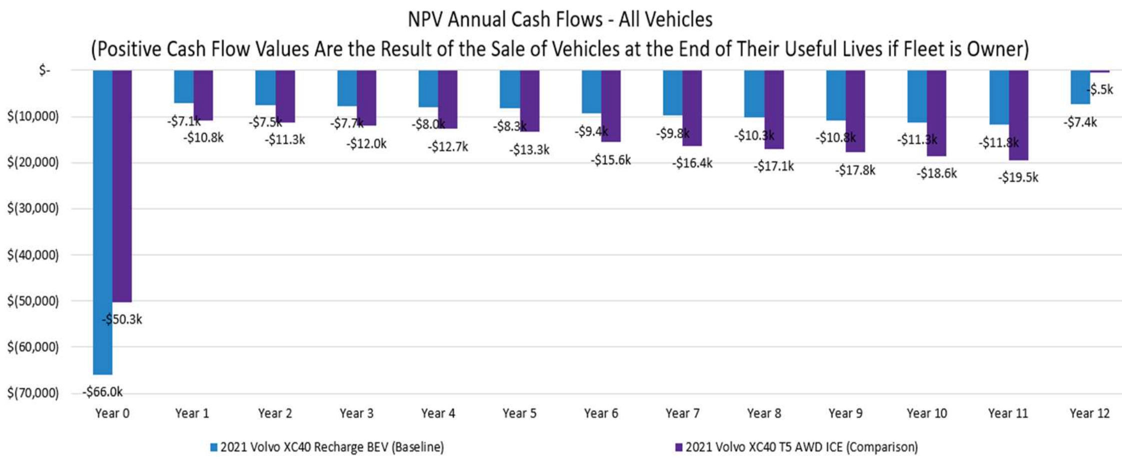

Fig.4.75. Cash flow chart over 12 years in the case of Volvo XC40 EV and XC40 ICE

Fig 4.75 shows in case ownership of 12 years for comparison 4, at the purchasing stage (years 0), the cash outflow for Volvo XC40 EV is considerably more than Volvo XC40 ICE. Whereas, at the end of the ownership period, the cash outflow of the XC40 EV is still more than its opponent, which means Volvo XC40 ICE has more value than the XC40 ICE. However, the net cash flow for both vehicles is negative.

Ownership period = 9 years

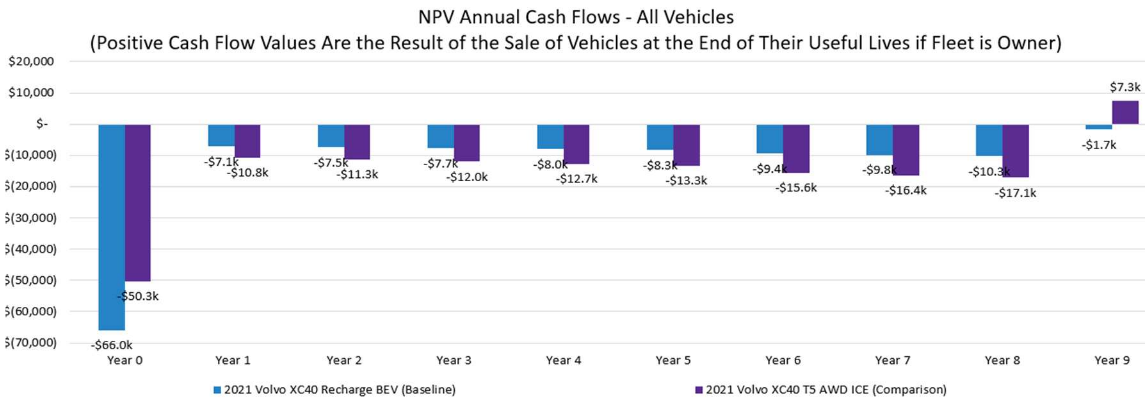

Fig.4.76. Cash flow chart over nine years in the case of Volvo XC40 EV and XC40 ICE

Fig 4.76 shows in case ownership of 9 years for comparison 4, at the purchasing stage (years 0), the cash outflow for Volvo XC40 EV is considerably more than Volvo XC40 ICE. Whereas, at the end of the ownership period cash outflow of XC40 EV is still more in comparison to its opponent, and the net cash flow of EV is still negative, while Volvo XC40 ICE has positive cash flow at the end of 9 years. This means Volvo XC40 ICE has more value than the XC40 EV.

Ownership period = 5 years

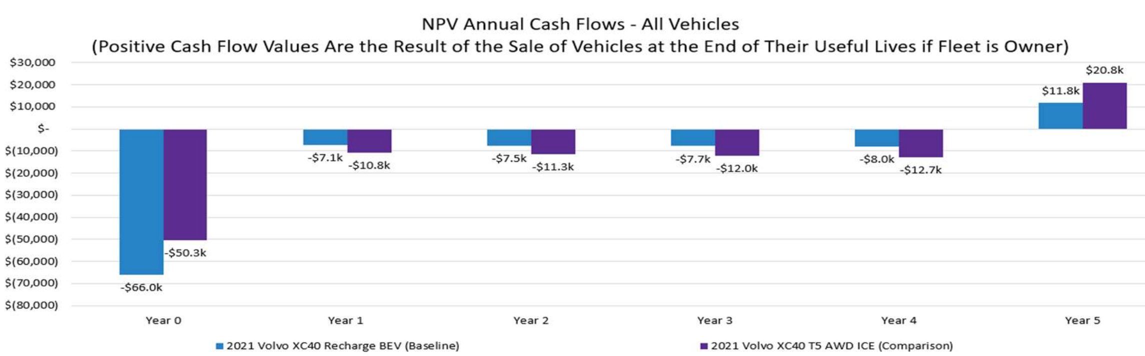

Fig.4.77. Cash flow chart over five years in the case of Volvo XC40 EV and XC40 ICE

Fig 4.77 shows in case ownership of 5 years for comparison 4, at the purchasing stage (years 0), the cash outflow for Volvo XC40 EV is considerably more than Volvo XC40 ICE. Whereas, at the end of the ownership period, the cash outflow of XC40 EV is still more in comparison to its opponent, but the net cash flow of EV is positive for both

XC40 EV and ICEV. Volvo XC40 ICE has more value than the XC40 EV.

4.1.5.5 *Comparison 5 (2021 Tesla Model 3 BEV (180Ah) vs 2021 Toyota Camry ICE)*

Ownership period = 12 years

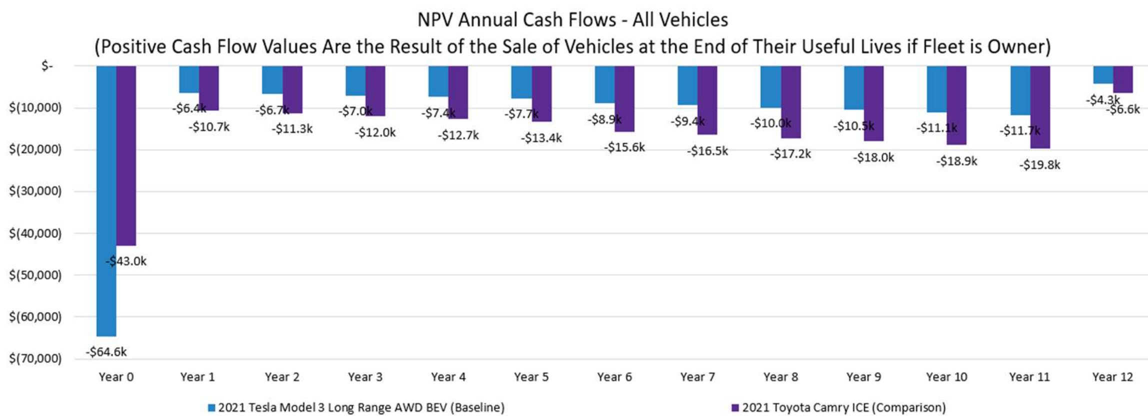

Fig.4.78. Cash flow chart over 12 years in the case of Tesla Model 3 and Toyota Camry ICE

Fig 4.78 shows cash flow for comparison five over ownership of 12 years. It represents that at the purchasing stage (years 0), the cash outflow for Tesla Model 3 is significantly more than Toyota Camry ICE due to the high acquisition cost of Tesla. Whereas, at the end of the ownership period, the cash outflow of the Tesla Model 3 EV is less compared to its opponent, which indicates the low operating Cost of EV compared to ICE. But both vehicles have negative net cash flow over the ownership of 12 years.

Ownership period = 9 years

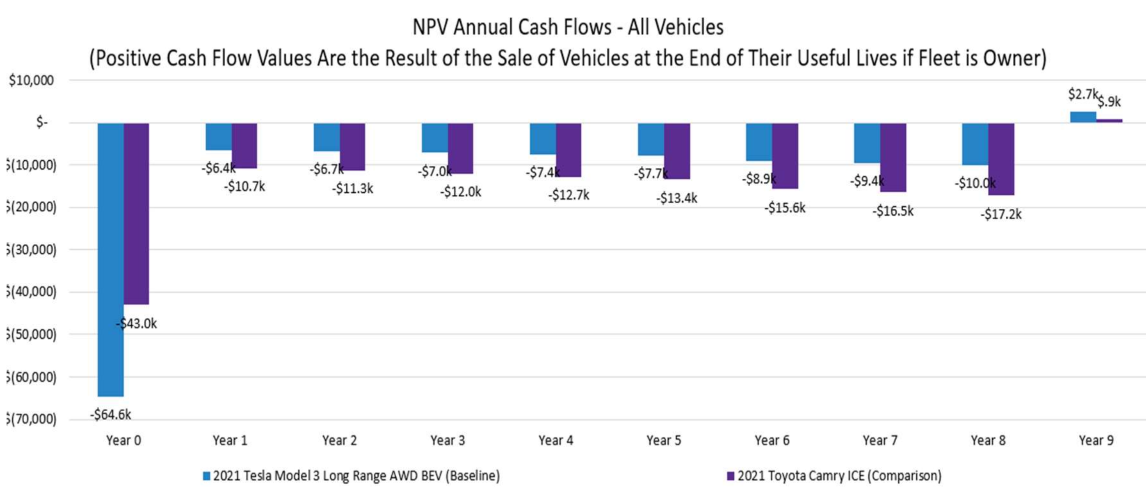

Fig.4.79. Cash flow chart over nine years in the case of Tesla Model 3 and Toyota Camry ICE

Fig 4.79 shows in case ownership of 9 years for comparison 5, at the purchasing stage (years 0), the cash outflow for Tesla Model 3 is significantly more than Toyota Camry ICE due to the high acquisition cost of Tesla. Whereas, at the end of the ownership period, the cash outflow of Tesla is less than its cash in-flow, so the net cash flow is positive. In comparison, Toyota Camry also has a positive net cash flow, but it is less than Tesla. This means the sale value of Tesla will be more than the Toyota Camry for the ownership of 9 years.

Ownership period = 5 years

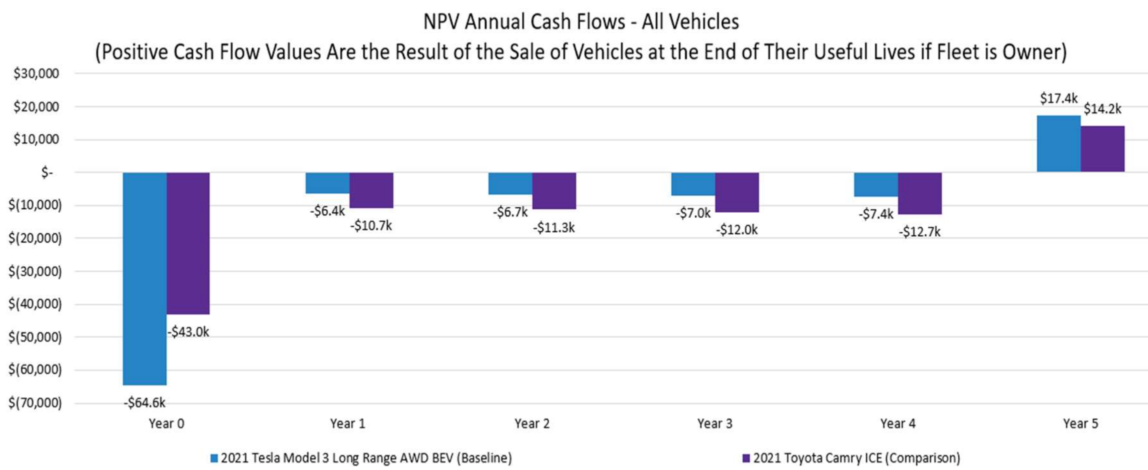

Fig.4.80. Cash flow chart over five years in the case of Tesla Model 3 and Toyota Camry ICE

Fig 4.80 shows in case ownership of 5 years for comparison 5, at the purchasing stage (years 0), the cash outflow for Tesla Model 3 is significantly more than Toyota Camry ICE due to the high acquisition cost of Tesla. However, at the end of the ownership period, the cash outflow of Tesla is less than its cash in-flow, so the net cash flow is positive. In comparison, Toyota Camry also has a positive net cash flow, but it is less than Tesla. This means the sale value of Tesla will be more than Toyota Camry at the ownership of 5 years.

4.2 *Discussion*

To reach out towards answering the stated questions in the introduction, the results are presented in compact form. First, an analysis of Economic percentages to come with a minimum ownership period at the current high gas price, followed by the analysis of Economic percentages to come with a minimum ownership period at the low gas price, and third, an analysis of Economic percentages to come with minimum gasoline price threshold at which on average an EV starts to become economical.

4.2.1 *Ownership duration at the constant high Gas price:*

The following figures show the percentage of the benefits of EVs concerning varying ownership periods at the continuous high gas price. The percentage increase in results represents how much your cost will increase when considering conventional ICE vehicles in place of PBEVs.

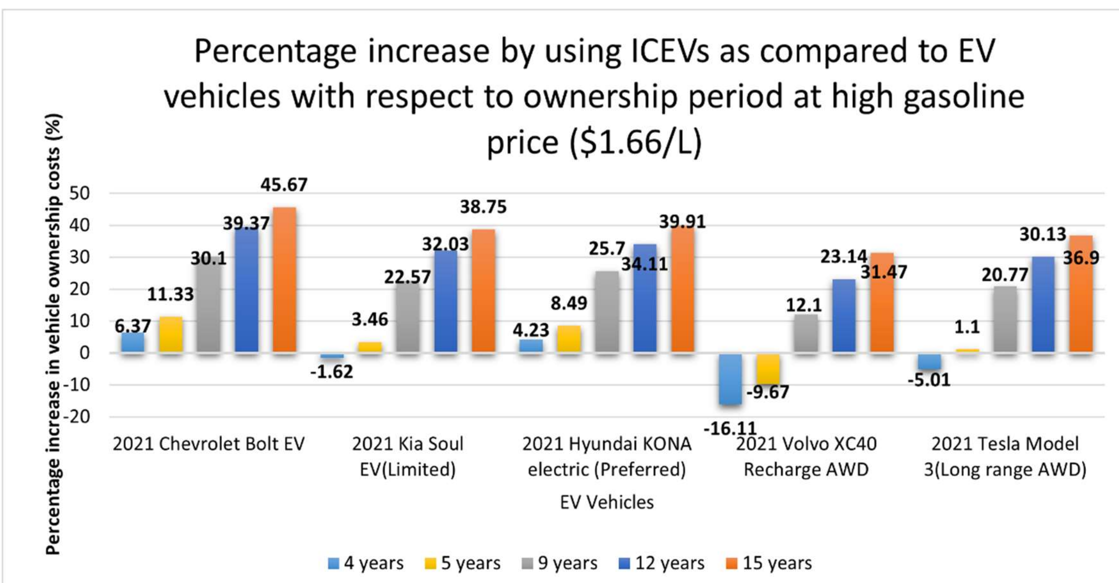

Fig.4.81. Economic profitability of Electric vehicles (Positive = Economic and Negative = non-Economic) at the current gasoline price

The results depicted in Fig. 4.81 show that, generally, the PBEVs may be more economical than the ICE vehicles. Specifically, when the ownership period is nine years or more, all PBEVs are more economical than ICE vehicles. On the other hand, when considering the ownership period of 5 or 4 years, some PBEVs (e.g., 2021 Kia Soul EV, 2021 Volvo XC40 and 2021 Tesla Model 3) may become less economical compared to the IEC due to high sticker price. Therefore, to ensure savings for the vehicle owner, the minimum ownership period of the PBEV is nine years.

4.2.2 *Ownership duration at the low Gasoline price:*

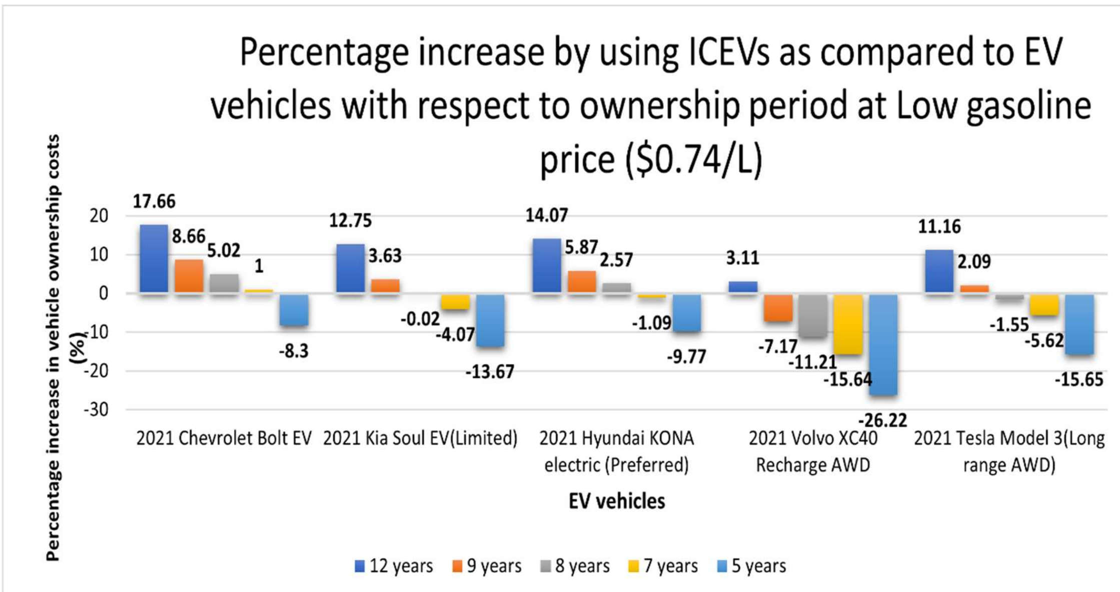

Fig.4.82. Economic profitability of Electric vehicles (Positive = Economic and Negative = non-Economic) at low gasoline price

The results in Fig. 4.82 show that EVs are still cheaper at the lowest price over the last five years, when the ownership period is nine years or more, except Volvo XC40 Recharge. At eight years of ownership, Chevrolet Bolt EV and Hyundai Kona will be beneficial. However, the percentage is significantly less. But, below eight years of ownership at this low price, EVs would not be economically healthy. Therefore, to ensure savings for the vehicle owner, the minimum ownership period of the PBEV is at least 8-9 years at this low price.

4.2.3 *Lowest Gasoline prices at the fixed Ownership Duration*

The third type of result shows how much PBEVs would be cheaper at the lowest gas prices.

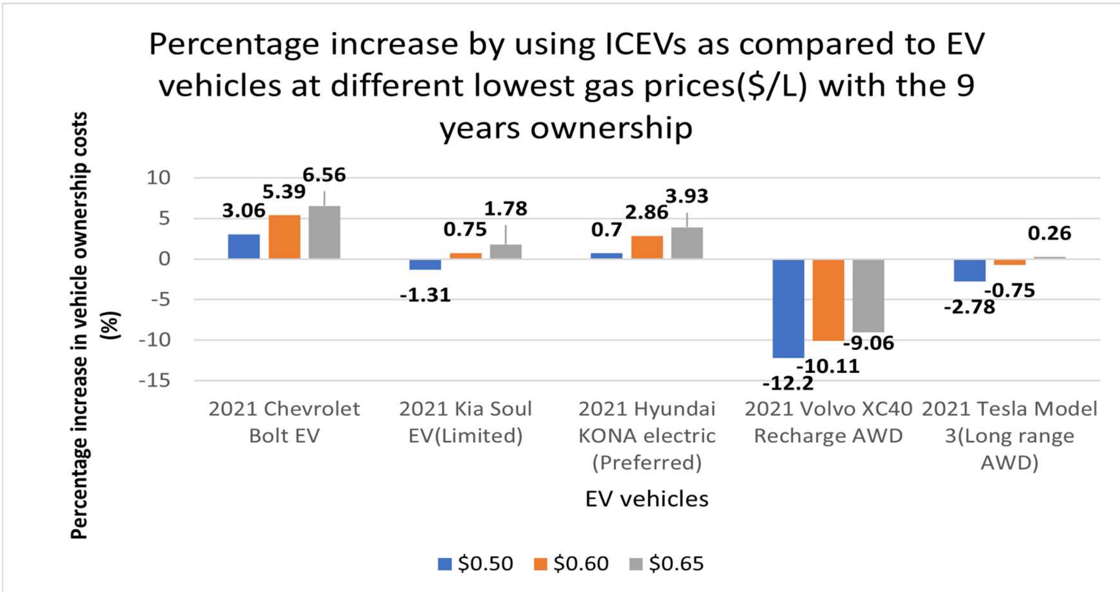

Fig.4.83. Economic profitability at various lowest prices with base ownership period

Fig. 4.83 shows that when gasoline prices drop below $0.60, PBEVs would not be economical except for Chevrolet Bolt EV and Hyundai Kona. However, these will be cheaper with the ownership of 9 years but has a significantly less percentage. On the contrary, the Kia Soul and Tesla Model 3 hold the advantage over their ICE counterpart till gas at $0.65/L, whereas Volvo XC40 Recharge would not be economical at these lowest prices.

To ensure the economic significance of PBEVs, combining low prices results, the minimum threshold for Gasoline prices would be $0.74/L, and the corresponding minimum threshold for the ownership period would be nine years.

As per analysis 1, 2-3 years are flexible in the minimum threshold at a higher gasoline price of over $1.50litrer. The higher the gas prices, the cheaper EVs will be, and there will be more flexibility in going below the minimum threshold. For the past three years, there has been an increasing trend in gas prices in Ontario as well as in overall Canada.

4.2.4 *Cash flow Analysis*

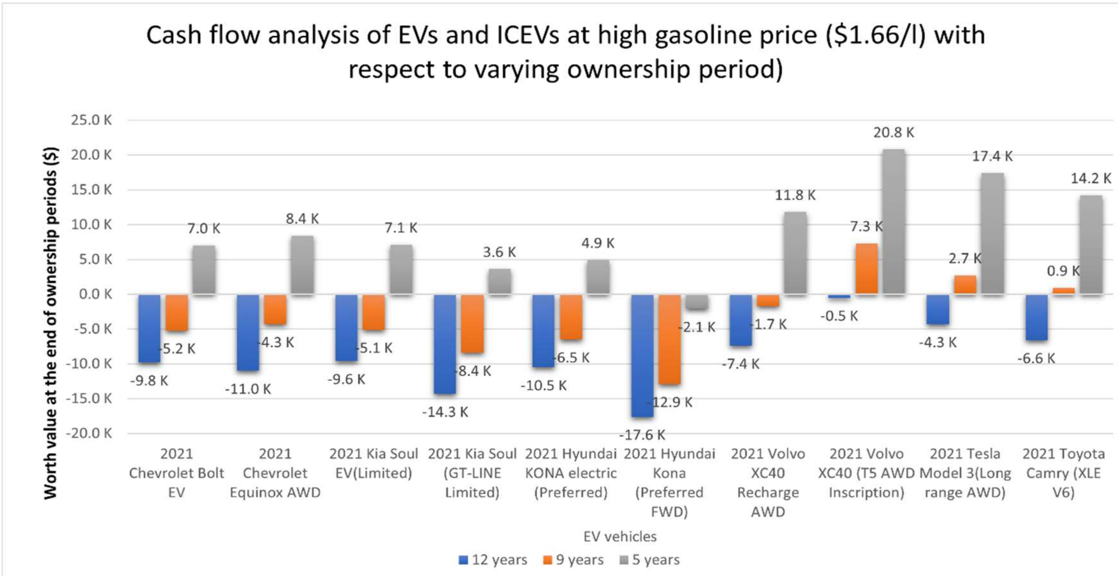

Fig.4.84. Net cash values of EVs and ICEVs at the end of ownership periods

Fig 4.84 depicts the net cash value of cars at the end of usage during specific ownership spam. It is shown that with less ownership spam, i.e., five years, all EVs show positive cash flow. This represents the positive sale value of EVs after your ownership duration. At high ownership periods, vehicles will not give satisfactory value upon the sale of cars. EVs generally give more value than their counterpart ICE vehicles, except for Volvo XC40 Recharge.

In another context, there is a trade-off between the salvage value of an EV and usage benefits. By keeping it for a long time, we will get payback, but on the other hand, the price of an electric car would be much lower due to the degradation of various components, especially the battery. We will get less payback and higher salvage value by staying with EV for a short period. Salvage value is the price of the EV at the end of the ownership period.

CHAPTER 5. CONCLUSION

This study presents a comparative economic analysis of PBEVs with conventional ICE vehicles. The results have shown that at the current higher gasoline price of $1.66/L, PBEVs are economical on a reasonable timeframe of 9 years of ownership. Moreover, the lowest gasoline price threshold at which PBEVs would be economical was found to be $0.74/L with ownership at nine years. The higher the years of ownership and Gasoline price, the more PBEVs become more economical. The study found that some vehicles, such as Volvo XC40 Recharge, the 2021 Kia Soul EV, and the 2021 Tesla Model 3, offer a low percentage of economics when ownership comes below nine years.

The study found that by using electric vehicles, the total ownership cost savings can reach up to $88,482 over 15 years. Based on the results, the most economical vehicle is Chevrolet BOLT EV due to its low acquisition cost as compared to other considered electric vehicles. The least economical electric vehicle is Volvo XC40 Recharge.

The vehicle's purchase price is the turning point from cheapness to expensiveness. Overall, we can conclude that, in general, PBEVs are economical compared to conventional ICE vehicles at an ownership period of 9 and higher years. Additionally, PBEVs are more valuable at the end of ownership periods than equivalent gasoline cars, except for Volvo XC40 Recharge.

This more extended ownership requirement is due to the higher sticker prices of PBEVs. This may be mainly due to high battery costs and less production. Due to technological advancement in battery production and the availability of various manufacturer models, the cost may go down in future. Moreover, the government should increase incentives and the limit for vehicle eligibility to bring down buying prices.

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