ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

COMPARATIVE LIFE CYCLE ANALYSIS OF ELECTRIC AND CONVENTIONAL VEHICLES IN BANGLADESH

A Thesis by

MD.SAMAWAT AHSAN MASHIYAT

MD ASIF AHMED

RAISUL ISLAM ATIK

Department of Mechanical and Production Engineering

Islamic University of Technology (IUT)

MAY (2022)

COMPARATIVE LIFE CYCLE ANALYSIS OF ELECTRIC VEHCILE AND CONVENTIONAL VEHICLES IN BANGLADESH.

MD.SAMAWAT AHSAN MASHIYAT, 170011022
MD ASIF AHMED, 170011031
RAISUL ISLAM ATIK, 170011073

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Bachelor of Science in Mechanical Engineering

DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

May (2022)

CERTIFICATE OF RESEARCH

This thesis titled "COMPARATIVE LIFE CYCLE ANALYSIS OF ELECTRIC VEHCILE AND CONVENTIONAL VEHICLES IN BANGLADESH" submitted by MD., SAMAWAT AHSAN (170011022), MD ASIF AHMED (170011031) and RAISUL ISLAM ATIK (170011073) has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Mechanical Engineering.

Supervisor

Dr.A.R.M Harunur Rashid
Professor

Head of the Department

16/05/22

Dr. Md. Anayet Ullah Patwari
Head of the Department

Department of Mechanical and Production Engineering (MPE)
Islamic University of Technology (IUT)

DECLARATION

I hereby declare that this thesis entitle "Comparative Life Cycle Analysis of Electric and Conventional Vehicles in Bangladesh" is an authentic report of study carried out as requirement for the award of degree B.Sc. (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of Prof. Dr. Md. A. R.M Harunur Rashid, Professor, MPE, IUT in the year 2022.

The matter embodied in this thesis has not been submitted in part or full to any other institute for award of any degree.

Md. Samawat Ahsan

170011022

Md Asif Ahmed

170011031

Raisul

Raisul Islam Atik

170011073

ACKNOWLEDGEMENT

In the Name of Allah, the Most Beneficent, the Most Merciful

First of all, I am grateful to ALLAH (SWT), the most benevolent and kind to provide me the strength and ability to write this dissertation. I want to thank my project supervisor, Dr. A.R.M Harunur Rashid for his strong and patient support through unpredictable problems during the project and his precious advice when I faced difficulties. His generosity, kindness and strong supervision during work made me feel less stressed in confronting unexpected troubles and be more productive in my personal life.

In the next step, I would like express my deep acknowledgment to my father and mother for their continued support and dedication towards my higher study.

TABLE OF CONTENTS

LIST OF FIGURES

Nomenclature

LCA	Life Cycle Analysis
WTW	Well to Wheel
WTT	Well to Tank
EV	Electric Vehicle
BEV	Battery Electric Vehicle
HEV	Hybrid Electric Vehicle
ICEV	Internal Combustion Engine
CNG	Compressed Natural Gas
HTP	Human Toxicity Potential
GHG	Green House Gas
GWP	Global Warming Potential
CO	Carbon Monoxide
CO_2	Carbon Dioxide
NOx	Nitrous Oxide
SOx	Sulphur Oxide
PM 2.5	Particulate Matter 2.5
PM 10	Particulate Matter 10
VOC	Volatile Organic Compound

ABSTRACT:

In many parts of the globe, electric cars are being promoted as a means to drastically improve urban air quality while also cutting greenhouse gas emissions. Utilizing a Life Cycle Analysis approach, this study examines and compares the potential environmental impacts of several types of vehicles in Bangladesh, including electric vehicle, gas, compressed natural gas and diesel. With this study, the researchers want to perform an in-depth investigation of a wide range of environmental influence categories. An environmental and economic Life-Cycle Assessment of conventional and electric vehicle technologies is performed in this article, with particular emphasis on the primary energy sources and greenhouse gas emissions throughout the vehicle running phase. A thorough evaluation of the Electrical mix was carried out, taking into consideration the contributions of each kind of main energy source.

When compared to equivalent internal combustion engines throughout the course of a vehicle's lifespan, battery electric vehicles met the aim of lowering greenhouse gas emissions in 2015, but this covers a greater human health impact among several other environmental side effects.

On the other side, electric vehicles have the potential to significantly increase human toxicity, freshwater ecotoxicity, freshwater eutrophication, and metal depletion, mostly via the usage of the car supply chain, as well as other environmental impacts. The assumptions made about the power supply, energy consumption throughout the utilization phase, vehicle longevity, and battery replacement schedules have an impact on the findings. It takes teamwork to improve the environmental profile of electric vehicles, including efforts to reduce supply chain impacts and to promote renewable energy sources in Electrical infrastructure planning and decision-making.

CHAPTER 1

INTRODUCTION

1.1 IMPORTANCE OF THE STUDY

LCA is a procedure in environmental science that involves calculating and assessing the ecologically significant inputs and outputs, as well as the potential environmental ramifications, of a product, material, or service throughout the course of its life cycle.

When we speak about the "life cycle", we're referring to the technological system of operations and transportation routes that are utilized or necessary throughout the process of raw material extraction, production, utilization, and disposal, as well as throughout the process of waste disposal (waste management or recycling). In certain circles, a "cradle-to-grave" review is referred to as a LCA . People that utilization LCAs include a diverse spectrum of individuals, including the following:

The environmental consequences of EV cars over their entire life cycle are a cause of increasing controversy, which is usually fueled by skewed media coverage and disinformation. Using life cycle performance data from conventional ICEVs and EV autos in Bangladesh, this article tries to provide a comparison between the two. Automobile technology (or any other product/system) LCA is a process for analyzing the environmental impact of a technological innovation on the environment. When conducting an environmental impact assessment (EIA), it is important to consider all of the environmentally significant operations that take place throughout the life cycle of a vehicle, from the sourcing of raw materials to component fabrication and assembly, transportation, vehicle utilization, and end-of-life treatment, among other things. Because it considers all periods of life, from conception to death, LCA eliminates the potential of moving the issue. The essential challenge, on the other hand, is how to make effective policy decisions when the vehicle-LCA literature provides evidence that is often in conflict with one another. As evidence for its point of view, the paper provides important findings from the vehicle-LCA literature, as well as specific simulations of scenarios in which the influence of carbon footprint on the performance of EV automobiles in Bangladesh is investigated.

Climate change is a worldwide security threat on a magnitude that has never been witnessed before. According to the United Nations' Paris Agreement, which was signed in 2016, the global temperature rise should not exceed 34.7 to 36 degrees Fahrenheit over pre-industrial levels. In order to achieve the global climate target via reductions in greenhouse gas emissions, each signatory country created a national determined contribution (NDC) that was submitted to the UN Framework Convention on Climate Change. Meanwhile, the United States has promised to lowering emissions by 26-28 % below 2005 levels by 2020, according to the United Nations Environment Programme[2]

As a result, since it is 95 % dependent on fossil fuels, the transportation sector contributes heavily to greenhouse gas (GHG) emissions, which in turn adds to worries about both local and global climate change. Transportation sector utilization accounts for 61.2 % of the world's oil reserves, subsidies account for 28 % of the world's total final energy supply [3], and accounts for 23 % of global CO_2 emissions [4]. As a consequence, there has been an increase in research towards ecologically friendly transportation systems as a result of this. The ultimate objective is to minimize reliance on fossil fuels while increasing the utilization of alternative fuels such as hydrogen and methanol in combination with EV cars, according to the United Nations. Coal is the most major source of energy and heat production in the United States, accounting for about half of total energy and heat output. Coal is a fossil fuel that releases a significant amount of CO_2 into the atmosphere. Coal is a fossil fuel that emits a lot of CO_2 gas.

The demand for new cars is increasing quickly as a consequence of increased access to mobility, and the number of vehicles is expected to more than quadruple by 2050, with the fastest growth rates expected in emerging countries [5].

EVs have the ability to address two challenges: energy insecurity and greenhouse gas emissions. Advanced EV drive cars have the potential to ease both issues [6], [7].Advanced EV drive vehicles include plug-in HEVs and all-EVs, which are examples of advanced EV drive vehicles . More than 0.113 million EVs were sold worldwide in 2012, according to the International Energy Agency. According to a study issued by the International Energy Agency in 2013, the Electric Vehicle Initiative (EVI) of the International Energy Agency (IEA), which now includes 15 countries, intends to sell 5.9 million EV cars per year by 2020, with the goal of selling 5 million by 2025. The transportation sector's energy consumption and associated greenhouse gas emissions are projected to increase by 46 % by 2035, when compared to 2005 levels. Transportation energy consumption and associated greenhouse gas emissions account for 82 % of the total increase in liquid fuel consumption, while EV power generation uses fewer liquid fuels than transportation energy consumption. It is certain that the environment and human health will continue to suffer if the power used in EV cars is generated from fossil fuels. There is an urgent need to study ecologically acceptable energy generating and distribution systems for EVs as a consequence of this development.

The well-to-wheel (WTW) evaluation is a technique that is often used in the literature to evaluate different vehicle systems. A Well-to-Tank (WTT) study focuses only on the production of gasoline or Electricity (Well-to-Tank) and the emission of tailpipe pollutants (Tank-to-Wheel). Because the environmental consequences of manufacturing certain components, such as batteries, are not taken into account in a WTW research, the results are skewed in favor of zero-emission cars.

It is possible for vehicle-LCA studies to provide contradictory findings depending on the data and modeling assumptions used, making it difficult for policymakers to draw significant conclusions about the industry's future. The results of a vehicle's life cycle study, which assesses the environmental impact of the vehicle, are often expressed as a single number. While this technique approximates the environmental effect of a single car, it falls short of providing decision-makers with a full picture of the possible repercussions of their decisions. One number cannot adequately explain the complexity, ambiguity, and variability of the system, and as a result, no single value can be used to accurately represent it. Example: When comparing two identically equipped vehicles, the overall quality of the comparison may be diminished or increased depending on the collection of vehicles used to compile the comparison. A multitude of outputs and interpretations may be derived from any single statistic, such as fuel consumption or vehicle weight, when changes within a certain vehicle technology and category are taken into consideration. Therefore, investigating the impact of all vehicle factors on LCA conclusions is crucial.

To address this gap in research, we used a cradle-to-grave (C2G) LCA framework to examine the effects of fuel and vehicle life cycles on energy consumption and CO_2 emissions, as well as emissions of five air pollutants, including VOCs, CO, NOx and PM 2.5.

1.2 PROBLEM STATEMENT

To conduct a comparative LCA of an EV and conventional vehicle in Bangladesh.

1.3 GOALS AND OBJECTIVE

The purpose of this paper is to evaluate the life cycle effects of EV cars, gasoline vehicles, and compressed natural gas vehicles, as well as to investigate the influence of vehicle characteristics on the LCA results. The authors of this article set out to offer a fair and thorough picture of the environmental effect of conventional and alternative fuel cars on the environment. All elements of vehicle production, transportation, manufacturing, utilization, maintenance, and end-of-life considerations are taken into account.

The following questions will be addressed by this investigation:

1. To what extent does the regional grid mix influence the quantity of greenhouse gas generated by an EV car that is battery-powered and runs on electricity?

2. The distinction between greenhouse gas emissions from battery-powered EVs and those from autos fueled by gasoline or compressed natural gas is unclear.

3. What are the environmental ramifications of driving an EV car fueled by batteries?

CHAPTER 2

LITERATURE REVIEW:

When it comes to powertrain efficiency, maintenance requirements, and zero tailpipe emissions, EV cars outperform conventional ICEV vehicles , the latter of which results in lower levels of urban air pollution[8].

Even more so when comparing technologies with significantly different powertrains, such as ICEVs and EVs, it is vital to evaluate the production implications of the choices made. When it comes to electronic equipment in particular, a varied range of components is required, making recycling more difficult and increasing worries about toxicity[9].

The findings of a full life-cycle assessment comparison between a HEV and a conventional version of the identical car are presented by Daimler AG [10] in this document. Despite the fact that this is most likely the most comprehensive EV life cycle inventory (LCI), it is for a HEV car rather than a pure-EV vehicle. A well-documented inventory is presented by Zackrisson and colleagues [11] for the purpose of assessing two potential next-generation lithium iron phosphate (LiFePO4) battery manufacturing techniques. Using a lithium manganese oxide (LiMn2O4) battery-powered EV car, Notter and colleagues [12] give one of the most transparent life-cycle evaluations (LCAs) of any such vehicle (EV).

In the opinion of Nemry [13] and Sadek [14], EV and HEV powertrains are developing as viable vehicle propulsion technologies with the potential to decrease greenhouse gas and other exhaust gas emissions connected with road transportation.

Helmers and Marx [15] provide a comprehensive overview of the technical characteristics and environmental consequences of EV and HEV vehicles, but they do not place a strong focus on a study of the literature. EVs beat conventional automobiles in a variety of ways, according to the researchers, but the LCA literature on the subject is "complicated."

Li [16] conducted research in China that assessed the performance of battery electric vehicles (BEV) and fuel cell vehicles that were fueled by a range of energy sources and technologies from the beginning to the end of the journey. The statistics were compared in terms of fossil energy utilization, total energy consumption, and greenhouse gas emissions, with the findings varied depending on whether Electricity or hydrogen was utilized as a source of electricity or hydrogen.

Rose [17] did a LCA on heavy-duty trash collection vehicles that were fueled by diesel and compressed natural gas. When compared to standard diesel automobiles, the data revealed that compressed natural gas (CNG) vehicles are favored due to their lower impact on climate change and lower cost.

Archsmith [18] investigated the impact of Electrical fuel source and performance under real-world conditions on total greenhouse gas emissions over the course of a life cycle. They created an integrated model of life cycle emissions for both the production and utilization of ICEVs and EVs , which takes into account the effects of climatic conditions on vehicle efficiency as well as the utilization of non-fossil energy sources for marginal Electricity.

Hawkins [19] and colleagues conducted a benchmarking study of 55 studies and examined the breadth of 51 of them in relation to their own recommended methodology and idea of a state of the art comprehensive LCA of EVs. As part of its examination and evaluation of data sets employed in this field of study, the report emphasizes inventory shortages for critical components such as batteries, EV motors, and electronic equipment that need to be addressed. So we want to complement Hawkins' work by recognizing that there are numerous valid aims for LCA studies of EVs and by introducing a learning approach to the industry.

Rita [20] used the criteria of environmental impact, this study presents a method for classifying light-duty automobiles that may be applied to any kind of vehicle. To arrive at the category, indications from the Life-Cycle Impact Assessment and vehicle operating indicators are merged using the Multi-Criteria Decision Analysis (MCDA) approach, which is based on many criteria.

According to Joeri [21] the BEV is charged using Belgian energy in 2011, it produces 31 grams of CO_2 equivalent per kilometer driven when fully charged. Changing from hydrogen to battery EV, or from plug-in HEV to battery EV, results in a reduction in overall CO_2 emissions during the vehicle's lifetime. For the time being, EV propulsion looks to be the most environmentally friendly mode of transportation for city travel, thanks to its low tailpipe emissions and high energy efficiency. Because it dictates how rapidly an EV can recharge, the charging time of an EV is essential in determining the car's total emissions performance. It is possible that utilizing off-peak charging instead of peak charging will result in a reduction of around 12 % in the vehicle's WTT CO_2e, PM, NOX, and SO2 emissions per kilometer driven as compared to when peak charging is used.

When compared to conventional automobiles, EVs have the potential to significantly reduce the environmental effects of ADP, GWP, and ODP, with the greatest potential for reduction in CO_2 emissions being the most significant. When compared to ICEVs, EVs lower carbon emissions by more than 50%. While EV cars outperform HEV and ICEV vehicles in areas such as acceleration, power, acceleration, acceleration, power and acceleration; HEV vehicles outperform ICEV vehicles in all categories.[22]

Because of the HEV vehicle's heavy weight and intricate manufacturing process, the vehicle's utilization phase is more energy efficient and emission-free than that of an ICEV vehicle. So HEV cars have a greater impact on the production process than either EVs or automobiles powered by ICEVs, for example.

In order to better understand the performance of hydrogen fuel cell passenger automobiles, the life cycle of four different Canadian locations, each with its own fuel supply and semi-urban driving circumstances, were researched in order to better understand their performance. The results of a LCA approach were compared to one another. In order to establish a baseline comparison, data from conventional gasoline-powered passenger automobiles was compared to the results of this study. Extensive research and development has gone into the many hydrogen-generating methods that have been developed (SMR). According to the sustainability score, the best case scenario for the transition to fuel cell automobiles is a thermochemical hydrogen production facility in Ontario, where a significant volume of high-temperature waste heat from nuclear power reactors could be used as an energy input.[23] Additionally, this research examines the life cycles of ICEV-powered vehicles, which may run on a number of fuels, ranging from hydrogen to gasoline, as well as EV and HEVs.

This study looks at conventional automobiles that are powered by liquefied petroleum gas (LPG), diesel, gasoline, and compressed natural gas (CNG). Alternative vehicles include hydrogen, ammonia, methanol, EV automobiles, and plug-in HEV EVs, to name a few examples. The assessments take into account the full passenger car life cycle, from manufacture through disposal, as well as the operation of the vehicle. According to the findings, hydrogen autos are the most environmentally beneficial choice in every category studied[24] Ammonia is the greenhouse gas that contributes the least to global warming and the ozone layer depletion, and it contributes less to global warming than EV autos.[24] However, if both ammonia and EV automobiles are fueled by renewable energy sources, it is possible that ammonia will have a less negative impact on the environment. While EVs do not emit CO_2 while they are in utilization, the production and disposal of batteries has a significant influence on the environment, resulting in acidification, eutrophication, and human toxicity. The utilization of non-fossil fuels to produce energy and power EVs and plug-in HEV vehicles (EVs and PHEVs) may assist to further alleviate environmental concerns. Given that methanol is derived mostly from natural gas, it is the most probable source of global warming emissions today.

According to Qiao [25] the production of an EV generates much more CO_2 than the production of an ICEV. CO_2 emissions from EV construction are 59 % higher than those from ICEV vehicles (ICEV) when the fundamental components of both vehicles are considered, such as the body and chassis (without the battery). This is due to the additional weight of EVs compared to ICEV vehicles. In part because of the larger weight and changeable composition of an ICEV's engine and transmission systems, the creation of these specialized components results in higher CO_2 emissions throughout the manufacturing process. In contrast, since the traction motor and electronic controller are exclusively found in EVs, the total CO_2 emissions from the production of specific components in an EV are 3 % more than in an ICEV vehicle (ICEV). Additionally, because of the large amount of CO_2 emitted during Li-ion battery manufacturing, the production of batteries and accessories, such as tires and lubricants, produces 3.8/4.0 times the CO_2 emissions associated with an EV with NCM/LFP battery compared to an ICEV, respectively.

Finally, because of the Li-ion battery manufacturing process, the creation of EVs produces additional CO_2[26].

According to the results of the life-cycle assessment scenarios, converting a used automotive from an ICEV to an EV motor has significant environmental advantages. Due to the glider's increased lifetime (an extra 100,000 km), the additional effect reductions were 16 % (in terms of CO_2-eq) and 19 % (in terms of Single score endpoint) greater than the baseline. [27] A skilled workshop may accomplish the conversion in as little as two days if they have a suitable and well-tested assembly kit on hand. The Smart model, on the other hand, demonstrated readiness for a quick and straightforward conversion as a result of structural criteria.

Specifically, this study found that the EV Smart has a major advantage over traditional combustion engine vehicles in terms of urban mobility. Even with Germany's current Electrical mix and a brand-new EV car, the BEV is more ecologically friendly when compared to the ICEV. As is well recognized, moving to renewable energy sources may have a substantial positive impact on the environment's performance.

A study of LCA assessments of EV cars indicated that environmental indicators for EVs in Poland were significantly higher than environmental indicators for EVs in the Czech Republic across all impact categories. [28]It was discovered that the energy needed to recharge EV batteries is the most important driver of all impact categories for EVs in Poland and the Czech Republic, based on the findings of the study.

In Poland and the Czech Republic, as a result of decreases in the amount of coal used in power production, the values of environmental indicators for each impact category have fallen from current to future EVs for each effect category. Charging an EV entirely using renewable energy decreases greenhouse gas emissions, fossil fuel depletion, land acidification, and particle matter creation, among other environmental advantages, when compared to other EV versions and ICEVs. In comparison to other EV designs that employ a variety of energy sources, charging an EV car entirely from renewable sources would result in significant reductions in negative outcomes across the impact categories of freshwater eutrophication and human toxicity, according to the EPA.

While hydropower has the lowest environmental indicators when compared to other renewable energy sources for electricity production, it has the lowest environmental indicators across all impact categories when used to charge EV car batteries.

For three Australian scenarios and seven Australian states and territories, as well as for the United States, a technical evaluation of battery-EV and conventional fossil-fueled passenger automobiles is conducted. Through the utilization of a probabilistic life-cycle assessment, it is possible to explicitly quantify uncertainty in the LCA inputs and outputs in this study (pLCA). A statistical technique is used in order to produce parametric input distributions, which are then utilized to generate parametric input distributions in turn. According to the available information, replacing fossil fuels with EVs would lower GHG by 29 - 41 % in Australia's 2018 power mix, which is now dominated by fossil fuels. [29]. When fossil fuels are used to provide marginal power alone, EV autos are expected to reduce greenhouse gas emissions by 10 % to 32 %, depending on the circumstances, according to predictions. [29] The scenario with a larger share of renewable energy sources results in considerable reductions in greenhouse gas emissions of between 74 and 80 % in comparison to the baseline scenario. Australian jurisdictions have a wide range of average LCA GHG emission factors for conventional automobiles (364–390 g CO_2 -e/km), but particularly for EV automobiles (98–287 g CO_2 -e/km), which reflects regional differences in the fuel mix used to generate Electricity in different parts of Australia. It is anticipated that electrifying Tasmania's on-road fleet would cut greenhouse gas emissions by 243 to 300 grams CO_2 equivalent per kilometer driven, in line with the LCA.[29]

This study [30] compared the energy usage and carbon emissions of BEVs with ICEVs. In the majority of China, with the exception of Beijing, Heilongjiang, Jiangxi, Tianjin, Shandong, Shanxi, and Hebei, promoting BEVs results in carbon reduction, demonstrating that BEV development helps to carbon neutrality. However, because of geographical differences in the mix of electricity produced, the technology used to generate thermal power, and the efficiency of electricity transmission, the efficacy of emission reduction varies greatly across China. Specialist tailored advertising is thus required in a number of different venues as a result of this. The marketing of EVs should be bolstered by cities with low carbon emissions from autos. The utilization of renewable energy should be prioritized in places with high levels of carbon emissions from automobiles. This will allow these areas to improve the efficiency of their energy mix by increasing their share of renewable energy. Additional ways in which governments may lower the carbon intensity of electricity are to encourage renewable energy generation and power exchange across many power grids, as well as to improve the efficiency of power producing technologies and transmission systems. Battery manufacturers must improve battery production methods and extend battery life in order to achieve the greatest possible reduction in carbon emissions. This is due to the significant carbon emissions generated by batteries throughout the material extraction, processing, and vehicle manufacturing processes.

The size of the battery and the method used to charge it both have an impact on the environmental performance of battery EV cars . Therefore, while analyzing the environmental performance of these technologies, it is necessary to take into account changes in the sector as well as battery renewal. Using three distinct scenarios, this study conducts a scenario-based LCA , evaluating the combined impact of four critical parameters on the battery-EV's life-cycle environmental performance: future changes in the charging Electricity mix, battery efficiency deterioration, battery refurbishment, and recycling.

According to the findings of the study, neglecting the consequences of future changes in the EU's energy mix might result in an overestimation of the climatic implications of BEVs, leading to policymakers being misinformed. Future improvements in Electricity production will have the biggest influence, with the dynamic scenario resulting in a 9 % decrease in CO2 emissions from current levels. [31] CC has a greater influence on the manufacturing stage than the BEV utilization stage, owing to changes in EU energy supply over time (from 43 % in the reference scenario to 47 % in the dynamic scenario when compared to the reference scenario without recycling).[31]

During the utilization-stage, battery efficiency declines by 7.4 to 8.1 %, increasing the amount of energy used by BEVs and having a detrimental influence on climate change. Recycling lowered the climate effect of BEVs by around 8 %, while decreasing human toxicity and MRS impacts by approximately 22 % and 25 %, respectively, in comparison to non-recycling.[31] Existing recycling techniques, on the other hand, provide a number of challenges and possibilities for advancement, including improved sorting, collecting, and recycling technologies that have the potential to significantly raise the recycling rate of BEV components.

Patricia [32] in order to account for the three different vehicle life expectancies, three different scenarios (A, B, and C) are computed. Scenario A depicts a cautious driver navigating across a flat metropolitan environment. There is no need for heating or cooling in this environment. Because of the peculiarities of the circumstance, the average velocity is much lower than it should be. As a consequence, consumption is often modest, averaging approximately 10 kWh/100km on average. Scenario B portrays a typical driver that mostly drives through a mountainous metropolitan zone, as seen in Figure 1. There is no need for heating or cooling in this environment. The characteristics of the scenario result in an average velocity that is medium. As a rule, the typical consumption is low, averaging around 15 kWh per 100 km.[32] Scenario C illustrates a vibrant driver who is traveling along a twisting road with his family. A considerable demand for heating and cooling is not now present. Because of the characteristics of the circumstance, the average velocity is rather high. It is as a consequence of these characteristics that the average consumption is high, at around 20 kWh/100 kilometers.[32]

GREET and PRELIM models were used to calculate the greenhouse gas emissions and energy consumption of diesel and LPG automobiles in Korea, according to the authors.[33] Because the WTW approaches provide energy and emission data that is vehicle-dependent, the statistics for each vehicle are different from the others. In an SUV and a one-ton truck, LPG generated lower greenhouse gas emissions per mile traveled than diesel. In the two autos and the 1,500kg truck, LPG generated greater greenhouse gas emissions per mile traveled than diesel. It is projected that improved fuel efficiency will result in a reduction in the greenhouse gas emissions generated by LPG vehicles.

The life-cycle greenhouse gas emissions of an EV (EV) in China were expected to be around 41.0 t CO_2 eq in 2015 and to decrease to 34.1 t CO_2 eq by 2020. In 2015, an ICEV emitted around 50.0 t CO_2 eq, but by 2020, it will emit approximately 49.0 t CO_2 eq. [34]

The WTW phase is the most significant source of greenhouse gas emissions, accounting for about 59 % to 62 % of the life cycle GHG emissions of an EV and 75 % to 79 % of the life cycle GHG emissions of an ICEV vehicle. [34]As a consequence, the pollution gap between EVs and ICEVs is expanding as the renewable energy grid expands. The other two stages, notably the CTG phase, emit essentially continuous GHG emissions, which will make it difficult for China to fully benefit from the environmental advantages of EVs.

The carbon intensity of the fuel cycle and the proportion of renewable energy in the mix have a major influence on the emissions generated by EV autos throughout their operation. If EVs are used in areas with a high proportion of natural gas-based Electricity and robust pollution control at power plants (such as California and the NPCC), they have the potential to reduce greenhouse gas emissions as well as total and urban air pollution by a significant amount (excluding total PM in CA). On the other hand, EV cars operating in locations where coal is the dominant source of energy, like in parts of China as well as three Midwestern states in the United States, might result in increased emissions, particularly in cities, or very small reductions in total emissions.[35]

In a lifecycle analysis, batteries were found to be responsible for a significant portion of the environmental impacts associated with EV production, accounting for anywhere between 10% and 75% of total manufacturing energy consumption and anywhere between 10% and 70% of total manufacturing GHG emissions[36]. The research of EV car batteries is especially busy at the moment, since the designs of these batteries are constantly evolving.

This article [37] presents the results of an investigation of the environmental performance of a number of existing and future mid-size passenger automobiles. a) Introduction We provide a LCA comparison on the basis of our unique integrated vehicle simulation system, which takes into consideration both vehicle parameter constancy and future technological advances. The findings suggest that, in order to prevent negative environmental consequences from transportation electrification, it should be supplemented with greater integration of life cycle thinking and management into energy and mobility regulations. In order to prevent negative environmental consequences from transportation electrification, the findings suggest that it should be supplemented with greater integration of life cycle thinking and management into energy and mobility regulations.

Increasingly interwoven with other sectors such as power, electronics, chemical manufacturing, and metals manufacturing, the personal transportation industry will grow in importance due to the widespread usage of BEVs and fuel cell vehicles. If EVs are to play a major part in the transportation industry's efforts to minimize the environmental impact of passenger transportation, it is critical that they conduct proactive research of the sectors' concerns and trends as soon as possible.

In this study, the major objective is to assess if increasing the battery capacity and driving range of EVs has an effect on their environmental impact . When compared to ICEVs, the principal sources of emissions from EVs throughout the course of their lifetime were unique . The CCP intensity of EV cars was between 6.3 and 7.1 kilograms CO_2-eq kg1 of vehicle from cradle to grave, while the intensity of ICEVs ranged between 3.9 and 5.7 kilos CO_2-eq kg1 of vehicle. [38] When it comes to cradle-to-gate CCP intensity differences between EV cars and internal combustion vehicles , battery manufacturing was the most important aspect to consider. Battery manufacturing contributed 31% – 46% of the entire impact of EV production. [38] In both conventional and EV autos, energy consumption and energy sources played a significant role throughout the whole usage phase, and this was true independent of the vehicle type.

According to the research, EV automobiles were responsible for between 55 % and 65 % of total lifetime emissions during their lifespan. [38] A total of around 4 % and 5 % of the total energy was lost throughout the charging procedures of the battery and charger, and correspondingly. The fact that EV cars have a somewhat bigger impact on end-of-life therapy than conventional automobiles is due to the end-of-life treatment that the battery receives. Between 14 % and 23 % of total EOL treatment emissions from EV cars were attributed to the battery, according to the findings. The battery was shown to be responsible for between 13 % and 22 % of the total lifespan impact of EV automobiles, depending on the study.[38]

A full life cycle evaluation of the transit vehicles under consideration using a range of fuel types is provided in this study[39], demonstrating the significance of the supply chain in transportation. Electricity and HEV fuels may be considered to be more ecologically beneficial than other types of fuel, according to some experts. While EV and HEV buses are less ecologically friendly than other means of public transportation, they are likely to be the most environmentally friendly throughout their whole service life.

Another important finding of this research is that slower average driving cycle speeds result in worse fuel efficiency; heavier stop-and-go operations may result in higher fuel consumption for transit buses that operate on diesel, biodiesel, compressed natural gas, or LNG fuel. The slower average speed HEV or EV buses has no influence on the total amount of emissions they produce. [39]. Longer running cycles and higher average speeds, on the other hand, reduce the efficiency of HEV and BE transit buses; nevertheless, developments in battery technology in this area look to be favorable. Furthermore, future study into alternative Electrical grid design may take into account the Environmental Protection Agency's air pollution regulations.

Since regional indicators such as electricity grid mix, fuel efficiency, and other factors are heavily relied on, future study should incorporate multi-criteria decision-making methodologies with cost analysis indicators.

The purpose of this study is [40] to assess the possible CO_2 emission savings related with large-scale vehicle electrification via the utilization of a HEV LCA. The creation of a comprehensive database of passenger EVs delivered in 2018 has also been completed, as has the development of a future scenario analysis that takes into account a wide range of technical advances. It is possible to get both of these goods via download. In 2018, it looks that vehicle electrification will fail to cut emissions, since the higher emissions arising from the manufacturing of newly marketed passenger EV cars would more than outweigh the emissions reductions achieved from on-road vehicles. Reduced emissions are expected to reach 49.64 million tons by 2030 and 62.16 million tons by 2050, according to research conducted using market-based data in 2018 and scenario analysis in 2030.[40] When it comes to reducing emissions, fuel efficiency is a key contributor to the reduction of greenhouse gases.

CHAPTER 3

METHODOLOGY:

3.1 LCA FRAMEWORK

LCA is defined as the process of assessing and analyzing a product or service's ecologically important inputs and outputs, as well as any possible environmental implications that may arise from their usage throughout the length of the product or service's useful life.

The scope of this research extends from infancy to tomb, taking into account five life cycle stages:

a. vehicle manufacture,
b. component manufacturing and transportation,
c. vehicle distribution,
d. utilization phase, and
e. end-of-life

With this approach, you can do a Well to Wheels research as well as a life-cycle analysis of the vehicle's equipment all in one step.

When we speak of the "life cycle," we are referring to the technological system of processes and transportation routes that are employed or necessary throughout the process of extracting raw materials, producing them, using them, and disposing of them (waste management or recycling). [2]. Because it analyzes the patient from conception to death, LCA is often referred to as a "cradle-to-grave" examination. Individuals from a diverse variety of backgrounds make utilization of LCAs, including those from the following fields:

Industrial and for-profit companies are examples of this.

- At the municipal, state, and federal levels, as well as at the intergovernmental and intergovernmental levels;
- Consumer and environmental nongovernmental organizations (NGOs) are examples of non-governmental organizations (NGOs).
- The number of customers (which includes governments as consumers).

While most LCA methodologies are guided by standards, a professional code of conduct has been created. In general, there are four components to an LCA:

(i)Objective and scope;

(ii) Stockpiling of supplies;

(iii) Evaluation of the consequences; and

(iv) Improvements are assessed and reported on.

There are three types of LCA : [1] environmental, [2] social, and [3] economic.

3.1.1 Objectives and Parameters

It is the first phase in the LCA process, and it is used to establish the goals and scope of activity . The purpose of the study is established in this stage. This part explains the research's purpose and target audience, as well as the justification for doing the study in the first place, as well as the findings of the study. Also defined are the specifics of what will be researched and the scope of the investigation. A few of the topics covered in this section are: study limitations, functions of the systems under investigation, the functional unit housing the systems, the systems boundaries, the system assignment methods, data and quality requirements, key assumptions, impact assessment and interpretation methods, and the report's format, to name a few examples.

3.1.2 Inventory

When conducting a Life Cycle Inventory (LCI) study, data is gathered and assessed, calculations are run, and inventory results are created and presented. The research results in a flow diagram depicting the operation of the technical system. Each process's carbon footprint, emissions, and material flows are calculated, and the results are presented.

3.1.3 Evaluation of the Result

When doing a Life Cycle Impact Assessment on a product or industrial system, it is important to examine the environmental impact of the product or industrial system (LCIA). In addition, the LCIA provides information regarding the stages of translation and interpretation that are involved. Four components are required for the determination of LCIA effect categories for comparative statements when using the LCIA method.

These are the ones:

1. Indicators and categorization methods are provided.

2. LCIA results are classified according to their nature.

3. Calculation of the findings of the category indicator (characterization), as well as the calculation of the findings of the category indicator

4. Analyses of the quality of the data.

The following are examples of optional components:

1. Calculating the size of the results of the category indicator tests in relation to a reference value (normalization).

2. Classification and attribution of weights

3. Improvements are being evaluated.

3.1.4 The Evaluation of a Process of Improvement

Based on the findings from the previous phases, an improvement assessment is conducted on aspects of the LCA that have been reviewed in conjunction with the objective and scope definitions, and judgments are formed, finding limits are identified, and suggestions are made on the basis of the findings from those phases (Following ISO 14043).

A comprehensive listing and categorization of the various cycle elements is included in the "inventory" section, and the "impact assessment" section describes and quantifies the consequences of the changes. The "improvement assessment" section will serve as a foundation for improving the existing cycle. To sum it all together,

3.1.5 Conceptualization of LCA

In its most basic version, the conceptual LCA is used to undertake a very basic analysis of environmental problems by applying a restricted and mostly qualitative inventory of the components at play, which is the most fundamental kind of environmental assessment. Some of the outcomes of a conceptual life cycle review are presented in the form of qualitative comments, infographics, flow diagrams, or simple grading systems, which demonstrate the components or materials that have the greatest environmental impact and why they have that impact. LCAs conducted on the basis of conceptual models provide conclusions that are unsuitable for commercial utilization or publication to the general public. Instead, they may assist decision-makers in deciding whether or not certain things provide a competitive advantage in terms of decreased environmental impact.

3.1.5.1 Simplified LCA (SLC Analysis):

The simplified LCA technique, which is based on the LCA approach, is a screening tool that may be used to a variety of different situations (i.e., covering the whole life cycle). The other hand, it only goes as far as to achieve this at a high level, depending on generic data and the most basic energy-production modules that are now accessible. Once the findings have been provided, they are subjected to a simplified assessment that concentrates on the most significant environmental factors and/or life cycle stages, as well as a comprehensive analysis of their reliability. LCA simplification is consisting of three phases, each of which is detailed in further detail further below.

In the preliminary screening process, the significant or data-gap components (life cycle) or basic flows of the system are identified. By focusing future efforts on the system's most vital components or core operations, as identified by the screening results, it is possible to simplify the system even more. Examine the final outcome's reliability to ensure that streamlining the procedure does not have a significant influence on it.

3.1.5.2 Detailed LCA:

Detailed LCAs include the whole LCA process, as well as extensive and in-depth data collection that is focused on the LCA's goal. Detailed LCAs are the most comprehensive kind of LCA. If the information is only accessible in a generalized form, it must be obtained specifically for the product or service under consideration, otherwise it will be useless.

3.2 LCA SPECIFICATIONS

LCA is covered by the ISO 14000 family of standards, which are significant in terms of standards since they are internationally recognized. The following are the most significant pieces of writing in this situation:

- ISO 14040 - LCA – Principles and Framework (Principles and Framework) (LCA – Principles and Framework) (LCA – Principles and Framework) (1997)

In particular, ISO 14041 – Life Cycle Inventory Analysis (1998) and ISO 14042 – Life Cycle Impact Assessment (1998) are also specified in this standard as well (2000)

- ISO 14043 - LCA and Interpretation (2000)

According to the information in the table below, a brief description of the contents of the LCA and environmental labeling regulations follows.

While it is true that not all of the standards have been published by Standards South Africa (previously known as the South African Bureau of Standards), it is also true that some standards can only be obtained directly from the International Standards Organization (ISO) in Geneva, where some of them were developed.3

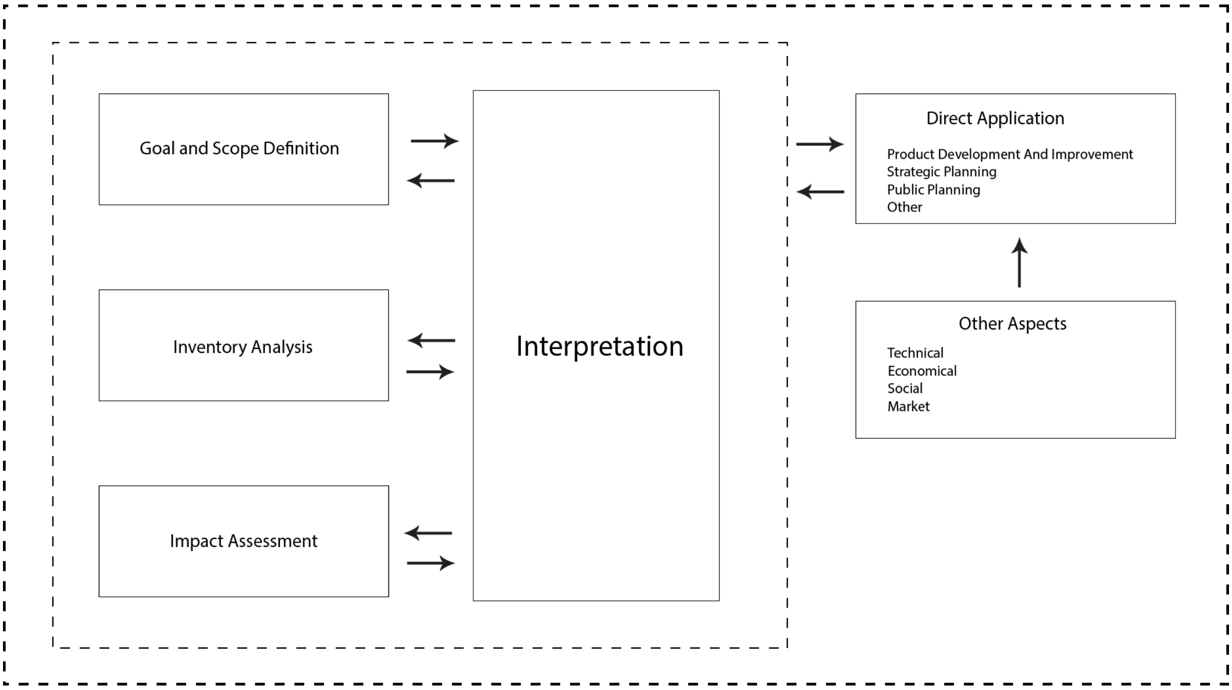

Figure 3.1 The LCA Procedure

3.3 LCA TECHNIQUES

3.3.1 Cradle-to-Grave

According to environmental assessment, the phrase "cradle-to-grave" refers to the complete LCA process, which includes everything from resource extraction through resource utilization and disposal. The usage of trees results in the production of paper, which can be recycled to generate low-energy cellulose insulation that can be used in the ceiling of a house for 40 years while conserving 2,000 times the fossil-fuel energy required for its production. When cellulose fibers are replaced after 40 years, they are destroyed in a variety of ways, the most common of which is by fire. At every stage of the life cycle, all of the inputs and outputs are thoroughly examined.

3.3.2 Cradle-to-Gate

In product LCA, the term "cradle-to-gate" describes the process of analyzing the life cycle of a product from its point of extraction (cradle) to its point of manufacture (gate). The term "cradle" refers to the point of extraction (cradle) and "gate" refers to the point of manufacture (i.e., before it is transported to the consumer). In this case, the phases of product utilization and disposal are skipped over completely. Occasionally, environmental product declarations (EPDs) are based on cradle-to-grave evaluations of a product's environmental effect, also known as business-to-business environmental product declarations (B2B EPDs). The life cycle inventory (LCI) is a critical component of the cradle-to-gate technique, as it is in any other method. A LCA can capture all of the effects before any resources are committed to constructing the facility in this manner. As a result, they may decide to include the phases of transportation to the plant and the manufacturing processes in their own cradle-to-gate values for the products they manufacture.

3.3. 3 Cradle-to-Cradle

This sort of review comes under the cradle-to-grave umbrella, and it is differentiated by the fact that the product's end-of-life disposal is done via recycling. Environmentally friendly product development involves the utilization of environmentally friendly manufacturing, operation, and disposal procedures, as well as the integration of social responsibility into the design process. Recycling results in the creation of new items that are virtually indistinguishable from their predecessors. There are significant LCA issues associated with allocating load for goods in open loop manufacturing systems. Other solutions, such as the avoided load approach, have been developed to address similar issues in this setting.

3.3. 4 Gate-to-Gate

In this scenario, it is a constrained life-cycle assessment that examines just one value-added step throughout the complete manufacturing process. Additional to this, modules that are connected to their respective industrial chains can be used to provide a comprehensive cradle to grave assessment of the product or service.

3.3. 5 Well-to-Wheel

In order to analyze the environmental impact of transportation fuels and automobiles on the environment, life-cycle assessments (LCAs) are performed from well to wheel. There are many terms that are often used in the area of analysis, including the terms "well to station" and "well to tank." Other terms include "station to wheel" or "tank to wheel" as well as "plug-to-wheel" or "plug-to-plug." In contrast to the second stage, which comprises the operation of the vehicle, the first step entails the production and processing of feedstock or energy, as well as the delivery and transmission of energy or fuel. The first stage is referred to as the "upstream" stage since it occurs first. The second phase is referred to as the "downstream" stage in the manufacturing process. It is common practice in the transportation industry to conduct a well-to-wheel study in order to estimate the total energy consumed by naval vessels, airplanes and automobiles; the energy conversion efficiency and emission effect of these vehicles; their carbon footprint; and the fuels used in each mode of transportation. With the utilization of WTW analysis, it is feasible to account for the varying efficiency and emission characteristics of energy systems and fuels at both the upstream and downstream stages, providing a more complete picture of real emissions.

The placement of the wells in relation to the wheels has a significant influence on the model used by the Argonne National Laboratory. The Greenhouse Gases, Regulated Emissions, and Energy Usage in Transportation (GREET) model was developed to assess the influence of new fuels and vehicle technologies on greenhouse gas emissions and energy consumption in transportation. The system investigates the implications of gasoline utilization from the well to the wheel, as well as the influence of the car from the time of its creation to the time of its death, among other things. In addition to volatile organic compounds, carbon monoxide, nitrogen oxide, particulate matter, and sulfur oxides, the research estimates the levels of six additional pollutants: sulfur oxides, volatile organic compounds, carbon monoxide, and nitrogen oxide. In addition, estimates of energy consumption, greenhouse gas emissions, and six additional pollutants are included in the study.

3.4 LCA CLASSIFICATION BASED ON IMPACT CRITERIA

3.4.1Evaluation of the Economic Life Cycle

The economics of inputs and outputs LCA examines aggregate sector-level data in order to determine the environmental impact of each sector of the economy, as well as the amount of products and services purchased by each sector of the economy, in order to determine the environmental impact of each sector of the economy. Because of this, it may be possible to mitigate the mapping problem that is inherent in process LCA.

3.4.2 Assessment of the Life Cycle rom an Ecological Perspective

While standard LCAs utilization many of the same methodologies and strategies as Eco-LCAs, the latter takes a far wider view of the environmental consequences of the decisions made. In order to serve as a guide for responsible human activity management, it was created with a focus on the direct and indirect repercussions of human activity on ecological resources and surrounding ecosystems, as well as their interrelationships. Developed by the Ohio State University Center for Resilience, the Eco-LCA is a methodology that estimates the cost of regulating and maintaining commercial commodities and products throughout the course of their useful lifetimes. This technique divides services into four primary categories: those that support, those that regulate, those that provide, and those that provide cultural services.

3.4.3 Assessment of a Product's Life Cycle Based on it' Energy Consumption

Throughout a process, exergy is defined as the maximum amount of work a system can perform in order to achieve equilibrium with a heat reservoir. In response to this knowledge, exergo-economic accounting and LCA approaches such as Exergetic material input per unit of service (EMIPS) were established. MIPS is defined in terms of the second law of thermodynamics, which allows for the calculation of resource input and service output in exergy units to be performed. This material input per unit of service (EMIPS) metric was created specifically for transportation technologies to measure their material input. Not only does the service assess the complete quantity of mass to be delivered and the overall distance traveled, but it also considers the mass transferred during each voyage and the delivery time.

3.5 IDENTIFYING THE RELEVANT TECHNOLOGIES FOR THE PROJECT

In the United States, the GWPs (GWP-100, also known as GHG-100) are a statistic that was developed to analyze the relative influence of greenhouse gases over a hundred-year period. Most important technologies involved in the lifecycle of an EV are those that are required to extract, process, and transport vehicle components, fluids, and batteries. They are also those that are required to dispose of or recycle auto components when they have reached the end of their useful lives. Throughout the life of an EV, various technologies and material fabrication contribute to the emission of greenhouse gases (GHG) (Figure 1). (Figure 1). According to the International Energy Agency, as compared to battery EV cars , the technologies that create GHG-100 emissions for ICEVs vehicles are only significantly different in a few features. The fueling cycle of an ICEV vehicle is responsible for the acquisition, processing, and transportation of oil. The engine of an ICEV vehicle, which uses gasoline to create mechanical energy, is also a component of the fueling cycle. Equipment necessary to extract, process, and transport the vehicle's components, fluids, and fuel, as well as equipment required to dispose of or recycle the vehicle's components, are the important technologies throughout the lifespan of an ICEV automobile.

The issue's definition from a life-cycle standpoint. The LCA of a vehicle may be split into two independent cycles: the "fuel cycle" and the "vehicle cycle."

3.5.1 The Following Steps form the "Fuel Cycle":

1. Energy consumption and greenhouse gas emissions associated with the generation of primary energy sources are estimated at this stage (natural gas and crude oil).

2. Transportation of hydrogen and gasoline feedstocks: Secondly, transportation of hydrogen and gasoline feedstocks is necessary as the major energy sources for hydrogen and gasoline must be carried to refineries and reforming plants. It is at this

point that the energy consumption and greenhouse gas emissions associated with the transportation of primary energy sources are determined.

3. Fuel production: This step estimates the energy consumption and greenhouse gas emissions associated with the processing of the basic energy sources that are utilized in the manufacture of gasoline and diesel fuel.

4. Fuel distribution: During this step, the energy consumption and greenhouse gas emissions associated with the delivery of hydrogen and gasoline to the cars' fuel tanks are measured and reported. A supply chain is often utilized in gasoline distribution: gasoline is transferred from refineries to terminals by ship or pipeline, then moved to road tankers, service stations, and eventually into vehicle tanks. Gas is delivered to decentralized refueling stations via pipeline or road tankers, where hydrogen is produced through the process of steam reforming, in a manner similar to that described above.

3.5.2 The "Vehicle Cycle" is Divided into the Following Phases:

1. Materials used in automobile manufacturing: This stage evaluates the energy consumption and greenhouse gas emissions associated with the manufacture of automobile materials. It is estimated that the weight of a normal automobile is around 890 kilos of ferrous metal, 100 kilograms of various types of plastic, approximately 80 kilograms of aluminum, and approximately 200 kilograms of additional components. Besides that, we need materials for fuel cell components such as polymer membranes, platinum as a catalyst, and graphite for the PEM fuel cell-powered car, to name a few.

2. Vehicle assembly: This section calculates the amount of energy used and greenhouse gas emissions produced by moving autos during the assembly process. A common misconception about assembly energy is that it is a linear function of vehicle mass. This is due to the convoluted supply chain of the automobile industry, as well as the difficulty involved in predicting vehicle assembly energy requirements.

3. Distribution of automobiles: This stage accounts for the energy spent and greenhouse gas emissions emitted during the transport of a vehicle from the production line to a dealership.

4. Vehicle utilization: The utilization of a vehicle corresponds to the "fuel cycle" stage of "fuel consumption," and it accounts for the energy consumption and greenhouse gas emissions associated with vehicle maintenance and repair over the course of the vehicle's estimated lifetime of 300,000 kilometers.

5. Disposal of vehicles: When a vehicle's useful life has gone, it is destroyed. The total energy needed for disposal is estimated by combining the energy necessary to convey the bulk material from the dismantler to the shredder and the energy required to shred the trash.

3.6 DEFINE THE SYSTEM'S BOUNDARIES AND CONSTRAINTS:

3.6.1 Manufacturing of Automobiles:

To begin, we created an inventory of generic car glider components free of ICEV or EV-specific components. Then we introduced ICEV and EV powertrains, with two battery types (LiFePO4 and LiNCM) being studied in the case of the EV. The various components of a vehicle includes approximately 140 subcomponents.

It was used to simulate the glider and ICEV powertrain, which was then scaled and fitted to the specifications of the Toyota Corolla 2020 model, subdivided further to obtain component-level data, and then supplemented with data from comprehensive industry inventories and reports, as well as data from comprehensive industry inventories and reports

Using our LCA, the CV weighs 1500 kg, which includes 1275 kg of vehicle components and 225 kg of engine. The BEV is expected to weigh 1575 kg, with the same 1275 kg of vehicle components as the PHEV, but with the addition of a 300 kg lithium-ion battery.

3.6.2 Assumptions Regarding the Electricity Mix.

Due to the fact that our basic scenario assumed that all charging would take place in California, we used the state's existing power mix to calculate the total amount of charging. These figures were derived from the EBL Securities report "BANGLADESH POWER SECTOR An appraisal from a multi-dimensional perspective (part-1)," and they included coal (2 %), natural gas (68 %), hydropower (1 %), diesel (3 %), furnace oil (16 %), and imported (10 %) as sources of el.

3.6.3 Assumptions Regarding Transportation

Transferring car components and batteries, as well as entire automobiles, is accomplished through the employment of three means of transportation: trucking, shipping, and rail. Almost all kinds of transportation require diesel fuel, including boats and airplanes. It was computed that the quantity of gasoline consumed was equal to the product of the number of miles traveled multiplied by the average mileage per unit weight. This allowed us to condense everything down to the components necessary for a single fully functional automobile.

3.6.4 Assumptions Regarding the Disposal and Recycling of Solid Waste

The BEV's battery is recycled in a different way than the CV's battery, which we discovered to be true. Several strategies for disposal were described in the literature, which we discovered to be true. During these steps, the automobile's components are dismantled, shred, and sorted before being sent to a junkyard.

3.6.5 Justify the Sources of Availability

Model 2016 (GREET): After reproducing our findings with various vehicle and grid mix configurations, we discovered that the GREET model 2016 was extremely accurate. This model was used to demonstrate how our findings could be replicated, for example, the weight of each component, except for the battery in EVs and the vehicle body weight in both types of vehicles. Additionally, GREET's default values include the weights of various fluids, such as braking and transmission fluids, and the weight of a braking and transmission fluid

These tables illustrate the many vehicle inputs that we utilized in our models, along with a breakdown of how they were split down.

3.7 DESCRIPTION OF THE PROCESS

The World Transportation Watch examines the environmental repercussions of vehicle energy consumption by taking into account the whole energy carrier (i.e., crude oil extraction, processing, and so on) as well as the final energy transfer performed in the vehicle. When we talk about the life cycle of a vehicle, we're talking about all of the operations that take place throughout the manufacturing, distribution, maintenance, and disposal of the vehicle.

The functional unit (FU) is a measurable representation of a product system's performance that may be used as a reference unit in the design of new products and systems. It makes it possible to compare two or more product systems on the basis of a common service. The functional unit in this work is one kilometer driven, which is defined as follows: The functional unit takes into account the vehicle's whole life cycle and calculates an average lifespan of 13.7 years as well as a total life mileage of 230,500 km. The average lifespan performance of a passenger automobile is projected to be 239,000 kilometers per person on the highway. Overall, an average utilization ratio of 1.59-1.6 passengers per vehicle is anticipated on a national level. As a consequence, the vehicles selected will have a lifetime of around 150,000 kilometers. The one-kilometer driving range is the functional unit of choice for LCA of autos since it represents the longest driving distance possible. The average age of a vehicle getting end-of-life treatment in Bangladesh is referred to as the vehicle's whole life duration.

To establish the bounds of the system, the cut-off allocation approach is used. This technique assigns the environmental benefits of recycling to a future producer who will make utilization of these secondary resources, rather than to the original producer. The model addresses the environmental consequences of recycling by accounting for secondary material market shares throughout the cradle-to-grave phase of the production process. In the case of vehicle technology, LCA is a comprehensive evaluation of all major activities required to complete the life cycle of a vehicle, as shown in Fig. 1.

The sections that follow offer an overview of the effect categories that were investigated in this study:

In this area, the most important topic to consider is the impact of harmful substances on the human environment. In this table, the hazardous compounds are given as 1,4-dichlorobenzene equivalents per kilogram of emissions for each chemical.

Due to the depletion of ozone in the stratosphere, an increase in the quantity of ultraviolet B radiation (UV-B) that is transmitted throughout the earth's atmosphere and onto the planet's surface has occurred. This has the potential to have a negative impact on human and animal health, terrestrial and aquatic ecosystems, biochemical cycles, and the physical and chemical characteristics of a broad variety of molecules, among other things. Many gases have an ozone depletion potential, which is measured in kilograms of CFC-11 equivalent per kilogram of emission, which is frequent.

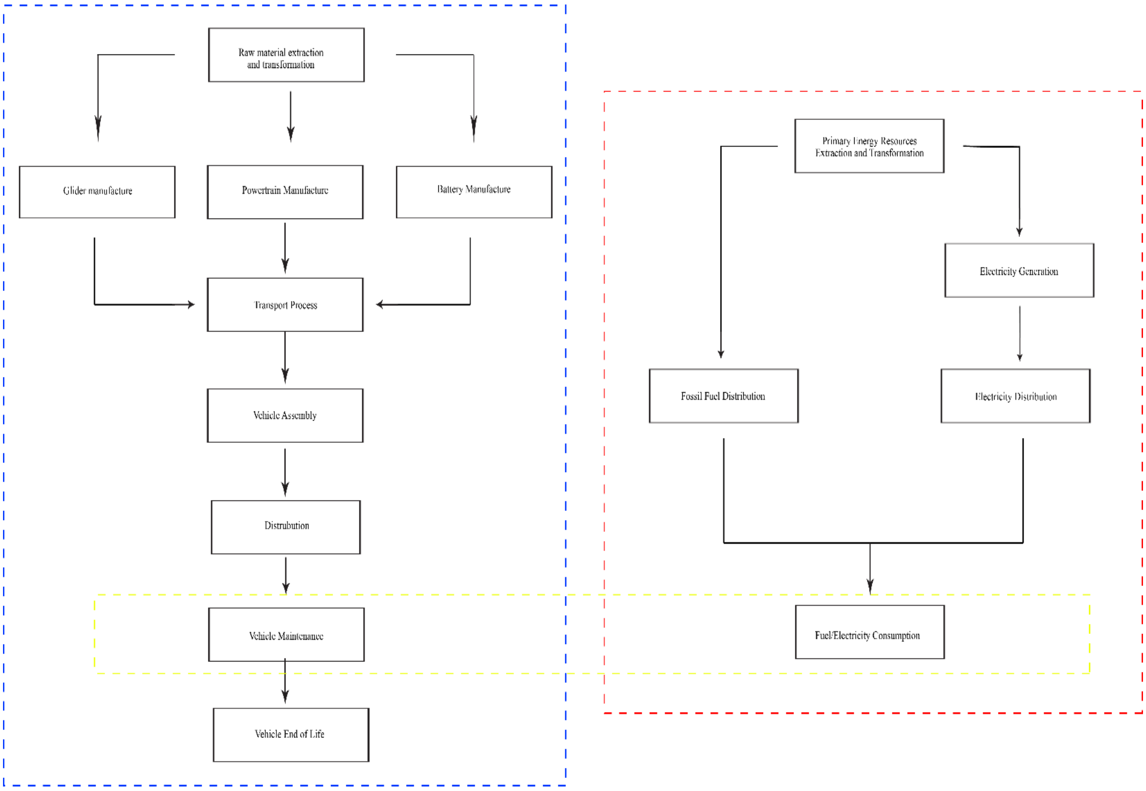

Figure 3.2 Vehicle's life cycle system boundaries

The impact categories considered in this study are briefly described in the following sections:

1. **Human Toxicity**
2. **Global Warming**

CHAPTER 4

RESULT AND ANALYSIS:

4.1 HUMAN TOXICITY:

The key concerns for this category are the consequences of harmful chemicals on individuals and the environment. Each toxic substance is measured in 1,4-dichlorobenzene equivalents per kilogram of emissions.

4.1.1 CO Emissions

CO are emitted by automobiles in large quantities. Higher concentration of CO in blood reduce oxygen transport in blood. The highest CO emission occurs in the CNG in both test cases. While the lowest emission is from EV which is about 95% less than CNG in our test. The highest CO emission of EV occurs from production and recycling of vehicle body.

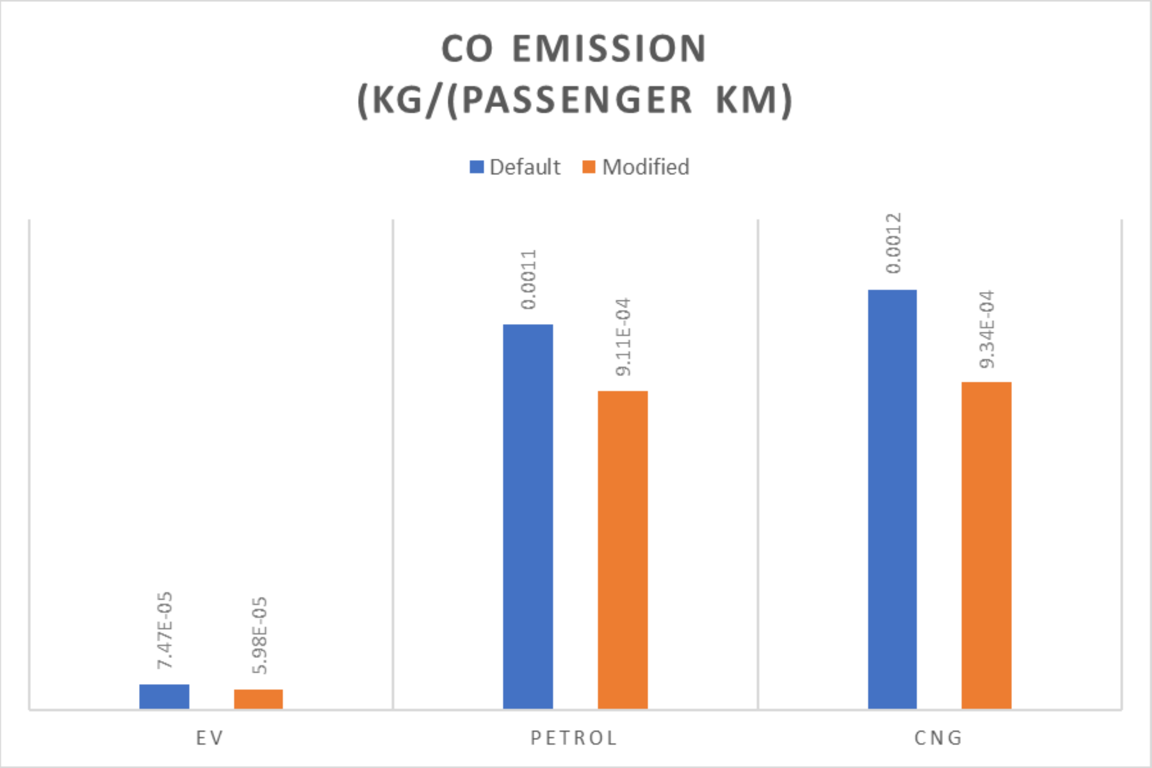

Figure 4.1.1(a) Emission of CO of different Vehicles.

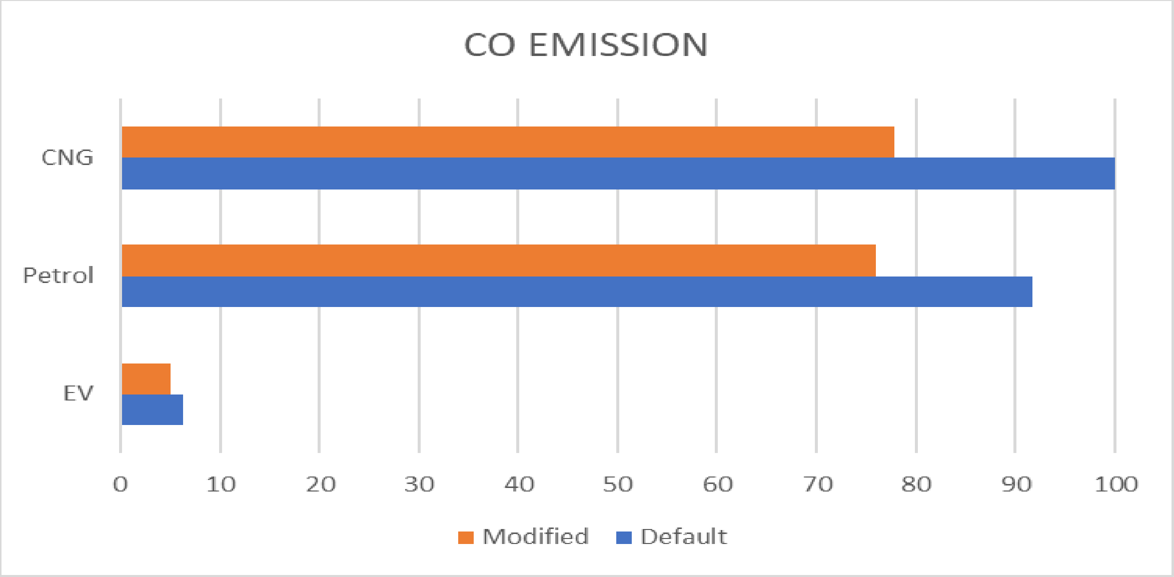

Figure 4.1.1(b) Comparative Emission of CO of different Vehicles.

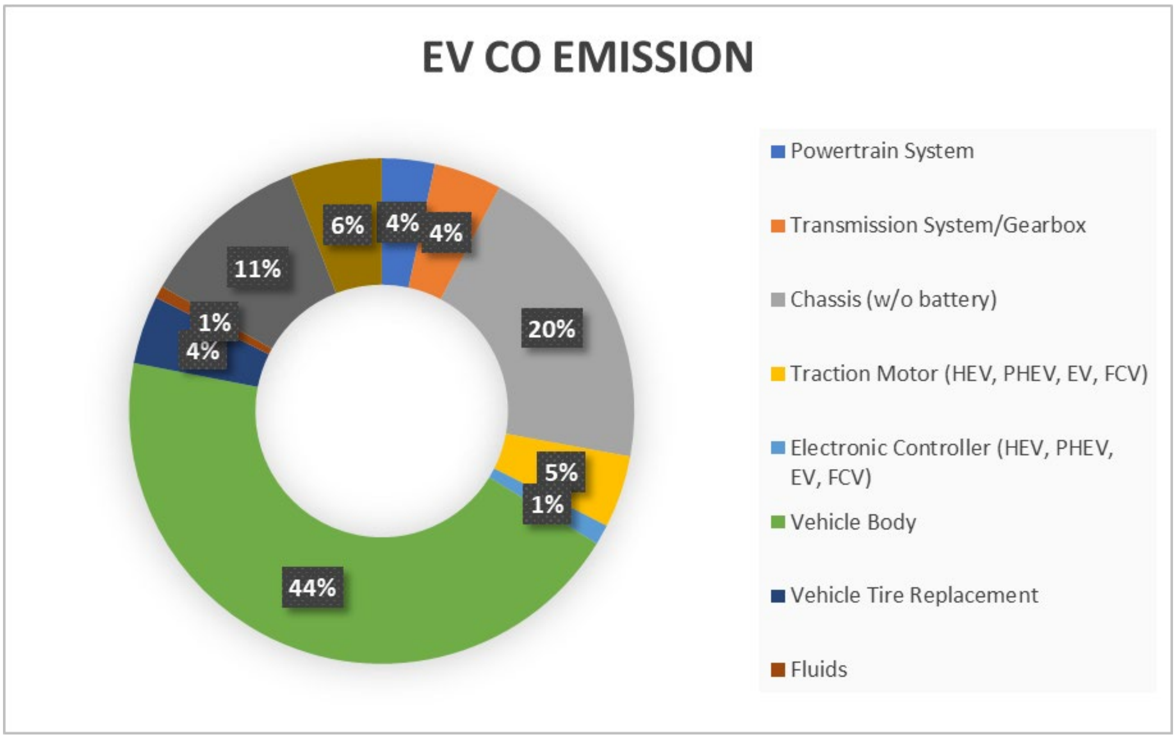

Figure 4.1.1(c) Various factors contribute to the emission of CO of electric vehicles.

4.1.2 NOx Emissions

NOx emission has both ecological and biological effects. NOx emission may lead to reduced lung functionality, breathing problems, damaged respiratory tracts etc. It can directly harm the ecosystem as well. It is estimated it kills more than 23 thousand people a year in the UK. EV's on average release 10-15% more NOx. The battery is primarily responsible for the high NOx emission, as it constitutes more than 42% of the total emission.

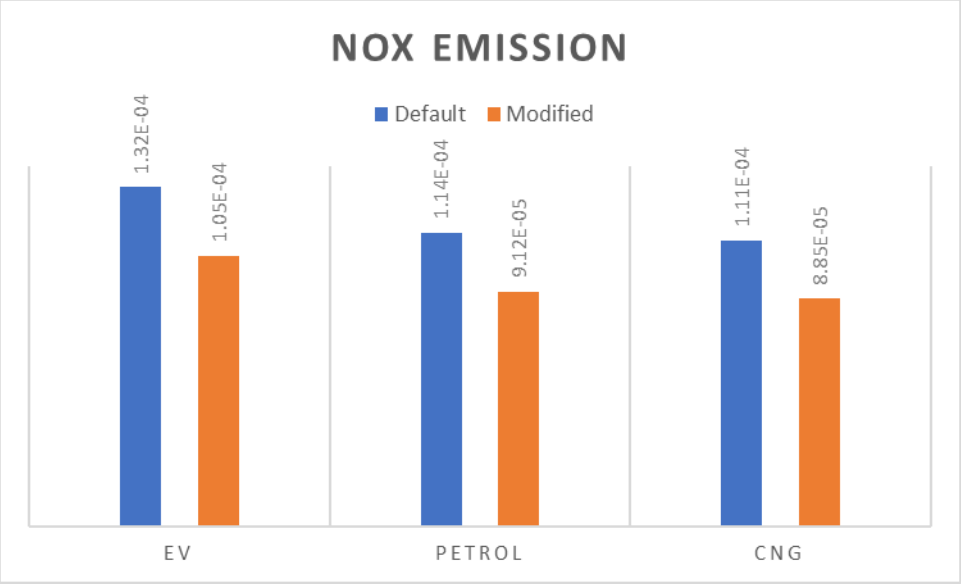

Figure 4.1.2(a) Emission of NOx of different Vehicles

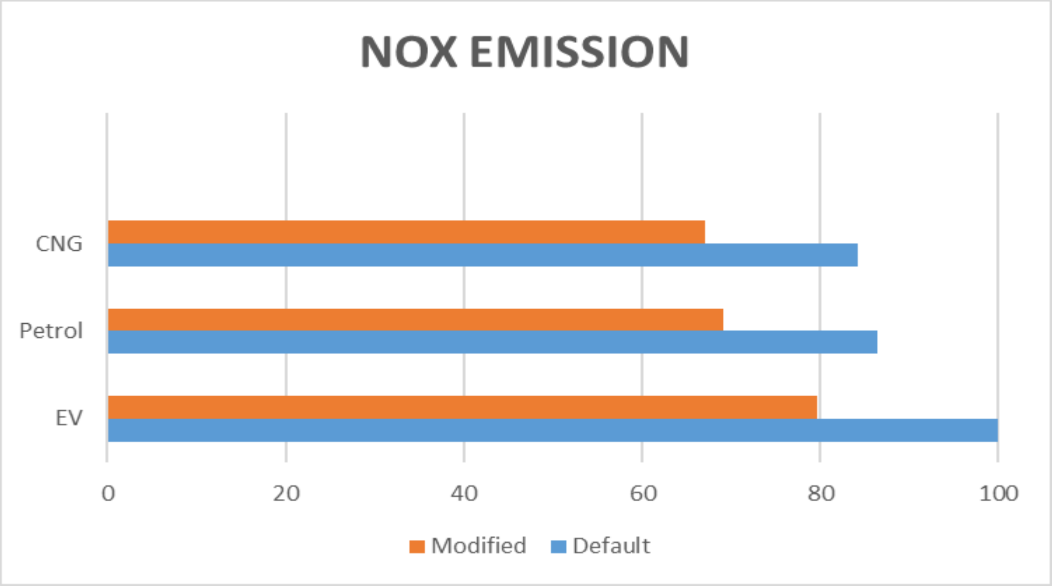

Figure 4.1.2(b) Comparative Emission of NOx of different Vehicles

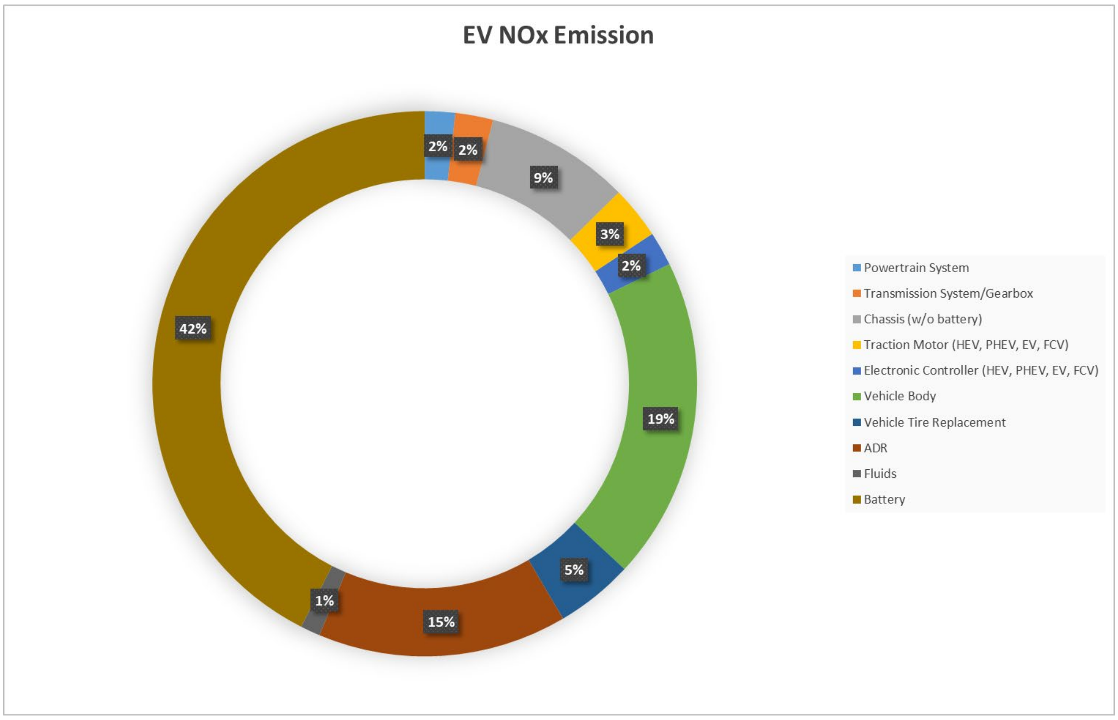

Figure 4.1.2 (c) Various factors contribute to the emission of NOx of electric vehicles.

4.1.3 PM 2.5 Emissions

PM 2.5 are fine particles that can traverse deep into the respiratory tract even going as far as the lung. Exposure to it may cause lung irritation, shortness of breath etc. Petrol and gasoline cars are by far the worst offender in this regard while CNGs have about 60 % less PM 2.5 emission. Whereas EV's are about 50% less harmful.

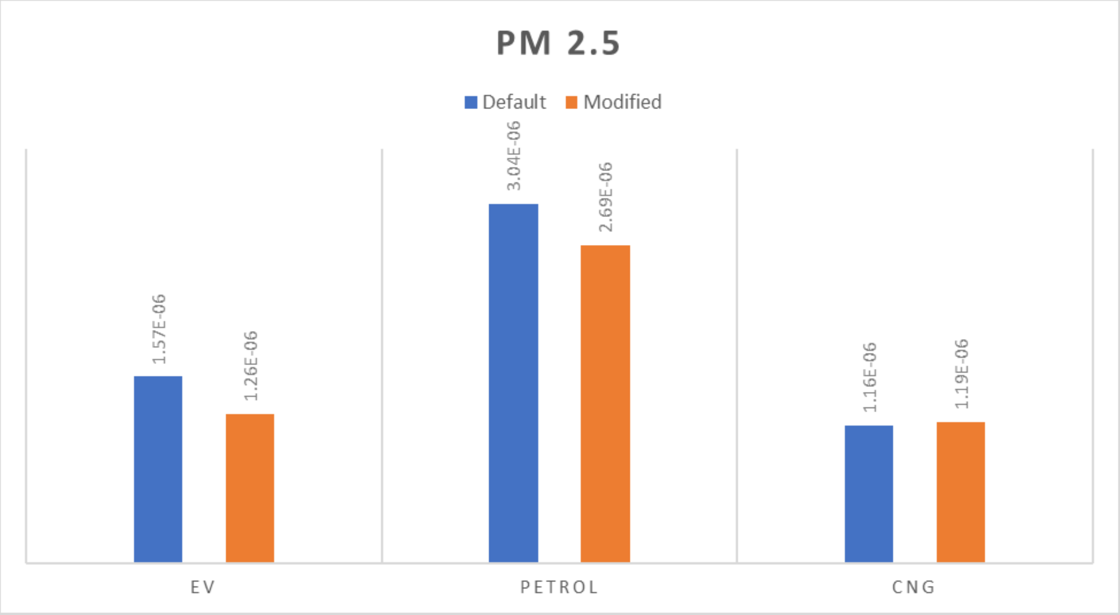

Figure 4.1.3(a) Emission of PM 2.5 of different Vehicles

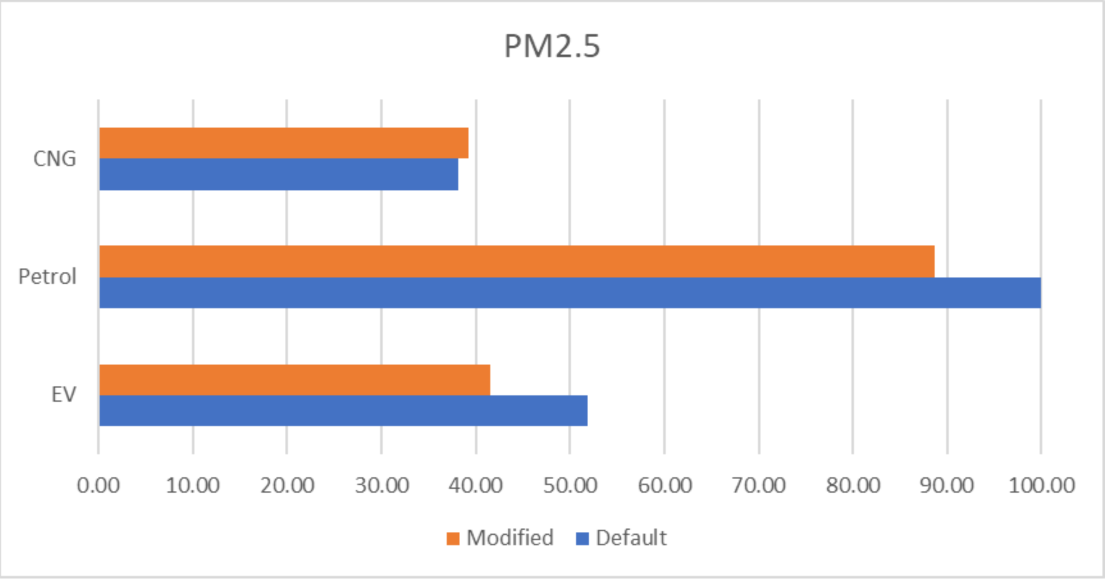

Figure 4.1.3(b) Comparative Emission of PM 2.5 of different Vehicles

4.1.4 PM 10 Emissions

PM10 penetrate deep into lungs, higher concentration may result in asthma attack, bronchitis, heart attack etc. EV and CNG's have comparable level of emission, whereas gasoline cars have a much higher rate of emission; being 90% or more. EV's emission can still be further improved with the help of improved battery production and recycling.

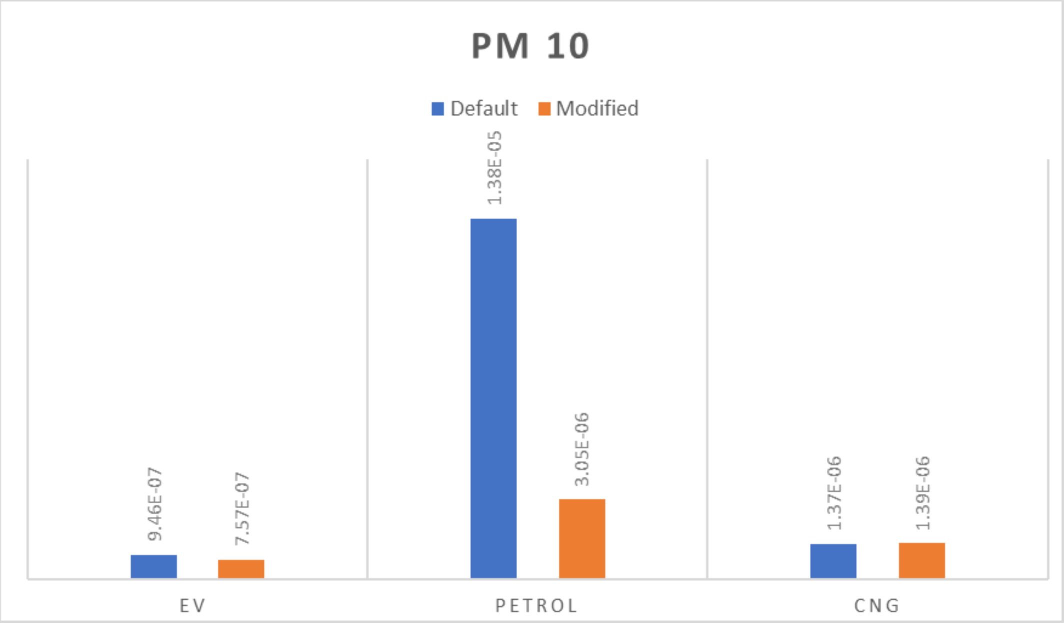

Figure 4.1.4(a) Emission of PM 10 of different Vehicles

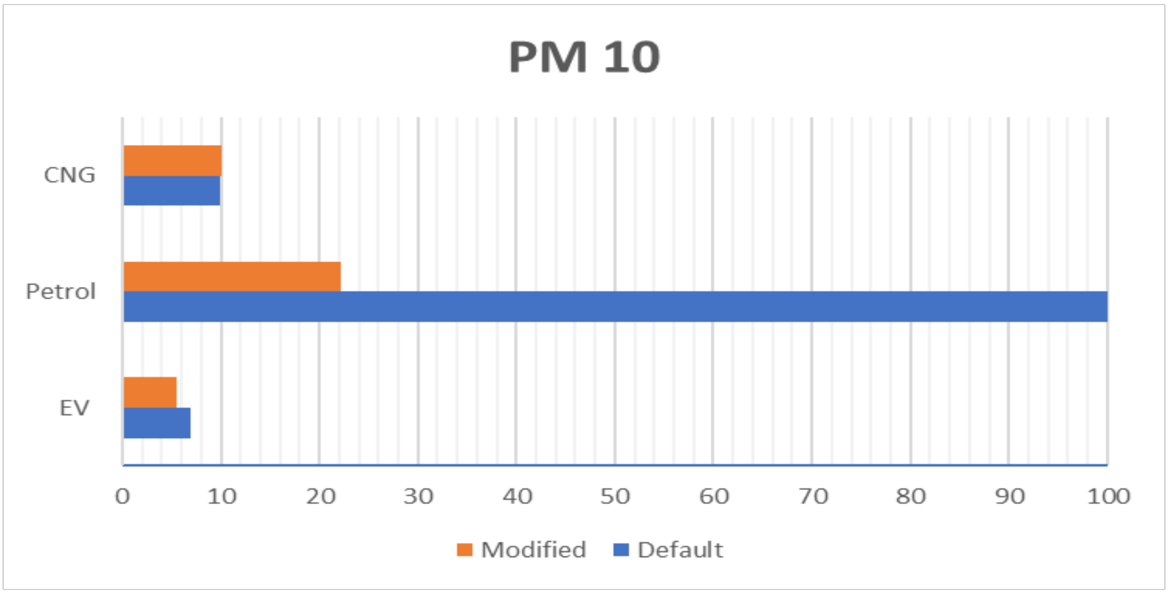

Figure 4.1.4(b) Comparative Emission of PM 10 of different Vehicles

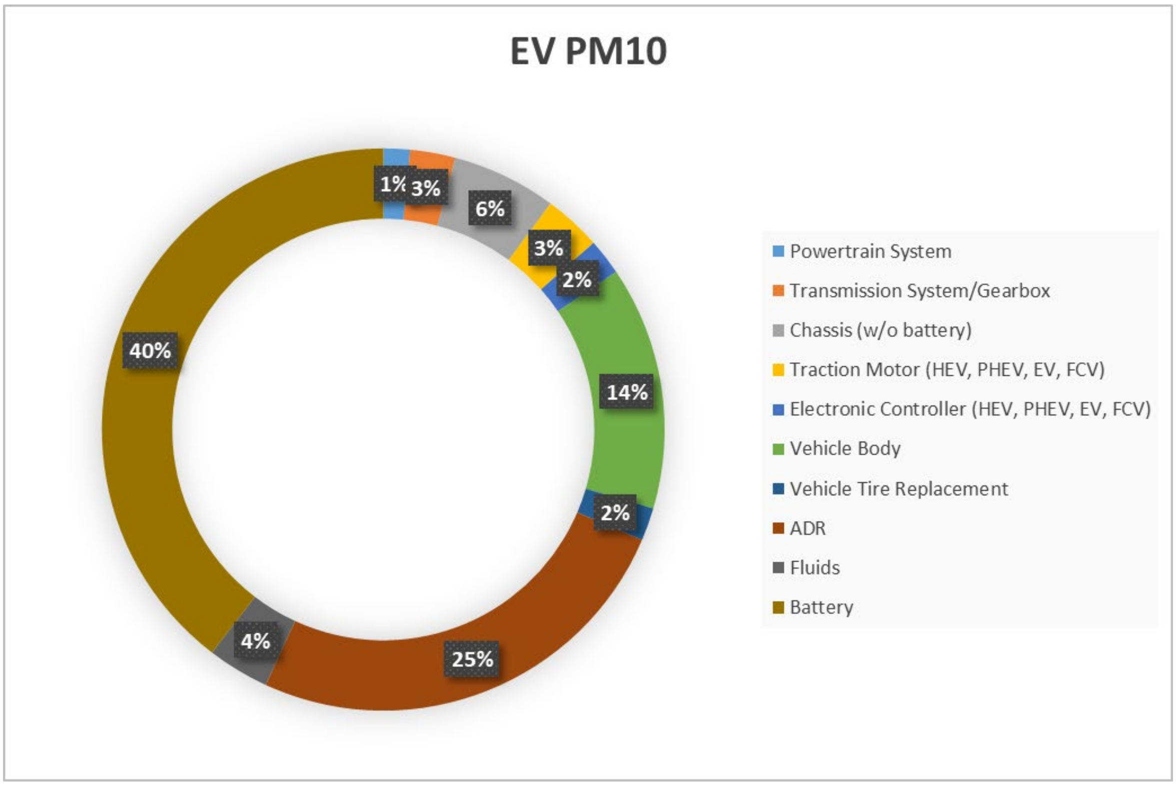

Figure 4.1.4(c) Various factors contribute to the emission of PM10 of electric vehicles.

4.1.5 SOx Emissions

SOx in high concentration results in inflammation and irritation of the respiratory system. EV’s have the highest SO emission by a wide margin owing to the high SO emission by the battery production and recycling. About 60% of the emission occurs from the battery alone.

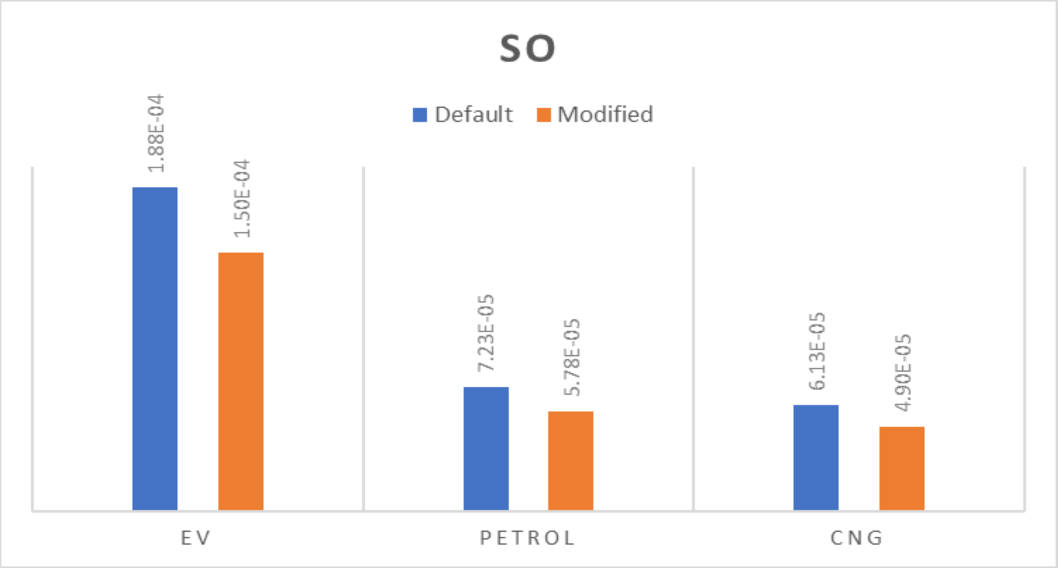

Figure 4.1.5(a) Emission of SOx of different Vehicles

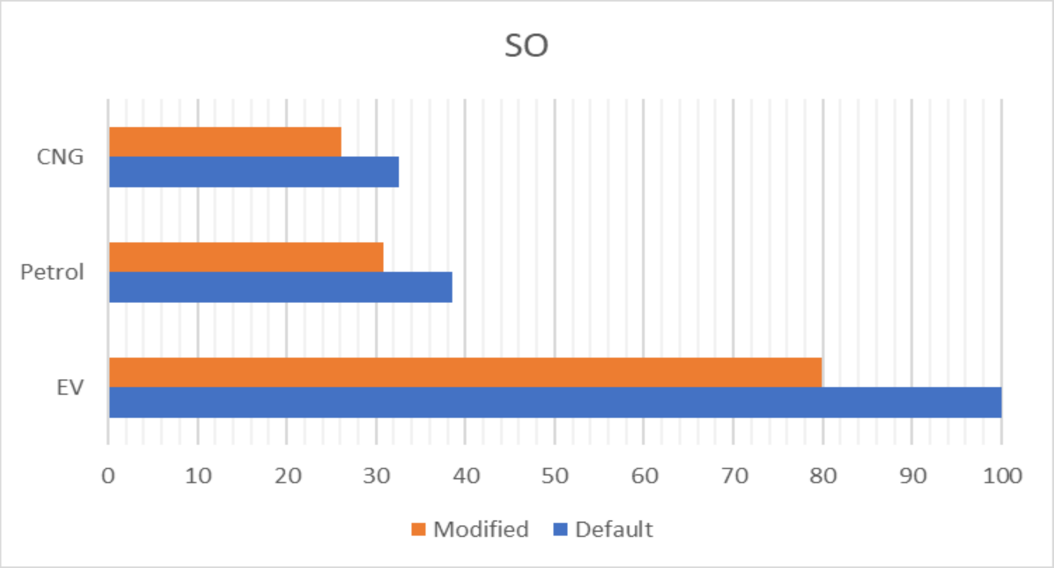

Figure 4.1.5(b) Comparative Emission of SOx of different Vehicles

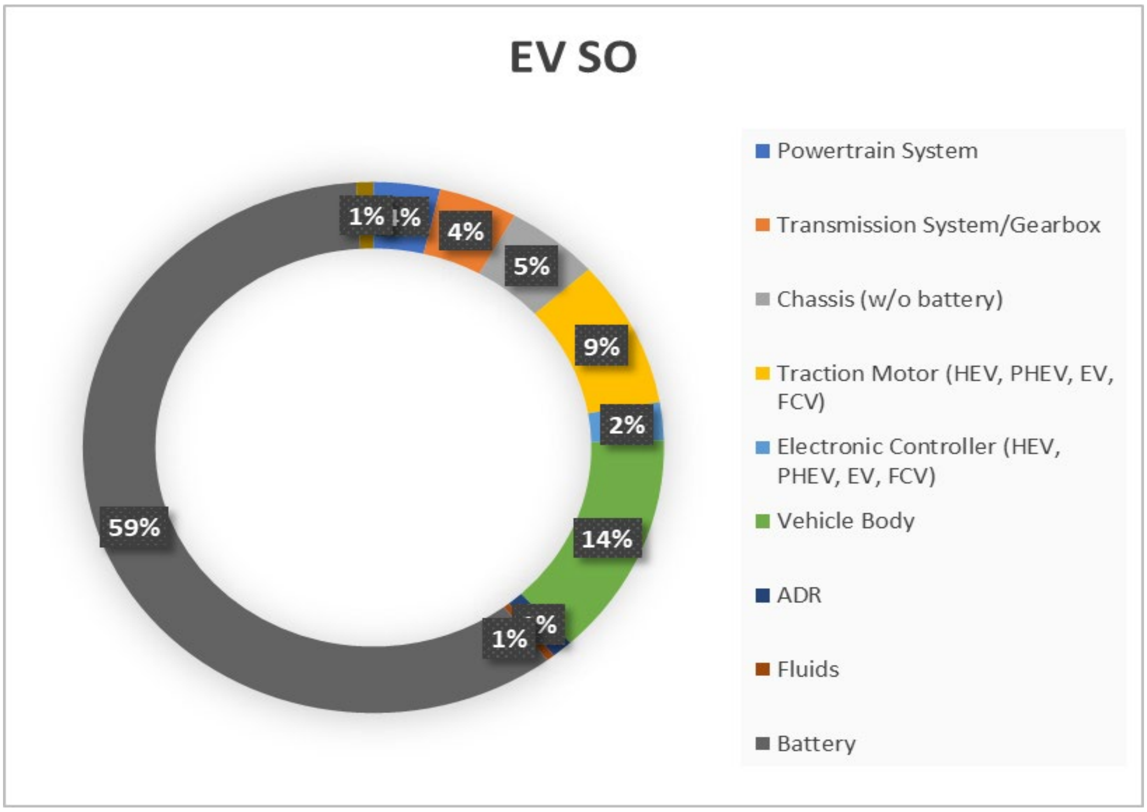

Figure 4.1.5(c) Various factors contribute to the emission of SOx of electric vehicles.

4.1.6 VOC Emissions

VOCs are a group of compounds that can irritate the eyes, nose, and throat, as well as induce headaches, tiredness, nausea, dizziness, and skin issues. At higher quantities, the lungs may become irritated, as well as the liver, kidneys, and central nervous system.

CNG's release highest amount VOCs compared to gasoline and EV's , in both test cases CNG released almost double quantity of VOC. The main source of VOC in EV is the disposal phase.

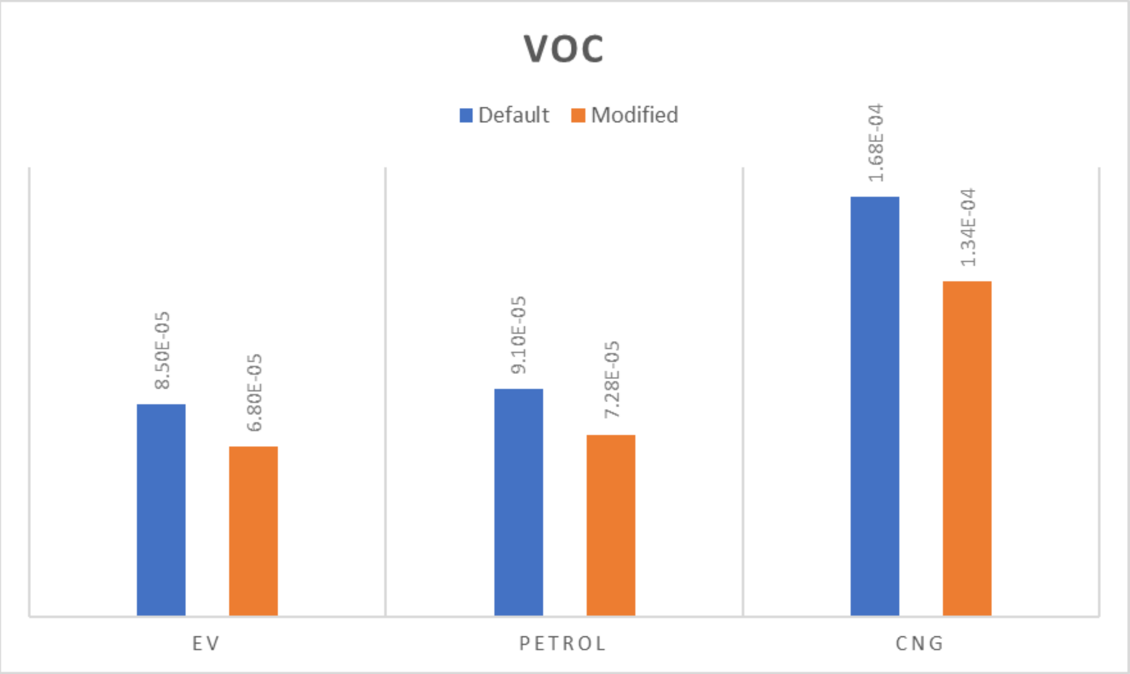

Figure 4.1.6(a) Emission of VOC of different Vehicles

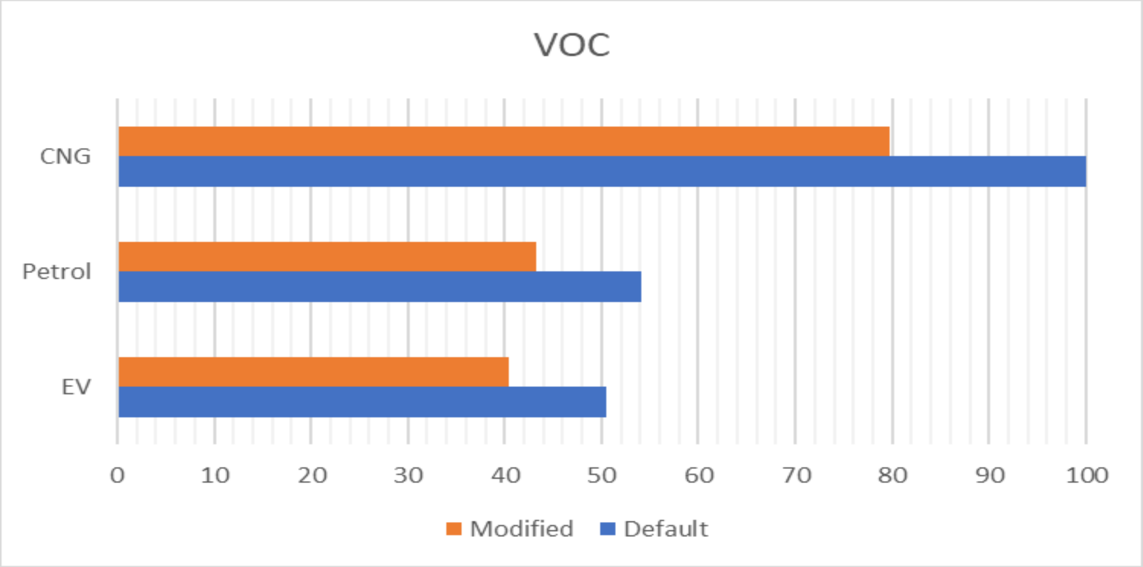

Figure 4.1.6(b) Comparative Emission of VOC of different Vehicles

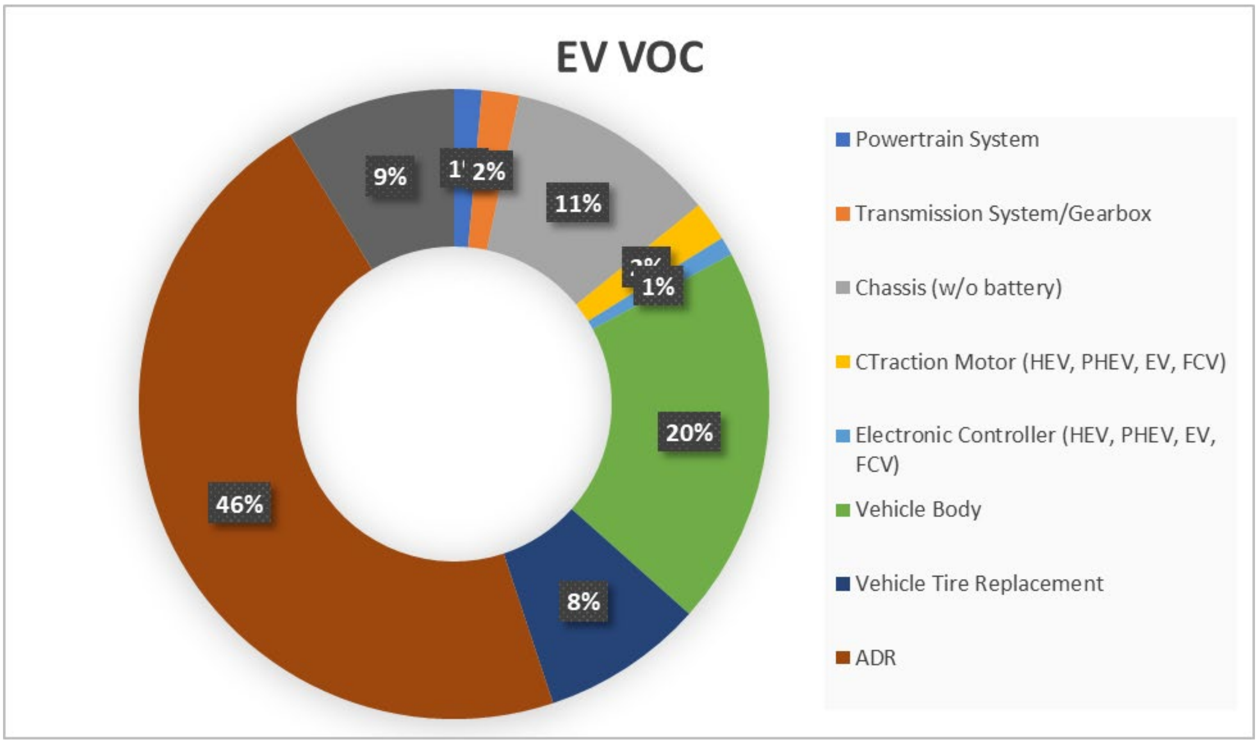

Figure 4.1.6(c) Various factors contribute to the emission of VOC of electric vehicles.

4.1.7 Human Toxicity Potential

Among the vehicles tested, the CNG vehicle had the lowest potential for human toxicity. This is attributed to the low harmful emissions from the WTW. Specific components of BEVs, such as the Li-ion battery, electric motor, and power electronics, account for a major portion of the overall impact. However, there is a significant difference.

Processes for mining raw resources, automobile manufacture, and as an energy carrier for electricity. Because of the mining of coal, and other fossil fuels in the fuel, the WTW stage of the BEV has higher emissions electricity production supply phases.

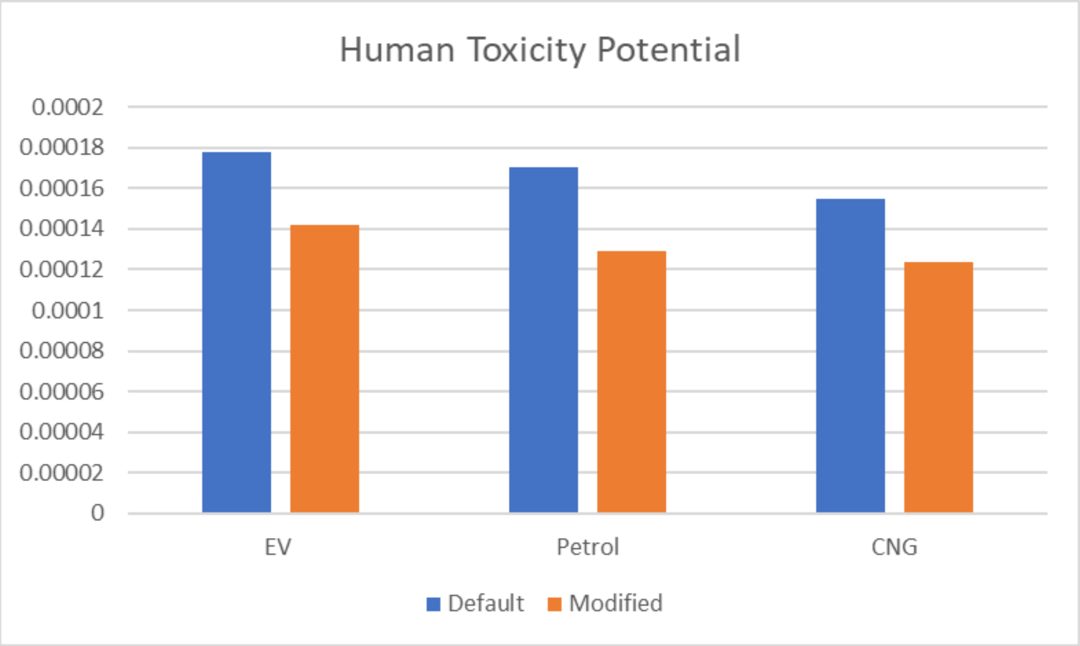

Figure 4.1.7(a) Human Toxicity Potential of different Vehicles

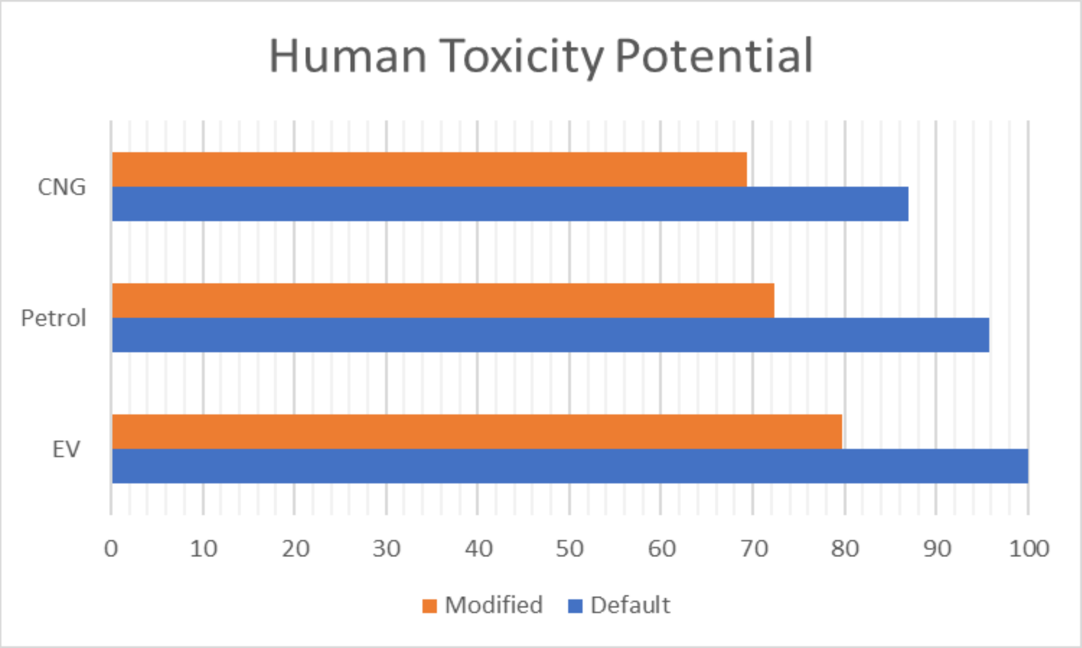

Figure 4.1.7(b) Comparative Human Toxicity Potential of different Vehicles

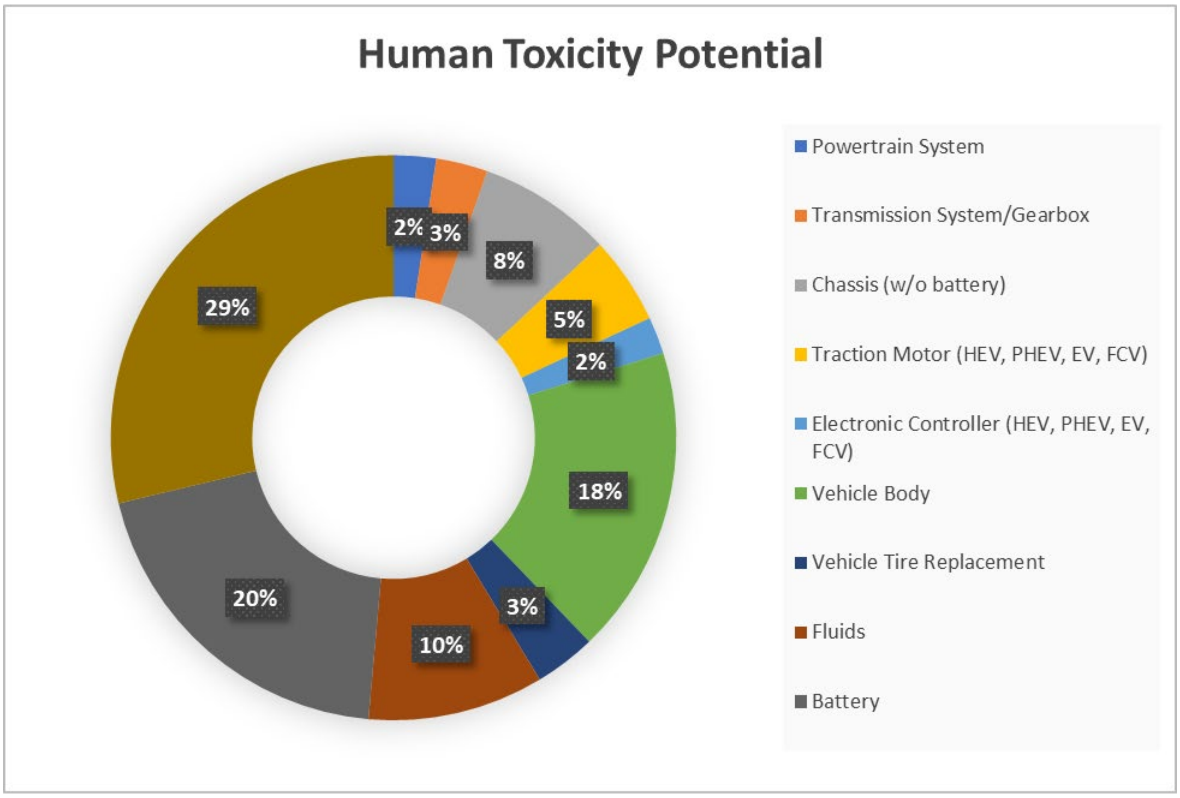

Figure 4.1.7(c) Various factors contribute to the human toxicity of electric vehicles.

4.2 GLOBAL WARMING:

Climate change is linked to the release of greenhouse gases into the atmosphere. Climate change has the potential to negatively impact ecological health, human health, and economic well-being. he GWP is expressed as a kilogram of CO2 per kilogram of emission.

4.2.1 CO_2 Emissions

Carbon dioxide emissions are mostly caused by human activities such as burning coal, oil, or natural gas for energy. Despite the fact that carbon dioxide is not the most potent greenhouse gas, it is the most prevalent contributor to climate change. Gasoline cars have 40-55% higher emission than EV depending on the test scenario. Battery technology contributes to 37% of the total CO_2 emission of EV’s.

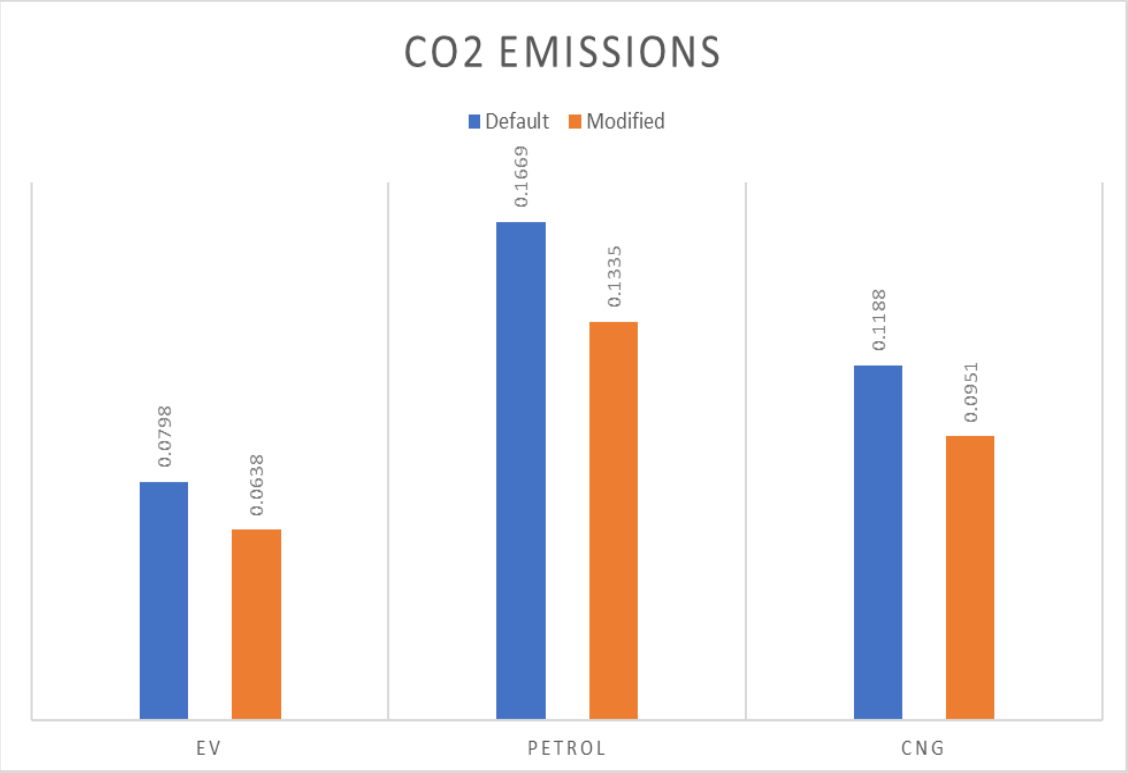

Figure 4.2.1(a) Emission of CO_2 of different Vehicles.

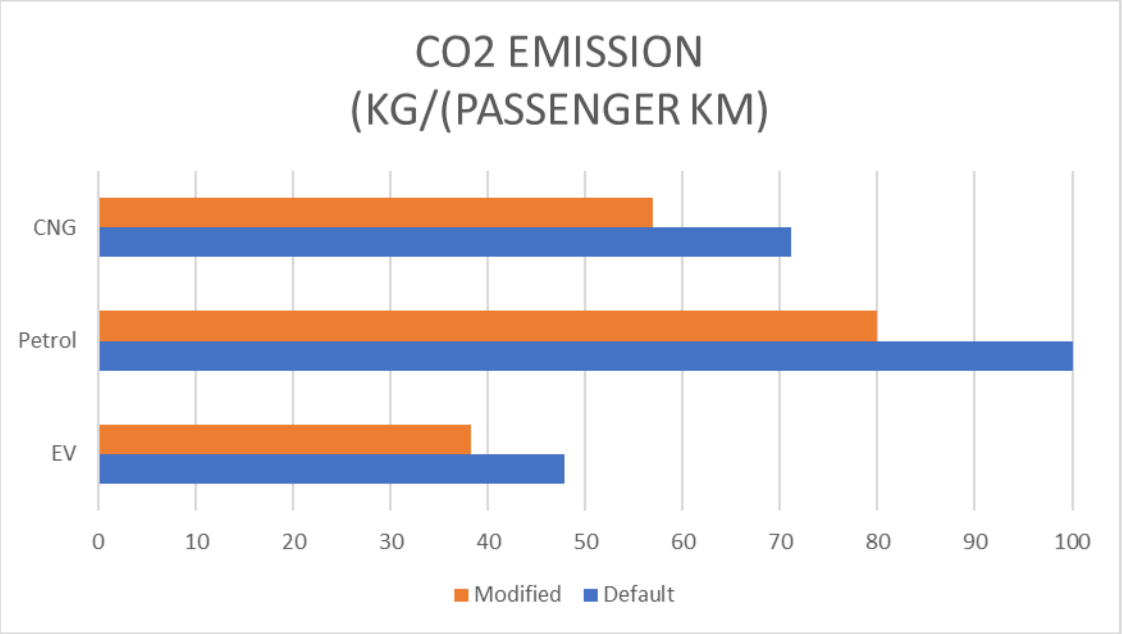

Figure 4.2.1(b) Comparative Emission of CO_2 of different Vehicles.

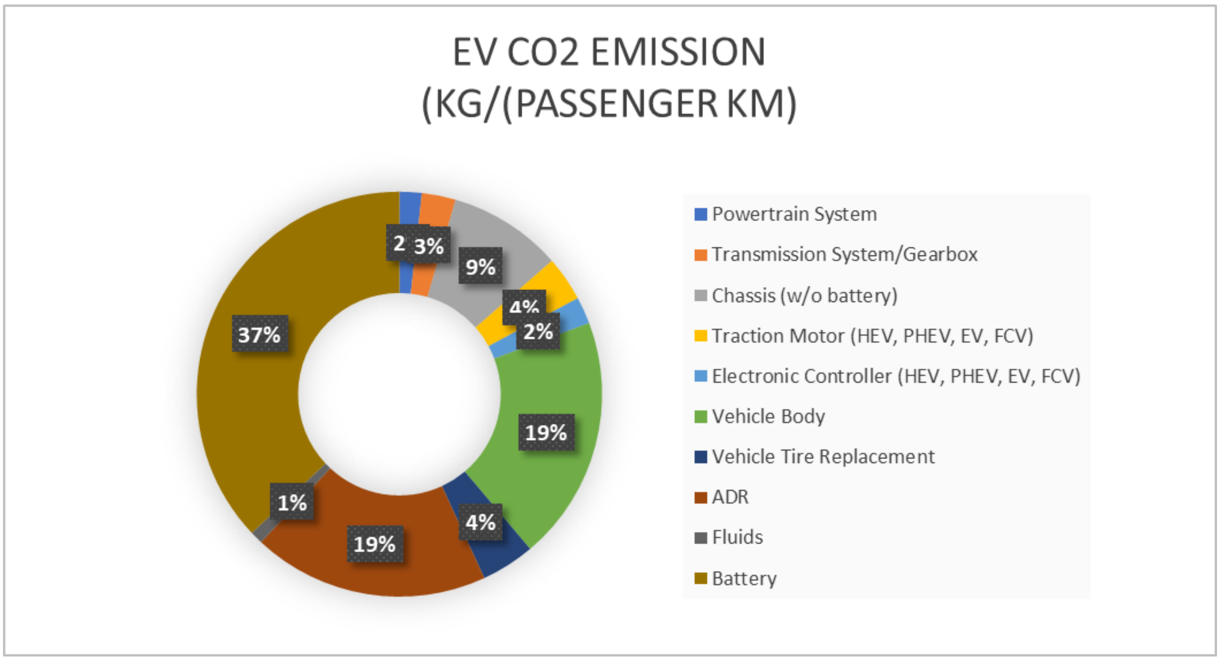

Figure 4.2.1(c) Various factors contribute to the emission of CO_2 of electric vehicles.

4.2.2 GHG-100

Greenhouse gases (GHGs) warm the Earth by collecting energy and preventing its release into space; they function as a insulation shielding the planet. Numerous GHGs have different warming impacts on the Earth. The ability to absorb energy (their "radiative efficiency") and the length of time they stay in the atmosphere are two important differences between these gases . GHG-100 denotes the total GWP of greenhouse gases in the life cycle of a vehicle.

Figure 4.2.2(a) GHG-100 of different vehicles.

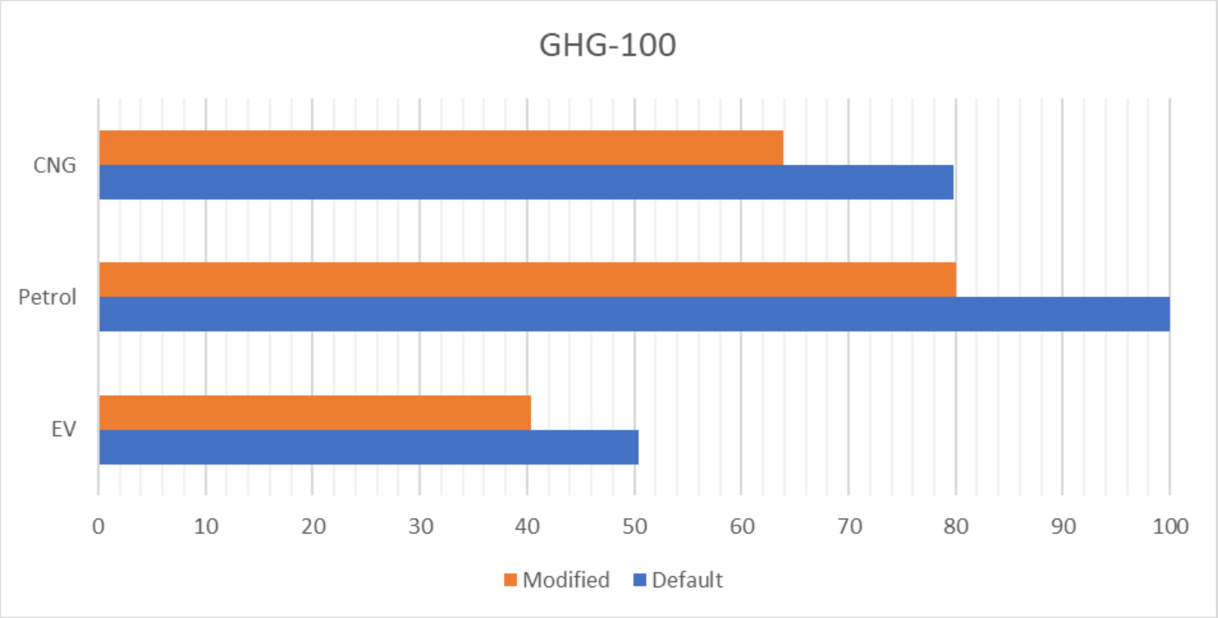

Figure 4.2.2(b) Comparative GHG-100 of different vehicles.

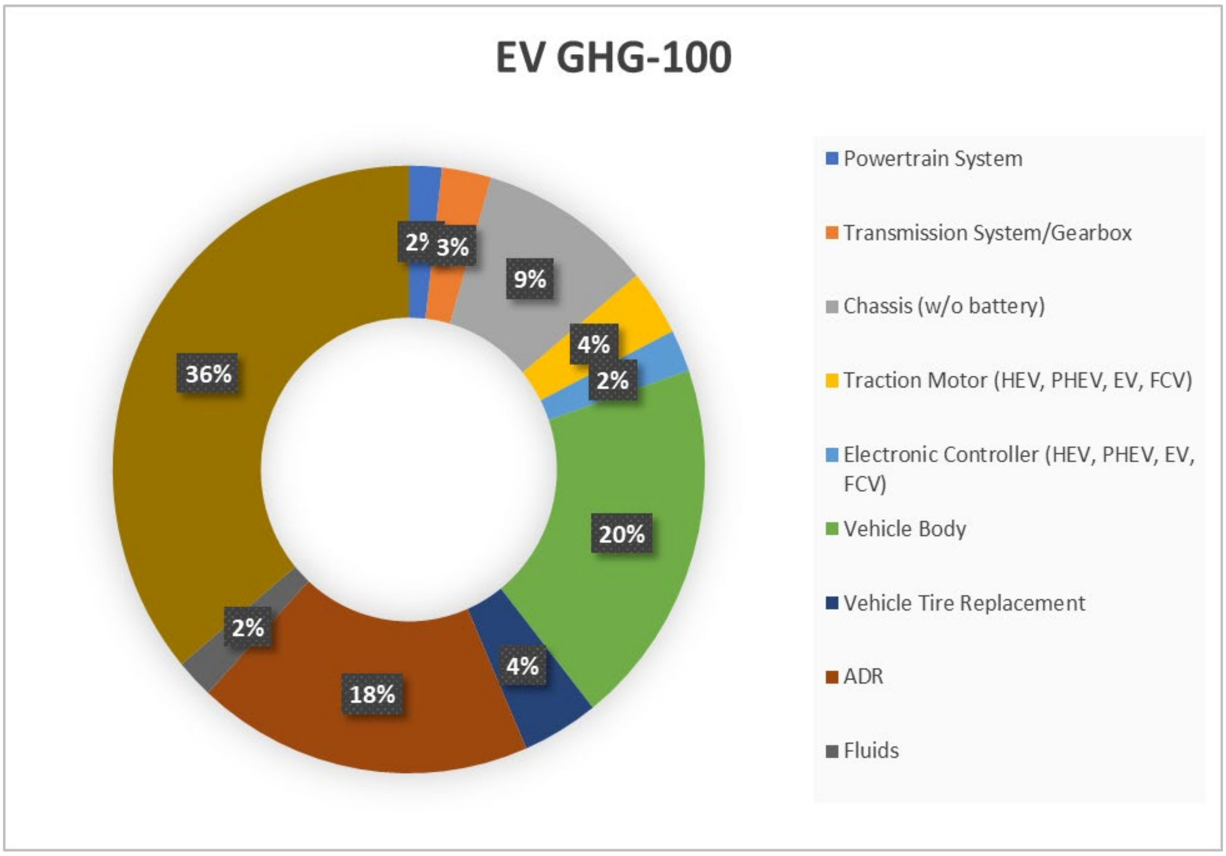

Figure 4.2.2(c) Various factors contribute to GHG-100 of electric vehicles.

4.3 LIMITATION OF THE STUDY:

It should be noted that this analysis applied average generation mixes. However, a status quo analysis based on average generation mix is not complete because generation mixes may vary depending on the time of day. Further limitations were encountered due to the lack of primary data regarding vehicle models and Electricity generation.

4.4 FUTURE SCOPE:

This study found that BEV is a potential solution for lowering the transportation sector's environmental consequences. Unfortunately, access to primary datasets remains a significant problem for LCA practitioners. As a result, future research will require more accurate data and primary data on battery deterioration and refurbished EV batteries in specific stationary applications, as well as future Power generation mix. Further reducing upstream climate impacts at the mining, material processing, and BEV manufacturing phases is also important.

REFERENCE

[1] John W. Brennan and T. E. Barder, “Battery Electric Vehicles vs . Internal Combustion Engine Vehicles : A United States-Based Comprehensive Assessment,” *Arthur D. Little*, p. 48, 2016, [Online]. Available: http://www.adlittle.de/sites/default/files/viewpoints/ADL_BEVs_vs_ICEVs_FINAL_November_292016.pdf.

[2] “U.S.A. First NDC Submission.”

[3] C. Z. Ibrahim Dincer, “Sustainable Hydrogen Production,” *Elsevier*, 2016.

[4] F. F. Combustion, *Iea statistics*. 2015.

[5] J. Dargay, D. Gately, and M. Sommer, “Vehicle ownership and income growth, worldwide: 1960-2030,” *Energy J.*, vol. 28, no. 4, pp. 143–170, 2007, doi: 10.5547/ISSN0195-6574-EJ-Vol28-No4-7.

[6] I. Meyer, M. Leimbach, and C. C. Jaeger, “International passenger transport and climate change: A sector analysis in car demand and associated CO2 emissions from 2000 to 2050,” *Energy Policy*, vol. 35, no. 12, pp. 6332–6345, 2007, doi: 10.1016/j.enpol.2007.07.025.

[7] H. Hao, H. Wang, and R. Yi, “Hybrid modeling of China’s vehicle ownership and projection through 2050,” *Energy*, vol. 36, no. 2, pp. 1351–1361, 2011, doi: 10.1016/j.energy.2010.10.055.

[8] Wang, “Magnitude and Value of Electric Vehicle Emissions Reductions for Six Driving Cycles in Four U.S. Cities,” *Transp. Res. Rec.*, no. 1416, pp. 33–42, 1993.

[9] J. Johnson, E. M. Harper, R. Lifset, and T. E. Graedel, “Dining at the periodic table: Metals concentrations as they relate to recycling,” *Environ. Sci. Technol.*, vol. 41, no. 5, pp. 1759–1765, 2007, doi: 10.1021/es060736h.

[10] U. Daimler AG, “Environmental Certificate Contents,” 2016.

[11] M. Zackrisson, L. Avellán, and J. Orlenius, “Life cycle assessment of lithium-ion batteries for plug-in hybrid electric vehicles-Critical issues,” *J. Clean. Prod.*, vol. 18, no. 15, pp. 1519–1529, 2010, doi: 10.1016/j.jclepro.2010.06.004.

[12] C. Qiu and G. Wang, “New evaluation methodology of regenerative braking contribution to energy efficiency improvement of electric vehicles,” *Energy Convers. Manag.*, vol. 119, pp. 389–398, 2016, doi: 10.1016/j.enconman.2016.04.044.

[13] B. M. Nemry F, “Plug-in hybrid and battery electric vehicles— market penetration scenarios of electric drive vehicles.,” *JRC Tech. Note. Eur. Comm. Luxemb. (Draft Tech. note JRC/IPTS JRC58748)*, 2010.

[14] N. Sadek, “Urban electric vehicles: A contemporary business case,” *Eur. Transp. Res. Rev.*, vol. 4, no. 1, pp. 27–37, 2012, doi: 10.1007/s12544-011-0061-6.

[15] E. Helmers and P. Marx, “Electric cars: Technical characteristics and environmental impacts,” *Environ. Sci. Eur.*, vol. 24, no. 4, pp. 1–15, 2012, doi:

10.1186/2190-4715-24-14.

[16] M. Li, X. Zhang, and G. Li, "A comparative assessment of battery and fuel cell electric vehicles using a well-to-wheel analysis," *Energy*, vol. 94, no. 2016, pp. 693–704, 2016, doi: 10.1016/j.energy.2015.11.023.

[17] L. Rose, M. Hussain, S. Ahmed, K. Malek, R. Costanzo, and E. Kjeang, "A comparative life cycle assessment of diesel and compressed natural gas powered refuse collection vehicles in a Canadian city," *Energy Policy*, vol. 52, pp. 453–461, 2013, doi: 10.1016/j.enpol.2012.09.064.

[18] J. Archsmith, A. Kendall, and D. Rapson, "From Cradle to Junkyard: Assessing the Life Cycle Greenhouse Gas Benefits of Electric Vehicles," *Res. Transp. Econ.*, vol. 52, pp. 72–90, 2015, doi: 10.1016/j.retrec.2015.10.007.

[19] T. R. Hawkins, O. M. Gausen, and A. H. Strømman, "Environmental impacts of hybrid and electric vehicles-a review," *Int. J. Life Cycle Assess.*, vol. 17, no. 8, pp. 997–1014, 2012, doi: 10.1007/s11367-012-0440-9.

[20] A. R. Domingues, P. Marques, R. Garcia, F. Freire, and L. C. Dias, "Applying multi-criteria decision analysis to the life-cycle assessment of vehicles," *J. Clean. Prod.*, vol. 107, pp. 749–759, 2015, doi: 10.1016/j.jclepro.2015.05.086.

[21] J. Van Mierlo, M. Messagie, and S. Rangaraju, "Comparative environmental assessment of alternative fueled vehicles using a life cycle assessment," *Transp. Res. Procedia*, vol. 25, pp. 3435–3445, 2017, doi: 10.1016/j.trpro.2017.05.244.

[22] N. Ha, "Comparative environmental impacts of Internal Combustion Engine Vehicles with Hybrid Vehicles and Electric Vehicles in China - Based on Life Cycle Assessment," *E3S Web Conf.*, vol. 118, no. 2019, 2019, doi: 10.1051/e3sconf/201911802010.

[23] P. Ahmadi and E. Kjeang, "Comparative life cycle assessment of hydrogen fuel cell passenger vehicles in different Canadian provinces," *Int. J. Hydrogen Energy*, vol. 40, no. 38, pp. 12905–12917, 2015, doi: 10.1016/j.ijhydene.2015.07.147.

[24] Y. Bicer and I. Dincer, "Life cycle environmental impact assessments and comparisons of alternative fuels for clean vehicles," *Resour. Conserv. Recycl.*, vol. 132, no. January, pp. 141–157, 2018, doi: 10.1016/j.resconrec.2018.01.036.

[25] Q. Qiao, F. Zhao, Z. Liu, S. Jiang, and H. Hao, "Comparative Study on Life Cycle CO2 Emissions from the Production of Electric and Conventional Vehicles in China," *Energy Procedia*, vol. 105, pp. 3584–3595, 2017, doi: 10.1016/j.egypro.2017.03.827.

[26] Ricardo, "Pilot study on determining the environmental impacts of conventional and alternatively fuelled vehicles through Life Cycle Assessment," no. 1, pp. 1–36, 2017.

[27] E. Helmers, J. Dietz, and S. Hartard, "Electric car life cycle assessment based on real-world mileage and the electric conversion scenario," *Int. J. Life Cycle Assess.*, vol. 22, no. 1, pp. 15–30, 2017, doi: 10.1007/s11367-015-0934-3.

[28] D. Burchart-Korol, S. Jursova, P. Folęga, J. Korol, P. Pustejovska, and A. Blaut, "Environmental life cycle assessment of electric vehicles in Poland and the

Czech Republic," *J. Clean. Prod.*, vol. 202, pp. 476–487, 2018, doi: 10.1016/j.jclepro.2018.08.145.

[29] R. Smit and D. W. Kennedy, "Greenhouse Gas Emissions Performance of Electric and Fossil-Fueled Passenger Vehicles with Uncertainty Estimates Using a Probabilistic Life-Cycle Assessment," *Sustainability*, vol. 14, no. 6, p. 3444, 2022, doi: 10.3390/su14063444.

[30] B. Tang, Y. Xu, and M. Wang, "Life Cycle Assessment of Battery Electric and Internal Combustion Engine Vehicles Considering the Impact of Electricity Generation Mix: A Case Study in China," *Atmosphere (Basel).*, vol. 13, no. 2, 2022, doi: 10.3390/atmos13020252.

[31] M. S. Koroma *et al.*, "Life cycle assessment of battery electric vehicles: Implications of future electricity mix and different battery end-of-life management," *Sci. Total Environ.*, vol. 831, p. 154859, 2022, doi: 10.1016/j.scitotenv.2022.154859.

[32] P. Egede, T. Dettmer, C. Herrmann, and S. Kara, "Life cycle assessment of electric vehicles - A framework to consider influencing factors," *Procedia CIRP*, vol. 29, pp. 233–238, 2015, doi: 10.1016/j.procir.2015.02.185.

[33] M. J. Kim *et al.*, "Life cycle assessment of LPG and diesel vehicles in Korea," *Korean J. Chem. Eng.*, vol. 38, no. 5, pp. 938–944, 2021, doi: 10.1007/s11814-021-0761-0.

[34] Q. Qiao, F. Zhao, Z. Liu, X. He, and H. Hao, "Life cycle greenhouse gas emissions of Electric Vehicles in China: Combining the vehicle cycle and fuel cycle," *Energy*, vol. 177, pp. 222–233, 2019, doi: 10.1016/j.energy.2019.04.080.

[35] H. Huo, H. Cai, Q. Zhang, F. Liu, and K. He, "Life-cycle assessment of greenhouse gas and air emissions of electric vehicles: A comparison between China and the U.S.," *Atmos. Environ.*, vol. 108, pp. 107–116, 2015, doi: 10.1016/j.atmosenv.2015.02.073.

[36] R. Nealer and T. P. Hendrickson, "Review of Recent Lifecycle Assessments of Energy and Greenhouse Gas Emissions for Electric Vehicles," *Curr. Sustain. Energy Reports*, vol. 2, no. 3, pp. 66–73, 2015, doi: 10.1007/s40518-015-0033-x.

[37] C. Bauer, J. Hofer, H. J. Althaus, A. Del Duce, and A. Simons, "The environmental performance of current and future passenger vehicles: Life Cycle Assessment based on a novel scenario analysis framework," *Appl. Energy*, vol. 157, pp. 871–883, 2015, doi: 10.1016/j.apenergy.2015.01.019.

[38] L. A. W. Ellingsen, "The size and range effect: Life-cycle greenhouse gas emissions of electric vehicles," *CONCAWE Rev.*, vol. 2017, p. 6, 2017.

[39] T. Ercan and O. Tatari, "A hybrid life cycle assessment of public transportation buses with alternative fuel options," *Int. J. Life Cycle Assess.*, vol. 20, no. 9, pp. 1213–1231, 2015, doi: 10.1007/s11367-015-0927-2.

[40] S. Xiong, Y. Wang, B. Bai, and X. Ma, "A hybrid life cycle assessment of the large-scale application of electric vehicles," *Energy*, vol. 216, p. 119314, 2021, doi: 10.1016/j.energy.2020.119314.