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Analysis of external benefit (Cost) of electric vehicles as an adaptation strategy for climate change

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Abstract

This paper studies about the external benefit -initial cost ratio of electric and fuel vehicles, pointing out the necessity of transitioning to electric vehicles (EVs) as an adaptation strategy due to global greenhouse gas (GHG) emissions from fossil fuels. With India's GHG emissions growing faster than the global average, the study tries to identify the environmental and economic implications of vehicle choices. The research employs a benefit-cost ratio framework based on the external benefit-cost dimension for the fulfilment of the objective. The comparative analysis evaluates the carbon emissions and saving, operational costs, and environmental impact of EVs versus internal combustion engine (ICE) vehicles based on the TATA Tiago XT (EV) and Tiago XTA (petrol) models. Along with this, data from survey and thematic reviews are used to assess consumer preferences and the barriers to EV adoption. The study found out that there is statistically significant association between gender and average fuel cost with a p-value 0.007398845. The findings underscore long run and short run dynamics of environmental and economic impacts of electric and fuel vehicles. The study argues that EV is a better option for traffic jam of the urban areas in Kerala.

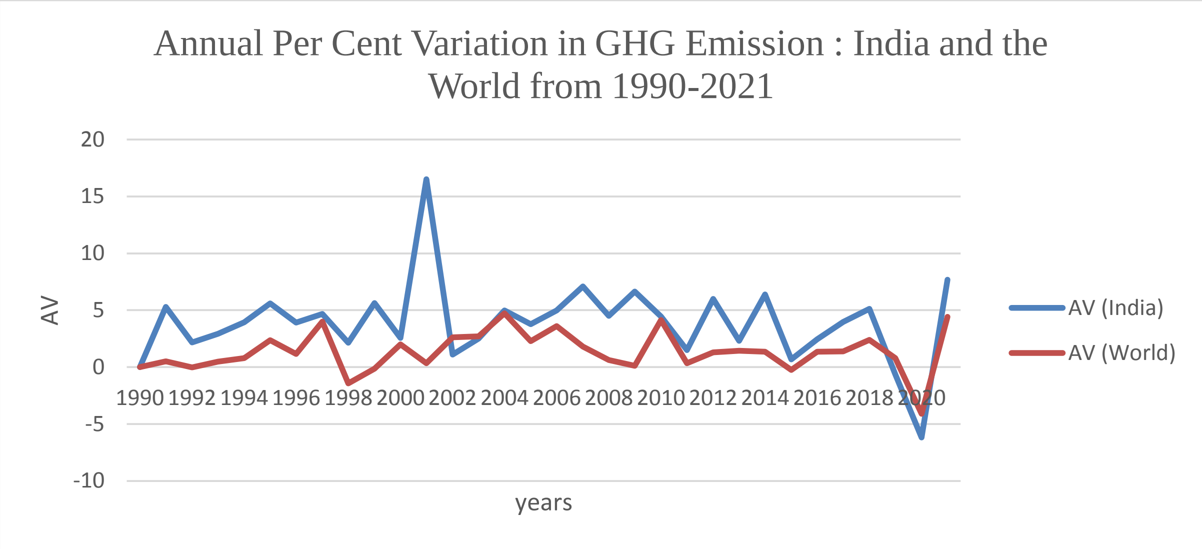
Keywords: *Electric Vehicle, Carbon Emission & Saving, Consumer Preference and Economic & Environmental Impacts*

Introduction

The history of motor vehicles dates to 1800s. In the 1830s immediately after the development of the first electrical machines, the first electric cars were built. The world faced major environmental and health problems from the horse manure because all vehicles at that time were horse drawn. The methane gas released from the horse manure had four times the greenhouse gas effect of carbon dioxide. In this context the real need for the first engine-based transportation emerged. Two major vehicle options of that time were steam and electrical vehicle. Among this people preferred electric cars because it didn't smell and had no noise or vibration like steam cars. Most importantly, they were easier to operate and had a simple gear system. During this period, advancements happened in the field of internal combustion engines (ICE). The first gasoline- fuelled engine was built in 1876 in Germany. During this period, advancements happened in the field of internal combustion engines (ICE). The first gasoline- fuelled engine was built in 1876 in Germany. Carl Benz began the first commercial production of motor vehicles. Meanwhile, the electric car production peaked in 1912. However, in the later years electric cars began to lose their share on the vehicle market. It was mainly due to the developments of ICE cars along with this the Texas crude oil boom led to tremendous economic change and the growth in the USA. Due to the sharp fall in the gasoline prices, ICE cars were cheaper to own and maintain for the average consumer. But during the 1960s and 1970s the petrol prices permanently increased. The most serious shock to the oil market occurred in 1973 when OPEC declared the global oil restriction. In addition, the ICE related air pollution also began to draw attention. The 1990s saw the reemergence of electric vehicles. The electrical transportation is the way to sustainable future for humanity (Szabo and lulia,2022). Globally India ranks among the top 10 automotive markets (Sreenath, 2022). As of 2023 there are 2.27Cr vehicles registered in India. Among this 1.8Cr are petrol vehicles, around 24 lakh are diesel vehicles and around 14 lakh are electric vehicles. The number of electric vehicles is increasing year by year along with this the number of petrol vehicles are also increasing. In the year 2022 the number of petrol vehicle was 1.7 Cr (PIB, 2024). So, there is an increase in 2,39,468 vehicles in 2023. The registered electric vehicles also showed an increase of 4,08, 427 in 2023. From this it is understood that people are realising the need for the electric vehicles. Even though there is an increase in the registered electric vehicle in India many people are reluctant to buy electric vehicles due to various reasons. It is important to know why people choose fuel vehicles over electric vehicles.

Before examining the reasons for such behaviour, it is apposite to check the historical GHG emission from India relative to the world whereas the discussion of EVs has become significant in the country. The Annual Variation (AV) in Historical GHG Emission in World and India is shown in fig 1.

Figure 1:



Source: computed based on Climate Watch, 2024

The figure 1 represents the annual per cent variation in ghg (Greenhouse gas) emission of India and the world from 1990 to 2021. Annual variation of India's historical emission was high in 2001 with 16.55% and the annual variation of world ghg emission is high in 2007 (7.09 %). Both India and world showed a diminution (-6.19 and – 4.11 respectively) in the historical emission during the covid time (2020). The average historical emission of India and world are 2146.71 MtCO2e[1] and 39459.12 MtCO2e respectively between 1990 and 2021. Coefficient of variation is higher for India with a fluctuation of 37.92%. The decadal average of ghg emission of both India and world stood at 3053.26 and 45793.66 MtCO2e respectively during the previous decade and it has been the highest mean value since 1990.

[1] Metric Tons of Carbon Dioxide Equivalent

Table 1 - India's Share in Global GHG Emission

Year	India	World	Share (%)
1990	1025.63	31552.5	3.25
1995	1246.36	32870.6	3.79
2000	1500.33	34713.74	4.32
2005	1973.75	39321.04	5.02
2010	2582.36	43486.55	5.94
2015	3043.88	45335.3	6.71
2020	3176.03	46109.75	6.89

Source: computed based on Climate Watch, 2024

Table 1 highlights the share of India in global ghg emission in the selected years. India's share is higher in 2020 with 6.89 percent compared to 3.25 percent in 1990.

The growth rate of ghg emission in India was high during 1990-2007. It was partly due to the low base effect. In short, both cases of growth rates came down after 2008 but, India's emission rate continued to be higher than that of the world. The significant difference is verified with the t test as shown in table 2.

Table 2 - Results of t-test for growth rate of GHG Emission in India and World

YEAR	*INDIA (GR %)*
1990-2007	*4.57*
2008-2021	*2.89*
	t = 4.4469 *d.f = 30* *p-value=0.0001105*

YEAR	*WORLD (GR %)*
1990-2007	*1.58*
2008-2021	*1.06*
	t = 2.306 *d.f = 30* *p value = 0.0282*

Source: Computed based on climate watch

This paper attempts to fix the external benefit/external cost analysis of electric and fuel vehicles and tries to give awareness regarding the global greenhouse gas emissions from fossil fuel and the urgent need for the adoption of electrical vehicles. The main objective of the paper is to compare electric vehicles to fuel vehicles. External benefit/cost ratio which is a measure of cost-benefit analysis is used for this purpose.

The paper is divided into five sections. First section deals with the introduction, review of literature, conceptual framework, objectives and method study. The second section deals with the data analysis and its interpretation. In the next section average annual carbon emission from a typical passenger car is calculated for selected kilometres and gives a brief overview of noise pollution from EVs and ICEs. The concerned section also gives a general overview regarding the estimation of expenses of both electric and fuel vehicles. Further, external benefit/external cost ratio and fuel vehicle is calculated to compare electric vehicles to fuel vehicles. The Final part evaluates the data collected through google form among the electric and fuel vehicle users and connects it with the themes of review of literature. The paper is concluded by explaining the results obtained from the study. Review of literature is arranged in six themes which are presented in the ensuing section.

Electric vehicle as an adaptation strategy in the context of climate change

Climate change, defined as long-term shifts in temperature and weather patterns, has both natural and anthropogenic drivers (UN, 2024). Houghton and Woodwell (1989) emphasized that human-induced emissions of greenhouse gases (GHGs) such as carbon dioxide (CO_2) and methane (CH_4) are significantly altering Earth's climate. Their review underscored the urgent need for mitigation measures to address the escalating environmental damages like GHG emissions, disrupting the ecosystem. Adedeji et al. (2014) further elaborated on the implications of GHG emissions, projecting an average temperature increase of 0.2°C per decade, potentially reaching 2°C above pre-industrial levels by 2050. They highlighted the disproportionate contribution of developed nations to global CO_2 emissions and emphasized that addressing climate change is crucial for achieving global developmental goals. They suggested adoption of electric vehicles to face the challenges related to climate change. Alanazi (2023) explored the benefits and challenges of EVs, emphasizing their potential to reduce GHG emissions and fossil fuel dependency. The study projected a significant increase in EV users by 2030, highlighting the efficiency of EVs compared to internal combustion engine vehicles (ICEVs) and their role in creating sustainable urban environments.

Hawkins, Gausen, and Stromman (2012) investigated the environmental implications of EVs through lifecycle assessments (LCA). Their study revealed that while EVs offer significant potential for reducing transportation-related emissions, their benefits depend on cleaner electricity generation and improved battery recycling practices. The study by Choma and Ugaya (2017) also emphasized that the reliance on thermal electricity can undermine the advantages of electric vehicles. They focused on the Brazilian context, analysing the performance of battery electric vehicles (BEVs) against ICEVs (Internal combustion engine vehicles). The study revealed that BEVs perform better in categories like global warming potential and ozone layer depletion but noted that reliance on thermal electricity generation can undermine these advantages. In the Indian context, Palaniswamy et al. (2022) explored the social, economic, and environmental impacts of EVs. The research emphasized the potential of EVs to enhance urban mobility and reduce air pollution.

According to an official website of the United States government (EPA.gov), the average gasoline car on the road drives around 11,500 miles per year. That is, 18507.46km per annum. Sun et al. (2017) analysed the feasibility of EV adoption in Beijing, China, emphasizing the importance of policies, charging infrastructure, and technical support. The study revealed that policies like "No traffic restrictions for EVs”, the availability of charging stations, and technical support are critical in shaping user perceptions and satisfaction. Langbroek et al. (2018) examined how EV adoption influences travel patterns, noting that range limitations can lead to increased reliance on public transport or changes in trip purposes, such as cancellations of shopping trips. Additionally, Hwang et al. (2021) provided insights into the adoption of fuel cell electric vehicles (FCEVs) in South Korea, identifying pathways such as increased hydrogen stations and government subsidies.

Policy assistance and infrastructure requirements for EVs

Fazeli et al. (2017) developed a framework to evaluate fiscal policies for EV adoption in Iceland, comparing five incentive scenarios using multi-criteria decision analysis. Their findings identified the "feebate + tax" model as the most effective policy for reducing GHG emissions and promoting EV adoption. The authors Choma and Ugaya (2017) emphasized the importance of integrating public policies to address the environmental drawbacks of EVs. Further, Hwang et al. (2021) provided the perception that government subsidies act as a pathway for the adoption of fuel cell electric vehicles (FCEVs) in South Korea. Later, Singh et al. (2021) analysed EV trends in India highlighting government initiatives such as the Automotive Mission Plan (AMP) and National Electric Mobility Mission Plan (NEMMP). Along with this a strength weakness opportunity and challenges (SWOC) analysis is performed and found out that high cost, battery concerns, and lack of access to recharging stations are the limitations that affects the adoption of EVs.

Das and Bhat (2022) explored the global and Indian EV policy landscape focusing on the relevance of initiatives like FAME 1(Faster Adoption and Manufacturing of Electric Vehicles), FAME 2, and the vehicle scrappage policy. They highlighted the challenges of lithium-ion battery disposal and reprocessing, emphasizing the need for sustainable solutions to support EV adoption in India. Palaniswamy et al. (2022) also emphasized the ambitious targets of government of India in the adoption of EVs. More, Alanazi (2023) noted the rapid growth of EV markets in Europe, the United States, and China, where policy initiatives aim to achieve substantial market penetration Delacrétaz et al. (2021) demonstrated the significance of infrastructure development in influencing consumer behaviour and accelerating EV adoption. Another study conducted by Hwang et al. (2021) identified increased hydrogen stations as pathway for the adoption of EVs. Additionally, Palaniswamy et al. (2022) highlighted challenges such as battery manufacturing impacts and inadequate charging infrastructure in popularizing EVs.

EVs and noise annoyance

A study by Salleh et al. (2013) observed a difference of 20 dB (Decibel) between the noise of EV and ICE when the vehicle is in an idle state or at low-speed running and this difference decreases as the speed of vehicle increases. In addition to this as the EV accelerates to 30–40 km/h, tire and wind friction become leading noise sources, making the vehicle more obvious to road users and bringing its noise level closer to that of ICE vehicles. The study suggests that at slow speeds, EVs remain much quieter than ICE vehicles.

Similar results were obtained by Iversen in 2015 also suggested that EVs can contribute to quieter urban environments at low speeds. They used Citroën Berlingo and Nissan Leaf (both are EVs) and Citroën Berlingo and VW Golf Variant (both are diesel) for the comparison and vehicles were tested at various steady speeds, also during acceleration and deceleration. When Citroën Berlingo (EV vs. ICE) were tested under the steady speed measurements, Berlingo EV was 5 dB silent than Berlingo ICE at 10 km/h and as the number of km increased to 20 and 30 km/h, the noise difference decreased to 1.5 dB and was no significant difference in the latter. Under the various steady speed Nissan Leaf and VW Golf also tested and found out that at 20 km/h Leaf was 4 dB softer than Golf and the noise levels difference reduced to 1.5 dB at 60 km/h. when deceleration (engine braking) is considered EVs were quieter (2-3 dB) than the ICE vehicles. The study concluded EVs have the probable to reduce noise levels at constant speeds below 20 km/h but the noise level difference descent at higher speeds. Also, the differences between these vehicles weakened as tyre or road noise became the dominant sound source.

The study by Schweizer et al. (2023) goes in line with the mentioned researches. The study examined the noise levels of seven EVs and seven ICEs in Switzerland using three measurements like constant speed, acceleration, and stop-and-go and concluded that EVs can significantly reduce noise, especially during acceleration and stop-and-go circumstances. At constant speed (on the low noise road surface) EVs were only somewhat softer than ICE vehicles with a slight difference of -0.2 dB in maximum noise levels. EVs showed a substantial noise reduction, averaging -5.2 dB compared to ICE vehicles when acceleration is considered and EVs were quieter by an average of -3.4 dB under stop-and-go conditions. The study further observed that tyre/road noise is a significant contributor to overall noise, particularly at constant speeds.

Further, Berge, Evensen and Olsen (2024) observed both M1 (passenger cars) and N1 (light commercial vehicles) classes under both urban and highway conditions and found out that there are no significant differences in maximum noise levels between the three engine types (EV, petrol, and diesel). As the above studies mentioned this study also supported that tyre/road noise is the leading source of road traffic noise, mostly at speeds above 30 km/h and there is no significant difference between the noise level of EVs and ICE at this point so a changeover from ICE to EV will not produce noise benefits.

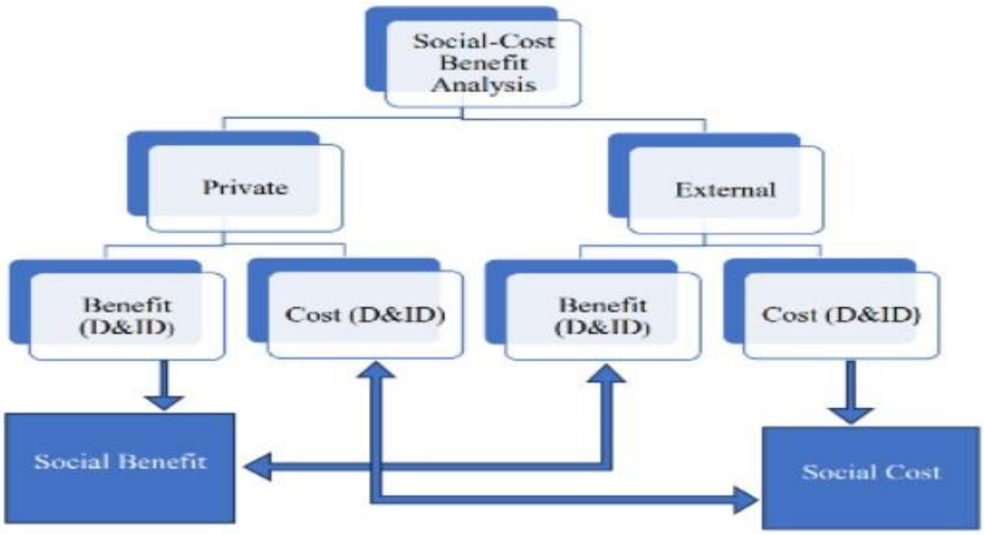
The ensuing section presents the method of the study.

II. Method of study

This study attempts to compare electric vehicles to fuel vehicles. The study uses external benefit/cost ratio which is a measure of cost-benefit analysis to check which vehicle is viable. Both primary and secondary data were used in this study. For calculating average carbon emission from a typical passenger car, the authors relied on secondary data sources. For the estimation of expenses of both fuel and electric vehicles details were procured from TATA showroom in Angamaly. Primary data is collected via google form (mainly focused on Ernakulam and Thrissur districts) to know the behaviour of people regarding both vehicles. T-test were used in the introduction part of the study. Benefit-cost ratio is an important measure in cost-benefit analysis. Studies which specifically examine the benefit-cost ratio of electric and fuel vehicles within the same car brand and model are limited in Kerala. Therefore, this study aims to address this gap by comparing the benefit-cost ratio of electric and fuel vehicles of the same brand and model. Also, the study initially endeavoured a social cost benefit analysis of both electric and fuel vehicles. However, External benefit (cost) analysis is conducted using external benefit initial cost ratio (benefit-cost ratio) due to the unavailability of private benefit data. Conceptual framework of the study is given in the following section.

III. Conceptual framework

Fig: 2



Source: Musgrave and Musgrave (1989), Malmgren (2016), Laver and Parsha (2021), Schriver Christensen and Ernst Christensen (2021) and Vardakoulias, 2023

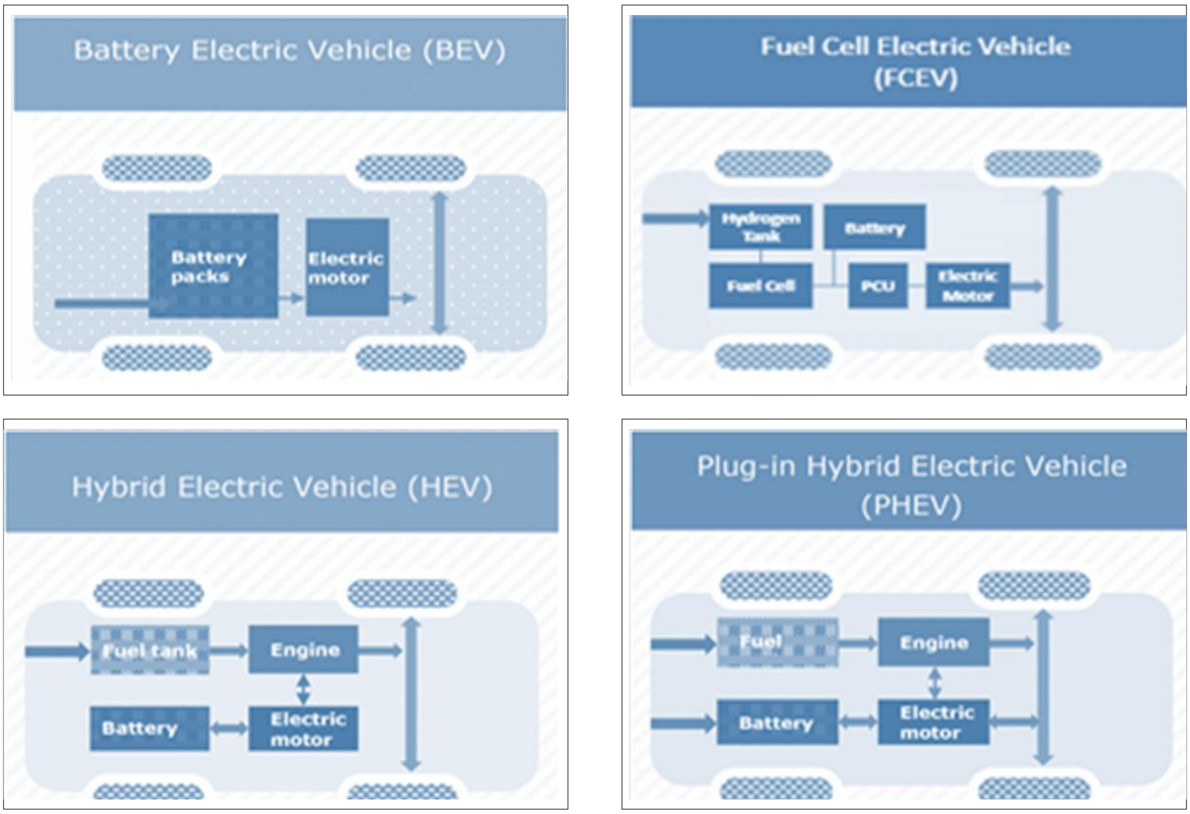
*D – Direct cost and ID – Indirect cost

Social Cost-Benefit Analysis (SCBA) is an expansion of economic cost-benefit analysis by including social and environmental impacts (Vardakoulias, 2023). Research by Schriver Christensen and Ernst Christensen (2021) compared an electric vehicle to a diesel vehicle (Renault) and found that the social costs over their times were nearly equal, with the electric vehicle being slightly less costly. Malmgren (2016) further analysed EVs by quantifying seven benefits, including fuel savings, reduced CO2 emissions, improved health from lower PM2.5 levels, improved national security through decreased fossil fuel reliance, and economic development from transportation electrification. The current study calculates CO2 emissions for distances of 500 km (kilometre), 750 km, and 2000 km monthly and assessing economic viability of both electric and fuel vehicle. Laver and Parsha (2021) conducted a cost-benefit analysis of policy tools to promote plug-in electric vehicles, considering excess purchase costs, subsidies, charging infrastructure investments, and taxation models for company cars. In SCBA, benefits and costs can be real or pecuniary; real benefits are those derived by final consumers of public projects. All real benefits and costs are included in cost-benefit analysis (Musgrave and Musgrave, 1989). The present study uses the benefit cost ratio as a measure of cost benefit analysis. External benefits and costs are accounted in the study. Both Direct (D) and indirect (ID) costs and benefits are also considered in this study. The direct cost in this study is the initial investment of both fuel and electric vehicles and its operating costs. The indirect costs are the spillover effects that was caused by the carbon emission from the fuel vehicles. The direct benefit is the amount of carbon saving due to the use of electric vehicles and the indirect benefit is that their use will reduce global warming and mitigate climate change. This paper is an attempt to conduct an External benefit (cost) analysis of both electric and fuel vehicles and cross paths with the above-mentioned concepts. The subsequent section gives an outline regarding electric and fuel vehicles.

IV. An overview of electric vehicles and fuel vehicles

"An EV is defined as a vehicle that can be powered by an electric motor that draws electricity from a battery and is capable of being charged from an external source" (Vermont statutes, 2024). Battery electric vehicle (BEV), hybrid electric vehicle (HEV) plug- in hybrid vehicle (PHEV), and fuel cell electric vehicle (FCEV) are the four types of electric vehicles. Among this BEV is fully powered by electricity and the most efficient compared to the other types (Figure 3).

Figure 3: Types of EVs



Source: e-amrit.niti.gov.in

The main benefit of electric vehicle is the zero tail pipe emission and lower fuel costs. It improves the fuel economy, progresses public well-being & the environment, and contributes to a robust transportation system (US Department of Energy, 2025). Fuel vehicles use different types of fuel. Diesel, petrol and CNG are the most common used fuels in India. But there are also vehicles that using Liquid petroleum gas (LPG), Bio- diesel and Ethanol (TATA AIG, 2024). But most of these fuel vehicles have tailpipe emission and it is harmful to the environment and leads to rapid climate change. While electric vehicles also create some amount of carbon emission during the manufacturing process of vehicles and charging of vehicles it has relatively low emission compared to fuel vehicles and its comparative advantage is growing (MIT Climate Portal, 2022).

For comparative study Tata Tiago is selected because it is the vehicle brand that provides cars at relatively least cost and has both electric and fuel vehicle of the same variant which has lowest cost. Hence, Tiago XTA (Automatic, petrol variant) and Tiago XT (Automatic, EV) are chosen for the comparison.

An overview of electric and fuel vehicles is discussed. The subsequent section deals with the computation of average annual carbon emission from a typical passenger car and addresses the noise pollution from EVs and IECVs.

V. Data analysis and interpretation

Air, water and sound pollution are the three major kinds of pollution that exist today. These pollutions are the key sources of negative externality. The present study focuses on addressing air and noise pollution which are contributed by passenger cars.

Average annual carbon dioxide (CO2) emissions of a typical passenger car

The average gasoline car on the road is driven around 11,500 miles per year (EPA.gov). That is 18507.46 km per annum. A typical passenger car emits about 4.6 metric tons of CO2 per year. So, when a passenger car is driven around 18507.46 km yearly, it emits about 4.6 metric tons of CO2 (5.0706306 ton; EPA.gov, 2023). To calculate the money value of CO2 emission $20 is taken as a standard rate (Harris and Jonathan, 2013). The average emission of CO2 per km from the typical passenger car is 0.000273978 ton[2]. Table 3 shows the average monthly carbon dioxide emission of a typical passenger car that is driven 500km,750 km and 2000 km in money terms. Here, the emission per month is calculated by multiplying the given km with the average emission of CO2 per km. The money value is calculated by multiplying the CO2 emission with the standard money value $20 (Harris and Jonathan, 2013). $20 is converted into Indian rupee (Rs. 1718.4) (USD/INR rate for 08-01-2025). With in the third row (column 2) of table 2, CO2 emission of a car that is driven 500 km is given. It is found by multiplying the given km by the average CO2 emission per km which was found by dividing total emission by total distance. Here the CO2 emission when a passenger car is driven for 500 km is 0.13698886 ton (500*0.000273978). The money value of this emission is Rs 235.402 (0.13698886 ton*1718.4). Other values are also calculated by using the same procedure.

[2] 5.0706306/18507.46 = 0.000273978

Table 3: Monthly Average CO_2 Emissions of a Typical Passenger car

Average km a passenger car drives around monthly	CO2 Emission per Month	Money Value (Rs)
500 km	0.13698886 ton	235.402
750 km	0.20548329 ton	353.102
2000 km	0.54795544 ton	941.607

Source: Computed from 1. EPA.gov.in and 2. Inch calculator

From table 3, it can be observed that as the number of kilometres a car rides increase, the CO2 emission also surges. Along with this the money value of emission also rises.

Noise pollution from EVs and ICEs

As discussed in the review the authors Salleh et al. (2013), Iversen (2015), Schweizer et al. (2023) and Berge et al. (2024) suggested that EVs remain quieter than ICE vehicles at slow speed. Urban areas in Kerala are famous for slow moving vehicles due to the traffic congestion. Also, air pollution is high in slow running ICE vehicles as they consume more fuel during low speed but EVs does not have this problem and noise pollution is relatively low for EVs then. Because of these reasons EVs are more appropriate in the urban context of Kerala.

In this section the average CO2 emission from a typical passenger car is computed and interpreted. Along with this noise pollution in the case of both EVs and ICEVs are also discussed. The following section gives a general overview about the total cost of electric and fuel vehicle.

A general overview regarding the estimation of expenses and economic viability of both electric and fuel vehicles

As mentioned earlier, Tiago XTA (petrol) and Tiago XT(EV) are chosen for the comparison throughout the study. Table 4 shows the purchasing price and the operational cost of the vehicles under consideration.

Table 4 - Price List of Selected Vehicles

Vehicle	Tiago Petrol Auto	Tiago EV
Variant	XTA	XT
On Road Price	7,77,192/-	10,92,689/-
Running Cost (Per Km)	6 Rs	1.3 Rs
Service Cost (1 Yr)	6000/-	2000/-
Battery Cost	6000/-	600000/-

Source: Collected from Tata Showroom, Angamaly

The average expense of both electric and fuel vehicle is estimated based on table 4. Tables 5 and 6 exemplify the average expenses of electric and fuel vehicles for those who drive around 1710 km and 990 km per month for 9 and 15 years respectively (these two kilometers were chosen through trial-and-error method at the point where EV becomes economically viable).

Table 5 - Estimated Expense for 9 Years (1710 km/month)

Vehicle	Tiago XT(EV)	Tiago XTA (petrol)
On road price (Rs)	10,92,689	7,77,192
Estimated km for 9 years	1,84,680 km	1,84,680 km
Running cost (Rs)	2,40,084	11,08,080
Service cost (Rs)	18,000	54,000
Battery cost (Rs) 8 yrs and 4 yrs	6,00,000	12,000
Total (Rs)	19,50,773	19,51,272

Source: Based on table 4

Table 6 - Estimated Expense for 15 Years (990 Km/Month)

Vehicle	Tiago XT(EV)	Tiago XTA (petrol)
On road price (Rs)	10,92,689	7,77,192
Estimated km for 15 years	1,78,200 km	1,78,200 km
Running cost (Rs)	2,31,660	10,69,200
Service cost (Rs)	30,000	90,000
Battery cost (Rs) 8 yrs and 4 yrs	6,00,000	18,000
Total (Rs)	19,54,349	19,54,392

Source: Based on table 4

The expense is estimated using the on-road price and the operational cost of both vehicles. Estimated km is computed by converting the monthly kilometre into 9 and 15 years. Running cost is calculated using this estimated km. For example, running cost of EV per km is Rs 1.3

and running cost for 1,84,680 km is 1,84,680*1.3 = 2,40,084/- (table 4). Regarding the battery cost, EV batteries have a warranty of 8 years and fuel vehicle batteries have a warranty of four years. So, for the calculation it is assumed that the EV battery is changed one time in both the period and fuel vehicle battery is changed 2 times in nine years and 3 times in 15 years. Therefore, battery cost of EV remains the same and Battery cost of fuel vehicle is Rs 12000 and Rs 18000 for 9 and 15 years respectively. The total expense is computed by adding the on-road price and operating expenses. When the expenses were computed for nine years authors came to know that EV is economically viable if it drives around 1710 km in a month and when the expense is calculated for fifteen years EV is economically viable if it drives around 990 km/month.

Battery costs in tables 5 and 6 are calculated by taking the warranty years (8 & 4 yrs for EV and Fuel respectively) under consideration. The warranty of EV battery expires when EV is used for 8 years or when it completes 160000 km. So, this 160000 km also should be considered while calculating the total expense. It is understood that warranty of fuel vehicle battery expires when vehicle is used for 4 years or when it completes 74,030.184 km. This quantity is obtained by multiplying the average distance a car drives around in a year (18507.546) with 4. There is no change in the total expense (for 9 yrs) of both vehicles when warranty (in distance) of batteries is considered. Table 7 presents the total expense of both electric and fuel vehicles by taking the battery warranty when it expires at 160000 km and 74,030.184 km respectively.

Table 7 - Estimated Expense for 15 Yrs (998 Km)

Vehicle	Tiago XT EV	Tiago XTA (Petrol)
On Road Price (Rs)	10,92,689	777192
Estimated Km for 15 Years	179640	179640
Running Cost (Rs)	233532	1077840
Service Cost (Rs)	30000	90000
Battery Cost (Rs) (160000 Km and 74,030.184 Km)	600000	12000
Total (Rs)	19,56,221	1957032

Source: Based on table 4

** See the first paragraph in section 5. As per that a fuel vehicle requires two batteries to cover a distance for 74,030.184*2 = 1,48,060.368 km*

When the expense is calculated for 15 years the total expense changes. The EV becomes economically viable when the car runs around 998 km per month. Initially, expenses were estimated for both EV and petrol car at 990 km per month by considering the distance covered (160000 km and 74,030.184 km respectively). However, EV is not economically viable at 990 km because when battery warranty based on distance covered (160000 km for EV and 74,030.184 km for petrol) is considered, the battery cost of petrol vehicle decreases from Rs 18000 to Rs 12000. Though it is noted that battery cost is not the reason for the economic viability of EV at 998 km per month, since it is same for both 990 km and 998 km. Therefore, economic viability of EVs is caused by the lower running cost of EVs[3].

From this, EV is economically viable when it is frequently used (table 7). Otherwise, fuel vehicle is economically viable. The main factor of increased expense is the battery cost of electric vehicles. It is important to promote the use of EVs because it is environment friendly, but the cost of vehicle stand as a hindrance for this. The government should adapt policies to reduce the cost of EV batteries. Along with tax credits, subsidies should be also given to reduce the cost burden of the battery. Government should also allocate more funds for the research and development (R&D) of EV battery. R and D should develop strategies to increase the lifespan of EV batteries. This will postpone the disposal of used batteries and also will reduce the battery cost there by increasing the demand for EVs.

Present section provided a general overview about the expense of electric and fuel vehicles. The following section compare electric to fuel vehicles using Benefit-cost ratio.

Benefit-cost ratio

To compare electric vehicles to fuel vehicles Benefit-cost ratio is used. Benefit-cost ratio is a measurement of cost-benefit analysis. Here benefit-cost ratio of both electric and fuel vehicle is calculated. For the calculation of benefit-cost ratio external benefit and external cost is used.

Formula for calculating benefit-cost ratio

Benefit-cost ratio = B/C*100

[3] Because when expense calculated for both 990 km and 998 km only running cost is changed. Running cost of Tiago XT (EV) and Tiago XTA(Petrol) at 990 km is Rs 231660 and Rs 1069200 respectively. Running cost of Tiago XT (EV) and Tiago XTA(Petrol) at 998 km is Rs 233532 and Rs 1077840.

B = Total present value benefit and C = Total cost

Before using the formula, the present value of external benefit and cost should be calculated. Here present value for 9 years is calculated at 7% of rate of interest and it is calculated from the present value tables.

→ Benefit-Cost Ratio of EVs

Here carbon saving (implies absence of carbon emission) is the external benefit and the on-road price of Tiago XT (EV) in Kerala is the initial cost. To get the present value for nine years external benefit is multiplied with values taken from the present value table (ICFAI, 2004) (at 7%). Money value of carbon saving is Rs 8713.372 a year (5.0706306*1718.4[4]). After finding the total present value (which is taken as total external benefit) the formula of benefit-cost ratio is used. For example, if Rs 8713.372 is the carbon saving and 0.9346 (at 7%) is the present value factor then present value of the first year is Rs 8713.372*0.9346 = 8143.517. Remaining present values are also calculated in the similar manner.

Table 8 - Present Value of Carbon Saving

Year	Carbon saving (Rs)	PV factor	Present value (PV) in Rs
1	8713.371623	0.9346	8143.517119
2	8713.371623	0.8734	7610.258776
3	8713.371623	0.8163	7112.725256
4	8713.371623	0.7629	6647.431211
5	8713.371623	0.713	6212.633967
6	8713.371623	0.6663	5805.719512
7	8713.371623	0.6227	5425.81651
8	8713.371623	0.582	5071.182285
9	8713.371623	0.5439	4739.202826
Total PV			**56768.48746**

Source: computed using present value table

Benefit-cost ratio = B/C*100 = 56768.48/1092689*100 = 5.20

The benefit-cost ratio of electric vehicle is 5.2%. It means when a person buys an electric vehicle 5.2% of the cost of vehicle is its external benefit.

[4] Refer to the subsection of section V titled Data Analysis and Interpretation (Average Annual Carbon Dioxide (CO2) Emissions of a Typical Passenger Car).

→ **Benefit-Cost Ratio of Fuel Vehicle**

In the case of fuel vehicle there is no external benefit but external cost is involved. The carbon emission in monetary terms is treated as the external cost and the on-road price of Tiago XTA (petrol) in Kerala is the initial cost. For computation of cost, carbon emission is considered. To get the present value for nine years external cost is multiplied with values taken from the present value table (at 7% rate of interest). Money value of carbon emission is Rs 8713.372 a year. After finding the total present value (which is taken as total external cost) the formula of benefit-cost ratio is used. Example for calculating total present value; if Rs 8713.372 is the carbon emission and 0.9346 (at 7%) is the present value factor. Then present value of the first year is Rs 8713.372*0.9346 = 8143.517. Remaining present values are also calculated in the similar manner. However, before computing benefit-cost ratio it is important to note that there is no external benefit for fuel vehicles. So, the total present value of external cost is added with the on-road price.

Cost = total present value of external cost + on road price of Tiago XTA (petrol)

= 56768.48746 + 777192 = Rs 833960.487

It is to be noted that fuel vehicles in this context have no external benefit but to facilitate computation facility the benefit is taken as a token amount of one. Hence the benefit-cost ratio of fuel vehicle = 1/833960.487*100 = 0.00012

The benefit-cost ratio is interpreted in three ways.

Benefit-cost ratio = 1, benefit=cost

Benefit-cost ratio > 1, benefit >cost

Benefit-cost ratio < 1, benefit <cost

The benefit-cost ratio of fuel vehicle is 0.00012 percent which means external cost exceeds external benefit. From an externality point of view, fuel vehicle possesses a large amount of negative externality. The benefit-cost ratio of electric vehicle is greater than one (5.2%) which means external benefit exceeds external cost. It can be concluded that from an externality point of view EVs are beneficial.

Findings from the survey conducted among fuel and electric vehicle users

As mentioned in the introductory part, a survey is conducted via google form to know the response of 70 people regarding the use of electric and fuel vehicles. Among these 62 respondents own a fuel vehicle, 2 of them have electric vehicles and 6 of them have both. The survey was conducted in Ernakulam and Thrissur districts.

Table 9 : Driving Licence

Type of vehicles	Do you have driving licence				
	Yes		No		Total
	M (Male)	F (Female)	M	F	
Electric	2	0	0	0	2
Fuel	31	25	1	4	61
Both	2	3	0	1	6
Total	63		6		69
Percent	91.30434783		8.695652174		100
Not responded	1 (F/Fuel)				

Source: primary data

Table 9 shows that 69 participants were responded to this question. Among this 91% have driving licence. This study shows that there is a significant number of females have driving license (85 %).

Table 10: Purpose of Using Vehicles

Type of vehicles	Purpose of using vehicles						
	Job oriented		Personal use		Others		Total
	M	F	M	F	M	F	
Electric	0	0	2	0	0	0	2
Fuel	2	6	27	22	2	2	61
Both	1		1	3		1	6
Total	8		56		5		69
Percent	11.594202898550		81.159420289855		7.246376812		100
Not responded	1(M/Fuel)						

Source: primary data

Purpose of using vehicles by each respondent is shown in table 10. 81% of respondents use their vehicle for personal use. Remaining 11.5% are job-oriented users and 7% uses their vehicle for other purposes. Tables 11 to 14 and figures 4 to 6 show the responses of fuel vehicle users.

Table 11: Average Distance Travel by Fuel Vehicle Users

Type of vehicles	If you have a fuel vehicle, what is the average distance you travel in a month							
	Below 500		500-1500		1500-2000		Above 2000	
	M	F	M	F	M	F	M	F
Fuel	13	21	14	8	2	2	2	0
Both	1	2	1	2	0	0	0	0
Total	37		25		4		2	
Percent	54.41176471		36.76470588		5.882352941		2.941176471	
Total	68							

Source: Primary data

Table 11 depicts the average monthly distance travelled a month by the fuel vehicle users. 54.41% of respondents travel below 500 km per month and 36.76% of them travel between 500-1500 km a month. Average distance travelled by male (803.03) is greater than female (550). As mentioned in the review of literature a typical passenger car is driven around 18507.46km per year. It means that a typical passenger car is driven around 1542.25 km per month on average. But the average distance of a respondent is 672.79 km per month.

Table 12: Average Maintenance Cost

Type of vehicles	Average maintenance cost of vehicle in a month								
	Below 1000		1000 – 2000		2000 - 3000		Above 3000		Total
	M	F	M	F	M	F	M	F	
Fuel	16	18	11	8	4	2	1	2	62
Both	1	3	0	1	1	0	0	0	6
Total	38		20		7		3		68
Percent	55.88235294		29.41176471		10.29411765		4.411764706		100
Not responded	2								

Source: Primary data

Table 12 highlights that maintenance cost of 56% of respondents are below Rs 1000. More number of females (21) falls into this category than male (17). Only 4.41% spends above 3000. Average maintenance cost of male respondents (1205.882) is greater than that of female (1058.824). Average maintenance cost is 1132.353 per month. By comparing the average distance travelled (table 11) and the maintenance cost (table 12) of fuel vehicle users it is found out that both are positively.

Table 13: Mileage of Vehicle

Type of vehicles	What is the mileage of your vehicle (Km/L)								
	Below 10		10 to 15		15 to 20		Above 20		Total
	M	F	M	F	M	F	M	F	
Fuel	0	1	13	11	9	6	10	10	60
Both	0	1	0	2	2	0	0	1	6
Total	2		26		17		21		66
Percent	3.03030303		39.39393939		25.75757576		31.81818182		100
Not responded	4								

Source: Primary data

Table 13 describes the mileage (in Km/L) of fuel vehicles. Many of the respondents (40%) are using moderately efficient vehicles as their vehicle's mileage ranges between 10-15. Average mileage of vehicle used by male and female are 17 and 16.4 respectively. The average of whole respondents is 16.7.

Table 14: Average Fuel Cost

Type of vehicles	What is the average fuel cost per month								
	Below 2500		2500 – 5000		5000 -7500		Above 7500		Total
	M	F	M	F	M	F	M	F	
Fuel	12	21	15	7	4	1	1	1	62
Both	1	3	1	1	0	0	0	0	6
Total	37		24		5		2		68
Percent	54.411764705		35.294117647		7.352941176		2.941176471		100
Not responded	2								

Source: Primary data

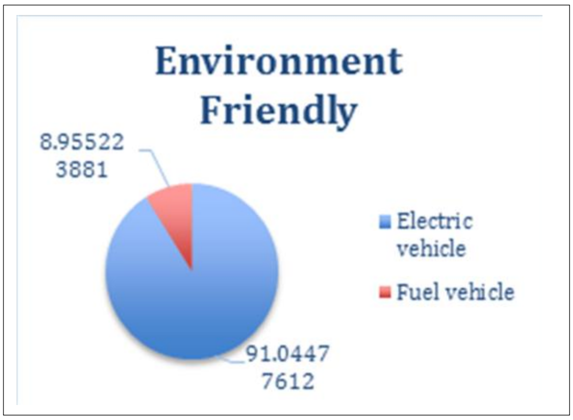
The average fuel cost per month according to the sample is 3014.705 (computed by splitting the classes into 0-5000 and 5000 to 10000). 89.7% of the respondents have an average fuel cost below 5000 (Table 14). Chi square test was conducted to identify if there is an association between gender and incurring of average fuel cost. For the purpose of conducting the test the of fuel cost was divided into below Rs. 2500 and above Rs. 2500.

H0: there is no significant association between gender and average fuel cost.

H1: there is significant association between gender and average fuel cost.

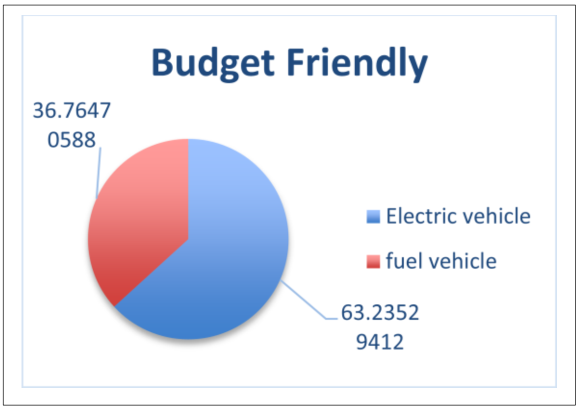
Since the p-value (0.007398845) is less than 0.05, the null hypothesis is rejected. That is, there is a statistically significant association between gender and average incurring of fuel cost.

Figure: 4



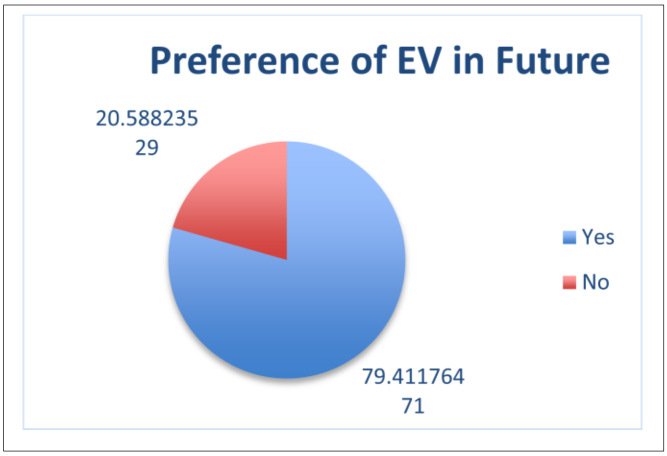
Source: Primary data

Figure 5



Source: Primary data

Figure: 6



Source: Primary data

Figures 4,5 and 6 depict the behaviour of respondents regarding electric vehicles. Even though a large portion of respondents agree that electric vehicle is environment friendly (91%) only 63.23% believes that it is budget friendly. Also 79% of respondents will prefer electric vehicle in future. Majority respondents (91%) know that EV is better for environment but 27.8% respondents among this choose fuel vehicle as budget friendly and 11.7% among this will not prefer EV for future use. However, according to think mobility (2025) a research report published by Google and BCG (Boston consulting group) opined one in three consumers considering EV as their future vehicle in India. 36% of the consumers are tending towards electric cars and 30 % are inclined towards electric two wheelers. It is more than 2/3 as per the present sample.

The ensuing part is the responses of electric vehicle users. As the responses were limited (EV users) the tables are not presented here. The survey asked about the average distance travelled by the electric vehicle users. Out of 8 respondents 4 of them travel around 300-600 km per month. Average distance travelled by the respondents during a month is 375 km which is less than that of a fuel vehicle (672.79 km). Further the survey queried how the EV users charge their vehicle and the average maintenance cost of electric vehicle per month. Out of 7 respondents 4 of them charge their vehicle at home and remaining 3 relies on both charging station and home. In the case of maintenance cost all respondents have cost below 2500 Rs/-. While comparing with fuel vehicle (1132.353) the average maintenance cost of electric vehicle is high (1250). Also, 7 out of 8 respondents chose electric vehicle because it is environment friendly. By comparing it with figure 4 the authors came to a general conclusion that majority of the respondents agree that electric vehicle is environment friendly. Additionally, four respondents are not sure if electric vehicles are affordable or not. Comparing with fuel vehicle respondents (Figure 5) major portion of them (63.23%) responded that electric vehicle is budget friendly however the remaining respondents (36.76%) who choose fuel vehicle as budget friendly is also dominant. According to think mobility report (2025) 45% of costumers find High Acquisition Cost of EV as a major concern. Further, most of the respondents (5) are aware of the subsidies provided for electric vehicles. Final question was related to the availability of charging station. 5 out of 8 respondents have charging station available in their locality. The study published by Google and BCG (2025) found that 51% of the customers are concerned with the charging infrastructure facilities. This goes in line with the fifth theme of review of literature in this study. Infrastructure development has a momentous role in inducing consumer behaviour and fast-tracking EV adoption.

As the data presentation is over the next section provides the concluding remarks.

Conclusion

The research analysed external benefit (cost) of EV as an adaptation strategy for climate change. The monthly average CO2 emission of a passenger car was computed and came to know that as more distance a car runs, the CO2 emission surges along with the rise in its money value. EVs remain quieter than ICE vehicles at slow speed and ICEVs create greater air pollution during low speed therefore EVs are more appropriate in the urban context of Kerala. From the estimation of expenses, EVs are economically viable only in the long run. By comparing both vehicles' external benefit-cost ratio, authors came to know that fuel vehicle creates a large amount of negative spillover effects and EVs creates a positive externality. Based on the survey among the vehicle users' average distance of a typical passenger car is 672.79 km per month. Majority respondents (91%) know that EV is better for environment and 63.23% believes that it is budget friendly. 79% of respondents will prefer EV in future. There is a statistically significant association between gender and average incurring of fuel cost with a p-value 0.007398845. The carbon footprint from the lithium-ion battery was not mathematically computed in the study but more research should be done on the carbon footprint of these batteries as its manufacturing is also a major factor that creates a negative externality to environment. It is suggested that along with tax credits, subsidies should be also given to reduce the cost burden of the battery. Government should also allocate more funds for the research and development (R&D) of battery. R and D measures should develop strategies to increase the lifespan of EV batteries. This will postpone the disposal of used batteries and also will reduce the battery cost there by increasing the demand for EVs. So that EVs will become an efficient adaptation policy for mitigating climate change.

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However, errors if any, are rest with the authors.

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