QATAR UNIVERSITY

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DATA VISUALIZATION FOR SUPPORTING INFORMED DECISION MAKING FOR SUSTAINABLE ALTERNATIVE FUEL BUS TECHNOLOGIES

BY

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ABSTRACT

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Title: Data Visualization for Supporting Informed Decision Making for Alternative Fuel Bus Technologies

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Compared to other transportation approaches, public transportation produces the most greenhouse gas emissions. There is a pressing need to comply with national guidelines outlined in Qatar's National Development Strategy 2 (QNDS-2; 2018-2022) and National Vision 2030, both of which outline Qatar's long-term national transformation plans, including the development of a modern transportation system (QNV 2030). An ecologically friendly transportation system was required to maintain transportation services that consider the environment, economy, and society. One method of accomplishing this is to install new environmentally friendly buses on the road. In order to provide the needed buses to be installed in terms of type and quantity and to calculate the cost and the returned benefits of the bus use, there was a need to implement the LCSA approach, then ensure that the results will be clearly illustrated, analyzed and visualized using business intelligence tools. Developing a business intelligence dashboard to evaluate the life cycle sustainability assessment of the alternative fuel buses utilizing a hybrid model is the primary topic of the thesis. A full LCSA study has been adopted data collected using EXIOBASES 3.4's MRIO database; then calculations were conducted and shown in the methods section to provide the outcomes of the AFBs in Qatar. Three different types of alternative fuel buses (AFB)s that have been adopted in this study which are the Electric Buses (EBs), compressed

natural gas (CNG), and diesel buses (DBs). Because many policymakers and decision-makers find it difficult to grasp and evaluate the Life Cycle Sustainability Assessment (LCSA) results, and as a result of the massive amount of data collected, a complete platform was required to portray the outcomes in a way that decision-makers could easily look at them, recognize them, and decide. A business intelligence dashboard has been developed using Microsoft Power BI software to show LCSA data and emphasize the significance of interpretations and conclusions. Also, it will illustrate and develop a system that will provide informative results and lead to show multiple options ending with forming recommendations that enable decision-makers to make decisions toward selecting the most convenient types of alternative fuel buses. Then to end up assisting in influencing policymaking to allocate resources efficiently towards the most optimal alternative bus technology (CNG, Diesel, or Electric).

The study links visuals to a user-friendly design and interactive dashboards using the results of standard LCSA objectives. In addition, a framework was established for potential development and enhancement. Finally, this study offers a novel decision-making platform based on the product life cycle.

DEDICATION

This thesis is dedicated to my wonderful daughter Taleen, who inspired and strengthened me simply by looking into her eyes. She encouraged me to pursue my studies as well as to demonstrate to her that she can be like me and even better than me when she grows up. Her unconditional love has been a source of strength and inspiration throughout my master's degree quest.

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CHAPTER 1: INTRODUCTION

1.1. Overview

This chapter will deliver an outline of the history of Alternative fuel vehicles. An outline for the information will be provided, starting by defining Qatar's transportation system, giving an indication of the public buses, explaining more how the alternative fuel vehicles were introduced into society, then explaining the short term and long term importance of using alternative fuel transportation systems. Moreover, the chapter will elaborate more on the upcoming plans related to the public transportation sector, specifically the public buses sector. Also, there will be an illustration of the study challenge (Problem statement) and the study goals and approaches. Further discussion will be held later related to the tools and methodologies that will be used to evaluate the data and aggregate alternative solutions.

1.2. Background

1.2.1. Qatar Transportation System

As a result of Qatar's rapid population growth, there has been an upsurge in demand for a new transportation system, leading to the necessity to establish a secure and technologically advanced public transportation system to accommodate the rising demand for more public transportation services (Shaaban & Khalil, 2013). Likewise, Qatar's current National Vision 2030 requires a robust multimodal transportation infrastructure which is essential to support the country's economic and social development. However, Qatar is preparing to host many important and critical events, including the 2022 World Cup. For the reasons stated previously, it is compulsory to develop a more robust transportation infrastructure that is resourceful, accessible, and environmentally friendly. Several initiatives are conducted related to the transportation system, focusing on the public bus transit system; the Qatari government has established these initiatives as part of the efforts to modernize Doha's transport infrastructure (Ghanim et al., 2020;Cihat Onat, 2022).

1.2.2. General Overview of Public Buses

Public transportation is an active part of the urban lifestyle as it helps minimize traffic congestion, provides the inhabitants with more opportunities, and aids in reducing greenhouse gas emissions. Buses are inexpensive, flexible, and superior in terms of capacity and speed; they play an essential role in the provision of public transit. Adding more to the benefits related to the bus transportation system, it maintains to appears that buses are the most appropriate choice in terms of economics, the environment, and social well-being when it comes to achieving a more balanced and sustainable urban development(Onat et al., 2019). As a result of the increment of the technology evolving on a daily basis, selecting the most appropriate bus technology is critical, as it must involve the assembly of new buses and the development of unique qualities such as environmental friendliness types (Hamurcu & Eren, 2020; Shen et al., 2009).

1.2.3. Difficulties In Introducing Alternative Fuel Buses

The stakeholder, decision-makers, and other authorities responsible for making the final decision regarding choosing alternative fuel buses are encountering a variety of challenges. The main significant reasons for these challenges are addressed below as follows:

- Knowledge perspective: The community is still unaware of the new buses' technologies moreover not aware of the harm that the conventional buses can cause in various ways, including the environmental, economic, and social aspects.
- Cost perspective: People frequently refuse to develop or invest in new

technologies out of fear of the associated expenses that will be involved in this process. The acquisition cost of the latest technologies can be prohibitively expensive, resulting in increased exploitation costs.

- Innovation perspective: the rapid evolution of the new technologies could prevent decision-makers from considering purchasing them, as the development cycle of the new public transportation technologies is rapidly outpacing the life cycle of buses. So, this might lead to a gap in catching up with the latest innovation.

These concerns prevent the authorities from investing more in new alternative fuel buses (CIVITAS, 2017).

1.2.4. General Overview On Public Transportation Alternative Fuel

The public transportation market has already made a significant success by being the most outstanding sector to introduce alternative fuel options. Some studies conducted a comparison of alternative fuel buses and found that they can compete extremely well with conventional buses in several aspects like reliability, operating costs, etc. for example, Natural gas, which demonstrated a massive ability to reduce PM and NOx emissions (Motta et al., 1996). According to various studies, alternative fuel is classified into four categories, including 1. Electric vehicles 2. Conventional diesel vehicles 3. Hybrid electric vehicles 4. The new types of the new fuel contain methanol, CNG, and Fuel Cell (Tzeng et al., 2005a).

1.2.4.1. Conventional Diesel Vehicles

Diesel is considered the most efficient type of combustion when compared to other internal combustion engines; it will remain a leading competitor as a power source in the twenty-first century, especially if the problem related to the (PM) and nitrogen oxides (NOx) emissions are resolved for this type of engines. There are different modifications that could improve the engine mechanism, such as the use of an inter-cooler turbocharger and cooled exhaust gas recirculation (Morita, 2003).

1.2.4.2. Electric Vehicles

The word "electric vehicle” originally appeared in 1828, when the inventor Nyos Jedlik created the first practical electric motor. (Guarnieri et al., 2012). To be more precise in describing electric vehicles, or EVs, they are road vehicles that operate and function in compliance with the electrical power source's criteria (Onat et al., 2019). EVs are categorized into several categories; the most significant types are Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), and Plug-in Hybrid Electric Vehicles (PHEV) (Configurations, n.d.). There are so many factors that contributed to the tremendous vicissitudes experienced in introducing electric vehicles to society; the most substantial reasons are the high cost of electric vehicles and the scarcity of gasoline at affordable prices (Rajashekara, 1994). Electric vehicles started to be well introduced in the early twentieth century as a result of substantial growth in public awareness of the environmental consequences of automobiles and the obligation to find an alternate energy source to petroleum. Commercialization assisted in raising community knowledge of the dangers associated with the increase in the use of internal combustion vehicles, as well as educating them on the consequences of such an increase (Ching Chuen Chan, 2013). There are a plethora of influences that may be used to convince people to switch to electric automobiles 1. the capability of EVs of not emitting tailpipe emissions 2. electric vehicles are ninety-seven percent more environmentally friendly than fossil fuel vehicles 3. preventing the spread of the carcinogen created in enormous quantities by fossil fuel vehicles 4. it would also hold and prevent a wide range of significant ailments such as asthma disorders and irritating respiratory systems (Holms & Argueta, 2010).

1.2.4.3. Hybrid Electric Vehicles

HEV has superior advantages and specifications, as the ICEs for hybrid vehicles are smaller than traditional ICEs, resulting in lower engine maintenance costs, and it supports reducing the fuel consumption in comparison with gasoline or diesel. HEV has lower GHG emissions for both direct and well-to-wheel basis, “which is the term to express the GHG emission from electric power plants.” There is no need to update the infrastructure in order to use HEVs because they can be filled up at the same stations that are used for gasoline or diesel vehicles (Ghadikolaei et al., 2021).

1.2.4.4. New Types Of The New Fuel (Methanol, Cng, And Fuel Cell)

1.2.4.4.1. Methanol.

Methanol is associated with gasoline-powered automobiles. A flexible-fuel vehicle or FFV is the one whose engine can use methanol fuel in a variety of combinations, and the engine can run smoothly on any ratio of gas and methanol. Methanol reduces the amount of black smoke and nitrous oxides (NOx) emitted into the environment. Based on an assessment related to the life cycle of biomass to fuel tank efficiency study, Methanol is the most energy-efficient fuel among the various viable alternatives for burning biomass in fuel tanks (Bromberg & Cheng, 2010).

1.2.4.4.2. CNG.

CNG has widely been utilized for standing engines, but the discovery of lightweight high-pressure storage cylinders has significantly improved the usage of CNG over the last generation. CNG reduced fuel consumption, operations costs, and maintenance expenses, and it increased engine oil life performance as natural gas used less carbon

(Semin, 2008).

1.2.4.4.3. Fuel cell.

Fuel cells are electrochemical systems that transform chemical energy into electricity and heat as a result of the chemical reaction occurring in the anode and cathode. This technology's reduced emission levels offer low maintenance requirements strengthening the interest in this technology; also, it provides lower fuel consumption (Muthukumar et al., 2021).

1.3. Sustainable Mobility

Vehicles are becoming a necessary method of transportation. Using all sorts of combustion engine vehicles has expanded dramatically due to the exponential growth in the global population. This has resulted in much higher energy consumption due to the resulting combustion of fossil fuels (Onat et al., 2017).

Moreover, transportation connects most of the sectors together, and those sectors play the main factor in the countries' economies. This concept will also lead to understanding that transportation links and integrate it into the economy and society. As the importance of transportation increases, other concerns are raised related to global climate changes, the rise of oil prices, and fossil fuel depletion (Onat et al., 2014a). It was necessary to conduct a transportation sustainability evaluation to prevent the negative consequences of transportation on the economy, society, and environment. Due to the expansion in the usage of fossil fuel vehicles, gas emissions have increased significantly(Onat et al., 2019); this caused numerous environmental catastrophes to occur, resulting in multiple health problems that endanger human life. (Lv et al., 2019). The points below will streamline the consequences of the increment use of fossil fuel vehicles and what each effect will impose, representing a sequential loop where each influence will drive to another.

1- Population increase leads to the rise of Fossil fuels Vehicles.
2- Energy consumption increases at a high rate.
3- Indicating an increase in GHG emissions (greenhouse gas emissions).
4- The rise of GHG emissions drives to unbalance the energy when it enters then released out of the earth, leading to climate change.
5- Weather-related disasters such as heatwaves and flooding would be exacerbated by climate change, which would also increase the incidence of heat-related illnesses such as heart failure, heat exhaustion, cramps, and rash.

Also, the increase in GHG would increase the air pollution concentration as it is a primary factor in increasing the number of people with cardiovascular illnesses, asthma, and cancer (Khandakar et al., 2020;Sen et al., 2020).

As a result of all the above reasons, the sustainable mobility system was raised as a main concern worldwide. This comes from the need for a system that can provide the essential economic, social, and environmental requirements. Concentrating on those key elements would significantly aid in the acceptance of the theory throughout society, particularly given that it is concerned with the financial aspect.

1.3.1. Banning Fossil Fuel Vehicle

Different countries worldwide started to realize the environmental impact of vehicles and how vital it is to start investing more in alternative fuel vehicles and use them as the main transportation system to reduce environmental pollution and climate change. In order to minimize fossil fuel vehicle use (Ayad et al., 2020). Table 1. Represent some countries that started to eject conventional vehicles to reduce emissions.

Table 1 Countries banned fossil fuel vehicles

Country	Targets and implementation of policies
Denmark	The final agreement on the new climate law was signed and ratified on December 6, 2019. The statute contemplates a reduction in greenhouse gas emissions of 70% by 2030, with further reductions continuing until zero net emissions are achieved by 2050. (*Denmark's Integrated National Energy and Climate Plan under the REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the Governance of the Energy Union and Climate Action*, 2019).
Iceland	Following the September 2018 adoption of a revised Climate Action Plan, Iceland's government stated that the primary goal is to increase efforts to reduce net emissions in order to meet the country's obligations under the Paris Agreement by 2030 and afterward lead Iceland to achieve the ambitious target of carbon neutrality by 2040. (*Iceland's Climate Action Plan for 2018-2030 Summary*, 2018).
Netherland	The Netherlands is rapidly transitioning to a carbon-neutral economy, intending to replace all current automobiles with zero-emission vehicles by 2030. As part of this strategy, the primary commitment is to cut greenhouse gas emissions by 49 percent by 2030 to achieve a total reduction of 95 percent by 2050 (Energy Agency, 2020).
Sweden	The Swedish government launched the "Fossil Free Sweden" campaign with the goal of making Sweden the world's first fossil-free country. The primary objective is to eliminate conventional automobiles from the country by 2030. According to the strategy they evaluated, by at least 2045, the country should have achieved net-zero emissions. (*Sweden's Long-Term Strategy for Reducing Greenhouse Gas Emissions*, 2020).
Scotland	Scotland's strategy in decreasing transport emissions is by promoting low- and zero-emission fuels and technology and encouraging modal shifts away from transportation vehicles via self-activity like (walking and biking). The target is to stop buying fossil fuel transportation vehicles by 2032 (Scottish Government, 2015).
French	To meet France's 2050 carbon neutrality goal, the country's environment minister announced that all diesel and oil-powered cars and trucks would be banned beginning in 2040. (Runkel, 2017).
Qatar	The number of cars in Qatar grew by 12% from 2012 to 2017, reaching a total of 1.5 million in 2017. By 2022, the number of vehicles is expected to reach 2.7 million, and the number of charging stations will get 400 stations in all (Wahedi & Bicer, 2020).

1.4. Environmental Impact of Public Transportation

This section delivers an overview of the environmental implications of public transportation powered by internal combustion engines and the environmental impacts of alternative fuel bus transit.

1.4.1. The Impact of Public Transportations Powered By Combustion Engines

The public transportation (PT) sector is considered one of the highest contributors to generating toxic gasses, which adversely affect the human immune systems, respiratory and cardiovascular and lead to a rising the risk of malignant and chronic diseases; based on that, transportation emissions have become a worldwide concern (Tartakovsky et al., 2013). From another perspective, a considerable impact was initiated by increasing the concentration of long-lived greenhouse gasses (which could last for eight years or more) and short-lived gasses that can be faded from the atmosphere or transferred to CO_2. Those gasses affect the global atmosphere triggering climate change and global warming (S. Abraham et al., 2012; Huboyo et al., 2021; Nagurney et al., 2010; Sausen, 2010).

Public transportation is responsible for increasing gasses emissions only and causes several types of externalities that significantly affect the environment, such as depleting raw materials and consuming fuel and energy. Those externalities have occurred because of the incremental increase in the vehicle fleet and the sudden development of the new road transport networks, which abruptly occurred (Condurat et al., 2017). Energy is an important source, and it has been consumed in large amounts through transportation sectors. Around 19% of the global energy was consumed in 2010; 69% of it was only related to the transportation sector. The expectations showed that the transport energy consumption will increase by 80% in 2050 (Karekla et al., 2018). Until now, the buses used by public transportation systems were powered by combustion engines that generated energy by burning fossil fuels. As a result of the harm caused by this type of engine, mainly the environmental impact, that is eventually leading to a severe effect on humans in the form of many diseases, in addition to climate change and global warming caused by the gasses emissions, the European Union has decided to agree on specific regulations to prevent pollution engendered by public transportation systems. (Sirca & Nicolae, 2020). To show the impact approach of the combustion engines, we can recapitulation the process as presented in Fig.1 below:

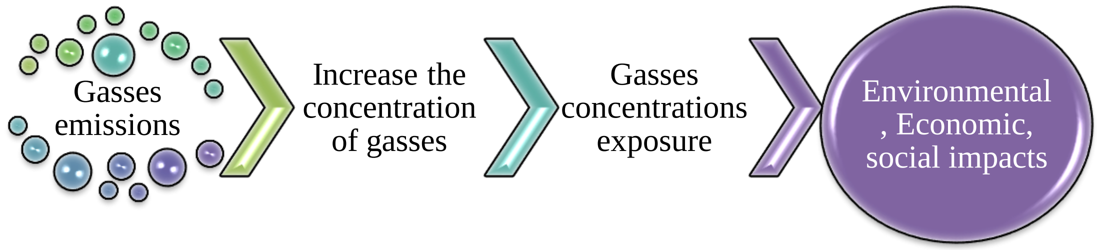


Figure 1 Emissions steps that lead to environmental, economic, and social impacts

1.4.2. The Impact of Using Public Transportations Powered By Alternative Fuel Vehicles

In order to prevent the highly toxic gases emissions and other effects related to the environment and caused by regular buss using combustion engines, developing a sustainable green growth system becomes an essential objective to make a positive contribution to reducing harmful environmental impacts, such as the environmentally-friendly vehicles using green fuels, electric and smart vehicles (Gabsalikhova et al., 2018). Electric buses are considered a promising alternative to the fossil-free transportation system; it's also considered the first take-off step to implement tower development of a sustainable transportation system. Numerous studies have been undertaken, and the results have demonstrated that electric buses have a lesser environmental impact when compared to buses powered by internal combustion engines in terms of pollutants. Furthermore, recent studies showed that people are getting affected by the noise caused by the regular traffic, as the noise is causing a sleeping disturbance that will reflect human health. However, Electric buses proved that it is more convenient and preferable to the users (Borén, 2019).

1.4.3. Internal Combustion Engine Efficiency and Environmental Impact Improvements

Currently, internal combustion engines (ICEs) power 99.8 percent of global transportation, and liquid fuels generated from petroleum account for 95 percent of total transportation energy. Many alternatives, such as battery electric vehicles (BEVs) as well as other fuel options such as biofuels and hydrogen, are being studied as alternative energy sources. The problem, however, has been that these alternatives begin at a very low position and then confront immensely significant impediments to unrestrained expansion along the way (Kalghatgi, 2018;Onat et al., 2020). 85–90 percent of all transport energy is expected to come from traditional liquid fuels and power-generating internal combustion by 2040, even at their most optimistic estimates (Smith, 2016). In order to minimize the local and global environmental impact of transportation, it is therefore critical that ICEs be enhanced. As a result, an upgrade in internal combustion engines became necessary, as demonstrated by the consideration of several practical alternatives that are presently available on the market. According to the American Society of Industrial Engineering, the best-in-class SI engines in the United States consume 14 percent less fuel than the average. Combustion and traditional engine innovations together have the potential to lower fuel consumption by more than 30% in light-duty vehicle applications (LDVs). Additional technologies, such as hybridization and light-weighting, could reduce fuel consumption by 50 percent when compared to the present average for light-duty vehicles (Australia & Ouyang, 2014; Energy Information Administration, 2019; Leach et al., 2020; OPEC, 2013).

1.5. Economic Impact of Public Transportation

More studies and information will be presented in this section about the economic impacts of public transportation, such as comparisons between regular buses using internal combustion engines (ICE) and electric buses, or more specifically, sustainable buses. Considering the costs associated with the significant impact on the environment, the loss of natural resources, and the reflection on the economic impact caused by public transportation, along with other concepts.

1.5.1. Comparison and Statistics on Sustainable Buses and Combustion Engines Buses and The Impact on The Economy

It is impossible not to emphasize the significance of public transit. The usage of buses is rising dramatically, affecting the environment and causing climate changes that are major aspects of driving economic damage (Ercan et al., 2017). As a result, it was important to obtain a more comprehensive understanding of the economic impact of the expenditures connected with bus transportation services. In general, Electric buses and conventional buses are pretty similar in physical appearance. Still, if we look at the internal structure, the difference will be in the main power generation of each type (Teoh et al., 2018).

In order to compare and contrast two different technologies, studies showed that there are internal costs and external to highlight and introduce. Internal costs are represented by the initial purchase costs, discount rates, residual value, operational costs, utilization costs, and energy costs. Also, the employment and salaries costs. On the other hand, there are the external costs related to the health issues formed by the air pollution that has been caused by the ICE buses (Laizans et al., 2016; Tong et al., 2017a). The first indication of E.B.s cost will give that the initial cost is much higher than the ICE buses. Still, once it is compared with the maintenance and operation costs of the E.B.s, it will offset the difference in the initial cost compared to the initial cost of the ICE buses. In addition to that, the benefits of zero tailpipe emission of the EBs since it is environmentally friendly buses will correspondingly reduce the healthcare costs. Also, it will not be affected by the increase in the future prices of diesel (Yusof et al., 2021).

1.6. Life Cycle Sustainability Assessment (LCSA)

LCSA approach was introduced in response to a need to combine the three components of sustainability – environmental, economic, and social – into a single formulation while keeping a life cycle perspective (Onat et al., 2016). We should emphasize that the LCSA approach is accessible in two variants. The first is that LCSA is a model established and proposed by Kloepffer in which all three components are included: an environmental life cycle assessment (LCA), a life cycle costing (LCC), and a social life cycle assessment (SLCA) (Kloepffer, 2008); it is illustrated in Fig. 2.

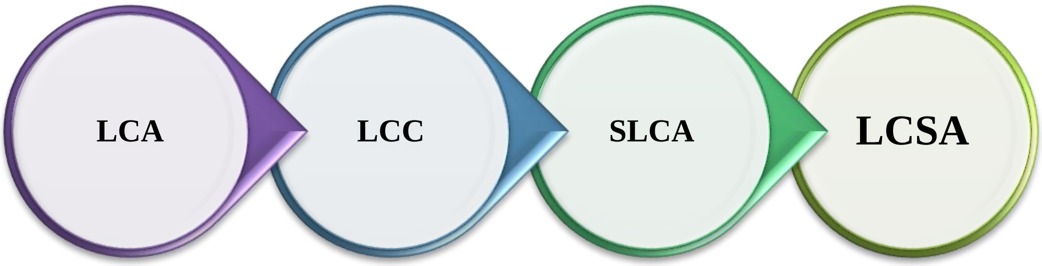


Figure 2 Three-pillar model of sustainability representing LCSA

The term life cycle assessment or LCA describes the process of an assessment of a product or service's environmental impact over the duration of its full life cycle. The LCC represents the Life Cycle Costing Assessment, whereas SLCA is an abbreviation for Social Life Cycle Assessment. The expansion and the integration of all three pillars result in a new concept of sustainable assessment, called Life Cycle Sustainability Assessment (LCSA) (J. Guinée & Guinée, 2016a; Tarne et al., 2017).

The second definitions demonstrate that LCSA is a framework rather than a model. It indicates a description similar to the original but with a comprehensive and holistic range; rather than a model, Guinee et al. established this prescription as a framework (J. B. Guinée et al., 2010) proposed that LCSA's scope should be expanded from primarily product-related concerns (product stage) to topics relating to a sector or the entire economy (sector stage or economy stage). It broadened the scope of the current LCA by incorporating economic and social links and relationships in addition to predominantly technological (or physical) interaction (which involves restrictions), permitting it to be combined with other techniques such as Material Flow Analysis, Cost-Benefit Analysis, etc. Additionally, the primary aspect that differentiates this technique from others is the process of scope expansion, as well as its strengths in incorporating normative elements such as discounting, weighting, and the concept of weak with versus strong sustainability (Fauzi et al., 2019; J. Guinée & Guinée, 2016b).

1.6.1. Life Cycle Assessment

LCA refers to an approach to determining the environmental impact of activities, processes, and other factors during their whole life cycle. The impact is measured through the raw material phase to the disposal phase. In general, LCA is usually used by policymakers and scientists (Nuri C. Onat et al., 2019). Recently, LCA has been extensively used in the transportation sector because of its ability to evaluate the influences of transportation activities in relation to the environment and the cumulative environmental impact throughout the transportation system's whole life cycle (Haanstra et al., 2020). Ultimately LCA will assess the vision of a lower-carbon energy future (Klass & Heiring, 2018).

1.6.2. Life Cycle Cost LCC

LCC is a technique for evaluating the systematic economy of an asset by examining its overall price of ownership for a given duration or the cost of an asset through its complete life cycle. (Potkány et al., 2018). LCC, likewise the LCA, looks at the asset life cycle from the design face going to the manufacturing up to operation and management, ending by the end of life. The difference here is that we don’t look at the environmental impact; otherwise, the main concentration will be on calculating the capital spending and costs (Raposo et al., 2018).

1.6.3. Social Life Cycle Assessment

S-LCA is a novel method in comparison to LCA and LCC, having been made available for the first time in 1993. The Social Life Cycle Assessment concept is to examine the implications related to the social aspect of a product or activity over the course of its life. (Gompf et al., 2020).

1.7. Decision Support System

The discipline of information systems that support and improve the management decision-making process is referred to as Decision Support System (DSS) technology. (Arnott et al., 2000). It is considered a critical computerized instrument for improving decision-making (Ocalir-Akunal, 2016; Philips-Wren et al., 2017). In general, DSS is deliberated as cutting-edge technological innovation. It has been used in the transportation system as an influential tool used to provide users with testing scenarios, information analysis, costs, and benefits to study the effects before implementation (Matzoros, 2002; Schlickmann, 2018).

1.8. Problem Statement

When compared to other systems of transportation, public transportation generates the most significant amount of GHG emissions. In addition to the fact that public transportation is becoming more widely known in the state of Qatar and that people from a variety of different sectors are beginning to rely on public transportation on a regular basis, there is also a pressing need to meet the national requirements of the state of Qatar, as outlined in Qatar's National Development Strategy 2 (QNDS-2; 2018-2022) and Qatar's National Vision 2030. (QNV 2030). It was necessary to convert to environmentally-friendly public transportation since it is one method of bringing new eco-buses onto the road with the goal of maintaining a sustainable transportation system that considers the environment, the economy, and social dimensions.

The Thesis will place emphasis on the creation of a business intelligence platform that will present a hybrid model of life cycle sustainability assessment of alternative fuel buses (AFBs). The types of AFBs that have been selected consist of electric (EB), compressed natural gas (CNG), and diesel buses. On the basis of multi-sustainable metrics such as the ones listed below, the platform will demonstrate the impact of the AFBs' life-cycle sustainability.

1. Global Warming Potential (GWP)
2. Life Cycle Cost (LCC)
3. Employment generation
4. Contribution to the gross domestic product (GDP)
5. Human Health Impacts caused by air pollution.

The platform will be designed on the basis of huge data that has been collected, validated, and verified for the three different types of AFBs: electric, compressed natural gas, and diesel. A total of seven countries that are deemed to be the leading manufacturers of alternative buses will have their data collected. The countries are as follows: China, Turkey, Poland, Sweden, India, Germany, and Spain. Fig. 3 shows the types of transportation buses manufactured in each country.

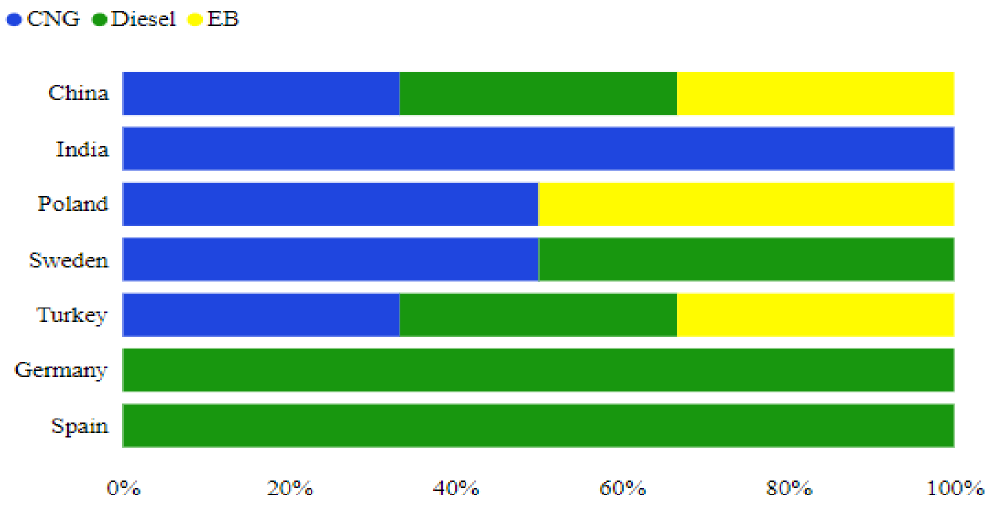


Figure 3 Top manufacturing countries

Figure 4 The distribution of manufacturing country and type of alternative vehicle

1.8.1. Research Gaps

There are fundamental problems or gaps that have been identified in this research, such as:

a) Lack of awareness in understanding data visualization is the main rule in simplifying and providing a better understanding of Sustainable methods such as LCA, LCC, and S-LCA.

b) Lack of methods that improve the capability of making decisions at a quick and accurate rate. Visualization dashboard will provide the needed critical information, which will support the final decision, then will lead to a set of new policies.

c) In order to improve the interpretation of LCSA outcomes, data analytics and visualization should be used.

d) LCSA discoveries or outcomes will be automated for use in practical decision-making.

e) Employing LCSA results in managing large amounts of data for better policymaking.

1.8.2. Research Objectives and Goals

Create a business intelligence platform that will provide accurate insights and various recommendations and outline the policies associated with those recommendations to assist the manager in making decisions. Additionally, it will assist in influencing policymaking to allocate resources efficiently to the most ideal alternative bus technology available today (CNG, Diesel, or Electric).

The Research objectives:

- ❖ Evolve a decision support system (DSS) using data visualization and dashboards to show the LCSA results in a clearer view.
- ❖ Automate the data by using the collected, cleaned, and validated data and importing them into the software to create clear and valid visualizations.
- ❖ Develop an LCSA decision support system for management decision-making.
- ❖ Develop a data-driven decision support system to support decision-makers and

provide alternative recommendations.

- ❖ To give the capability to the decision-makers to select different preferences based on the available capabilities and resources.

The research Goals:

- ❖ Show the power of using the data analysis tools to illustrate the data to reduce time and effort and simplify the results for the end-user.
- ❖ Visualize and represent the three sustainability aspects by creating dashboards that evaluate and compare the thirteen sustainability indicators.
- ❖ Creates a dashboard that reflects the LCSA system boundaries to show which region or country can deliver superior results during the life cycle process, from production to end-of-life (EOL).
- ❖ Presenting the two end-of-life scenarios were investigated as either by recycling the buses in China or India.

1.8.3. Research Scope

In order to achieve the research's primary objectives, the collected data will be imported to the Power BI software, then a business intelligence platform will be developed for sustainable public bus transportation; after that there will be an illustration of the valuable results that will assist decision-makers in making better judgments and decisions, and then develop new policies based on the findings of our research.

The following are the details for each phase:

I. Use the Collected life cycle inventory data of the social, economic, and environmental impacts, then accurately measure the sustainability implications of alternative fuel buses over their entire life cycle.

II. Develop a sustainability performance model using Power BI software considering economic, environmental, and social impacts.

III. Create a business dashboard and use visualization tools to display the LCSA analysis results for better decision-making and decision support. The M.S. Power BI program will be used to create a data visualization platform.

IV. Providing the final outcomes and recommendations.

1.8.4. The Novelty In Using Business Intelligence Tools

The novelty of the thesis is represented by the following:

1- This study will demonstrate a novel application representing the LCSA results in an easy and understandable way.

2- This study will provide a platform that can select and control the data to get the desired exact result.

3- This study will show how data visualization platforms can be used as a decision support approach or technique.

The uniqueness of utilizing business intelligence technologies to communicate sustainability data in a more understandable format is presented in three important aspects:

1. The platform's utilization and the impact on the end-user decision-making
   a. Assemble a unified platform related to the LCSA results to ensure that all end-users receive the same outcomes and concentrate on the critical information provided to make better judgments.
   b. Bringing together the environmental, social, and economic dimensions of the LCSA in a unified platform.
   c. Enable decision-makers-to-manger communication.
   d. Displays the most crucial information that users need to know in clear

visualizations.

e. Establish a centralized source of all data and information in one database that can be updated all the time.
f. Adaptable to be utilized with computers or mobile phones.

2. The benefits for the end-user (anticipates and requirements)
   a. Save the end-user time and effort by not requiring them to spend time reviewing large data files and making decisions with a significant chance of missing critical information that could influence the conclusion.
   b. Be confident that the data will be protected, and ensure that the end-user has no difficulty utilizing the platform.
   c. Maintain an awareness of updated data and changes.
3. The reflection on simplifying the large, complicated data sets associated with the LCSA results.
   a. To demonstrate LCSA data and to underline the importance of the interpretations and findings.
   b. Exhibit and develop a platform that will produce useful results and lead to present many possibilities, which ultimately lead to the formulation of recommendations that allow the selection of the most convenient forms of alternative fuel buses.
   c. To end up assisting in influencing policymaking to allocate resources efficiently towards the most optimal alternative bus technology (CNG, Diesel, or Electric)

CHAPTER 2: LITERATURE REVIEW

This chapter will cover the comprehensive investigations and methodologies that have been used to address pertinent issues relevant to the study topic. The literature search was conducted based on each sub-section title; the method of the search used the following query string illustrated in the table below:

Section title	The search query string	Document results
Buses Selection Using Decision Support Systems	("Buses Selection " OR " Buses Decision Support Systems ") AND ("Buses" OR " alternative fuel buses ")	75
LCA of Buses	("Life cycle assessment" OR "LCA") AND ("Public transportation" OR "Buses" OR "transportation" OR "electric vehicles" OR "electric cars" OR "emerging mobility") AND (" Decision Support Systems" OR "DSS ")	41
LCC	("Life cycle cost" OR "LCC") AND ("Public transportation" OR "Buses" OR "transportation" OR "electric vehicles" OR "electric cars" OR "emerging mobility") AND (" Decision Support Systems" OR "DSS ")	28
LCSA	("Life cycle sustainable assessment " OR "LCSA") AND ("Public transportation" OR "Buses" OR "transportation" OR "electric vehicles" OR "electric cars" OR "emerging mobility")	14
Sustainability Indicators in Public Transportation	("Sustainability Indicators " OR " Indicators") AND ("Public transportation" OR "Buses") AND (" Decision Support Systems" OR "DSS ")	24
Data Analytics and Visualization Tools	("Data Analytics " OR " Data Visualization " OR "Data Analytics and Visualization") AND ("Public transportation" OR "Buses" OR "transportation" OR "electric vehicles" OR "electric cars" OR "emerging mobility") AND (" Decision Support Systems" OR "DSS ")	46

The following section will discuss the Thesis contribution and provide additional details on the approach that was developed and used to accomplish the research objectives.

2.1. Buses Selection Using Decision Support Systems

DSS is used to provide solutions for complex decisions and to address complex problems; as problems get more complex over time, DSS is becoming increasingly important (Ocalir-Akunal, 2016). DSS becomes essential because it makes use of computer technology to assist in emphasizing the alternatives. The usage of DSS has become increasingly popular in the transportation industry. The DSS techniques will be extensively discussed. that was implemented in the selection of public transportation options (Aboushaqrah et al., 2021a).

(Tzeng et al., 2005b) Examined and evaluated a total of eleven alternative fuel buses based on eleven evaluation criteria. Multi-criteria analysis has been used by a variety of specialists from a variety of decision-making domains (MCA). Starting with the AHP technique, which is concerned with weighing the criteria. Following that, two approaches were chosen: TOPSIS and VIKOR, which were then compared to determine which was the best alternative fuel bus. According to the VIKOR technique, the best alternative is the hybrid electric buses along with a gasoline engine, which is the closest thing we have to an optimal answer. The TOPSIS approach, on the other hand, revealed that the electric bus with an exchangeable battery received the greatest rating for alternative fuel buses; however, the solution is more tied to the term of the ranking index and hence cannot be viewed as the perfect solution. Because of the advance rate employed by VIKOR and the unanimous consensus of the experts, the Hybrid electric bus was determined to be the best solution and was selected.

(Brown, 2010) Developed an analytical framework that will be transformed into the approach to making a decision for the purchasing of the new public transportation buses. It is anticipated that the conclusion of this method will provide a better deep intuition in terms of emissions requirements and the perspective of the trends in technological progress, as well as recommendations and considerations of alternative bus fuel technology. It is important to mention the ambiguity around emission requirements, which can render the available buses inefficient. Consequently, this modification will necessitate an upgrade on the buses, which will undoubtedly cost money and have an impact on time due to the disruption of the entire system and resulting in service loss. It is necessary to employ socio-technical systems (STS) to clarify the fundamental principles of the problem and to demonstrate the interplay between the social and technical components. An analytical framework was developed that incorporated the STS components and provided a better understanding of their interactions. Fig. 5 below depicts the interaction between the elements in STS, taking into consideration that the terms actor and rules represent the multi-actor network, rules represent the standards and regulations that can be classified as formal or informal, and technology depicts the physical network such as buses, engines, and so on.

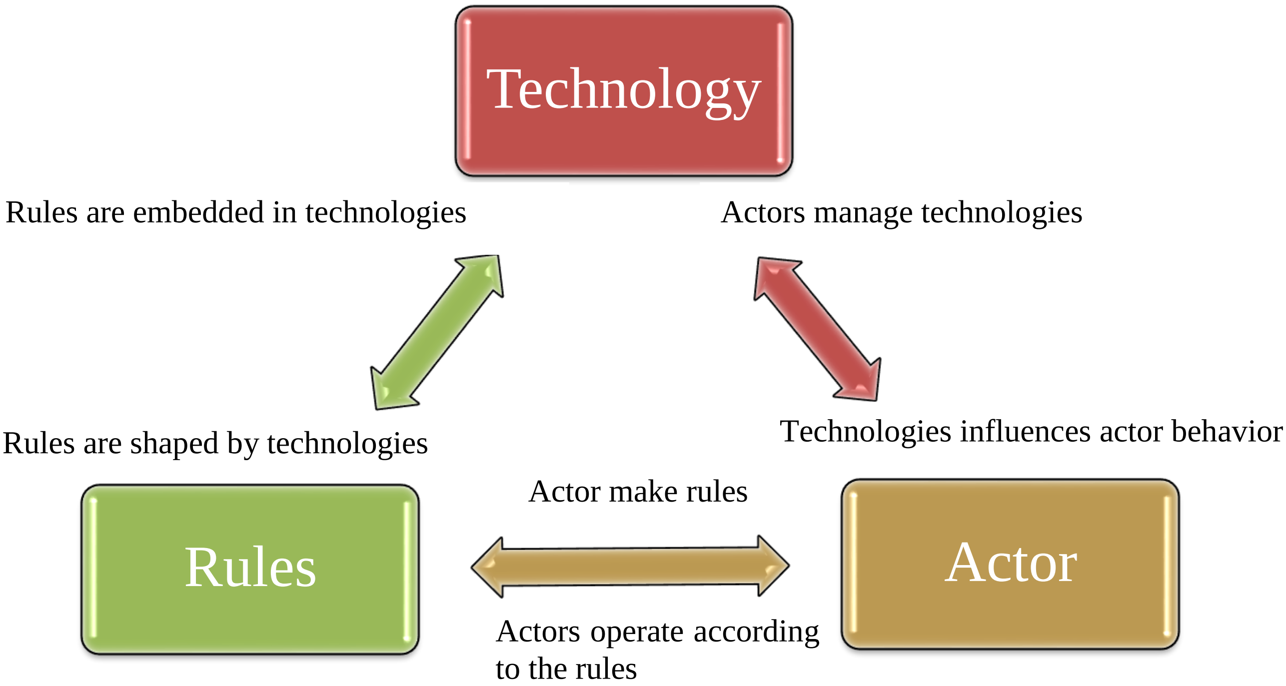


Figure 5 Interactions within a Socio-Technical System

The alternative fuel technologies that were evaluated and compared in the report included hydrogen, compressed natural gas (CNG), clean diesel, hydrogen, and hybrid. Following a comprehensive examination of each possibility, the authors suggested the use of hythane technology.

(Vahdani et al., 2011) Proposed a couple of different fuzzy multiple criteria decision-making (MCDM) methods: the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and PSI, representing the Preference selection index. The first method proposes using linguistic variables to estimate rating and weight components. Both triangular and trapezoidal numbers can be used to communicate used to convey this language evaluation. Following that, a hierarchical MCDM technique based on the fuzzy sets principle is suggested to address the problem of selecting fuel buses. Once the TOPSIS approach has been used to calculate the distance between the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS), the alternatives' ranks will be established. Language factors are employed in the second approach to gauge success. The second way extends the PSI's scope to include a fuzzier setting. It's important to point out that the second approach employed when determining the importance of an attribute's value is challenging.

(Aydin & Kahraman, 2014) Combined the two techniques, the fuzzy AHP and fuzzy VIKOR techniques. The measure and sub-criteria were weighted using fuzzy AHP, and the alternatives were ranked using the fuzzy VIKOR approach. To implement the method, a hierarchy was created with four levels, including three main criteria (Economic, social, and technology), 17 sub-criteria were chosen, and a set of nine alternatives to fuel buses was chosen. After implementing the methodology, calculating the weights, and ranking the alternatives, the end results showed that *Compressed Natural Gas Buses (CNG)* are the best alternative.

(Mousaei & Hatefi, 2015) Introduces a model that focuses on fuel replacement for the transportation sector, providing low emission fuel alternatives, focusing the most on Natural Gas (NG). The four fuel options that the application used are CNG, LNG, DME, and GTL. The Decision Support System proposed consists of the following, Data-Base subsystem (DB), Model-Base subsystem (MB), and finally, the decision-making model using multiple attribute decision-making (MADM). After using the model, the results help in selecting the proper alternative fuel and provide recommendations of the key guidelines.

(Babakan et al., 2016) Proposed the approach of selecting the adequate alternative public transportation utilizing the GIS or the Geographic Information System with the MCDM approach. The alternative options were Bus, Taxi, Bus Rapid Transit (BRT), and the railway. The results concluded that BRT is the most proper selection for most of the indicators that have been considered, but it wasn't convenient for the environmental indicators, so the suggestion was to go from conventional fuel BRT to alternative BRT that uses clean fuel to overcome the pollution issue.

(Lanjewar et al., 2015) Oriented the effort toward cleaner fuels technologies by utilizing hybrid multi-criteria approaches, with the work provided in applying graph theory and matrix approach (GTMA) together with analytic hierarchy process being particularly remarkable (AHP). When the GTMA visualizes the alternative fuel technologies, it links them together to demonstrate the interrelationships between each feature. Finally, it paradigmatized a matrix that compares the alternatives based on the fuel preference index. In terms of the AHP approach, it was required to employ this method in order to assign weights to the available possibilities, particularly when there are several alternatives, and it will also assist in delivering more stability and reliability for the judgments.

(Nuri Cihat Onat, Kucukvar, et al., 2016a) Addressed the importance of studying the interrelationship of the environmental, economic, and social dimensions. Also, the research demonstrates how studies concentrated solely on the life cycle cost when it came to assessing the economic impact of alternative vehicles while omitting to consider the economic impact at the economic level as a result. The integration of multi-criteria decision making (MCDM) and Life cycle sustainability assessment (LCSA) was utilized in this study, which included sixteen macro-level impacts connected to sustainability and seven different vehicle types.

(Oztaysi et al., 2017) Demonstrated the selection of alternative fuel vehicles (AFV) utilizing one of the MCDM approaches, which is the interval-valued intuitionistic fuzzy sets (IVIFS) method. Several applications involving the IVIF method have been carried out in order to concentrate on the most important aspects, such as the use of interval-valued intuitionistic fuzzy numbers (IVIFN), which is concerned with acquainting the expert assessments in terms of membership and non-membership degrees, as well as the hesitancy of their reviews, with the essential aspects. For the pairwise comparison matrices, the interval-valued intuitionistic fuzzy weighted averaging (IVIFWA) is employed as an aggregation operator of the interval-valued intuitionistic fuzzy network (IVIFN). To demonstrate his model of the mixed-cluster decision making (MCDM), the author later employed a mixture of interval-valued intuitionistic fuzzy preference relations (IVIFPRs) and the IVIF-TOPSIS approach to illustrate his point. Five different types of AFVs have been chosen (Biodiesel, CNG, Electric, Ethanol, and LPG). The evaluation criteria were chosen based on their suitability for covering the three primary approaches: environmental, economic, and social approaches. This resulted in a total of twelve criteria, which were divided into five broad groups for further consideration. According to the findings of the study, compressed natural gas (CNG) vehicles are the best alternative form of AFV.

(Soegoto & Ramadhani, 2020) Focused on the inspection procedures to determine if the vehicle can operate properly on the road. The study made use of a decision support system, and the results of the study will provide suggestions and recommendations through the use of a mobile application that will collect data related to the criteria that have been set, then analyze it and provide a recommendation that will assist the rhamp check officer in selecting the most suitable transportation vehicle to operate on the job site.

(Hamurcu & Eren, 2020) Addressed the importance of the electric vehicles' transportations, as it is considered the most environmentally friendly with zero-emission; this reflects on improving the air quality, especially for the cities with high population density. The study focused on six types of electric buses with six criteria;

the main goal was to choose the most suitable electric bus technologies to improve the environment. A variety of decision-making procedures are used, consisting of the analytic hierarchy process (AHP) and TOPSIS, which represent the mechanism for ranking solutions according to their similarity to the ideal solution. The study goes into several steps as shown below in Fig. 6:

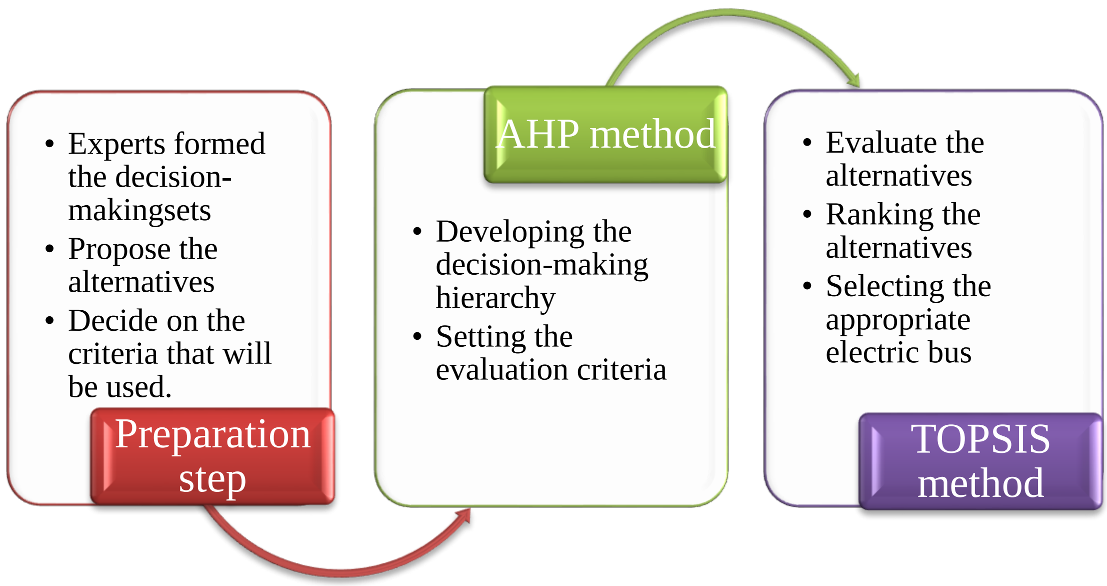


Figure 6 The methods used in the research to select the best electric bus

2.2. LCA of Buses

During a life cycle assessment, the environmental implications related to the product are evaluated at each point of its life cycle, beginning with production and progressing to the use stage, and finally to the last stage, which can be characterized by the term end-of-life (EOL) stage. LCA usually uses a couple of methodologies to specify the environment's implications: the process-based methodology or the economic input-output (EIO) approach (Samaras & Meisterling, 2008).

(McKenzie & Durango-Cohen, 2012) Demonstrate a life-cycle assessment (LCA) of expenses and greenhouse gas emissions using a hybrid input-output model of buses that compares ultra-low sulfur diesel with different fuel types (compressed natural gas, hydrogen fuel-cell, and ultra-low sulfur diesel) and how this relates with other fuel types (compressed natural gas, hydrogen fuel-cell, and ultra-low sulfur diesel). LCA is used to estimate the long-term costs and gas emissions reduction of alternative fuel buses over the progress of their entire life cycle. Examine the results' sensitivity to changes in expenses, demand, and client numbers by assessing the changes in those variables over time. The analysis also included the impact on the emissions and performance based on the technological characteristics. The upshots of the study presented that the utilization of alternative fuels decreases the operational expenses and emissions, but on the other hand, they increase the life cycle cost.

(Ercan & Tatari, 2015) Objective is to use an input/output hybrid life cycle assessment model with Monte Carlo simulation integration to address the uncertainties caused by life cycle inventory. The model implemented on buses uses various fuel types, such as GNG, LNG, BE, and hybrid (diesel-electric), to show the overall air pollution and water retreatment impact. The analysis indicated that the electricity and hybrid bus flow over the complete lifetime of the bus are the best environmentally friendly types.

(Jwa & Lim, 2018) Investigated the lithium-ion EV buses and the diesel buses LCA using GREET 2016 model, using which the emissions are calculated, the well to pump (WTP) evaluated, and the pump to wheel evaluated (PTW). The most pressing issue is assessing the environmental impact of alternative fuel buses. The study focused in particular on the energy consumption and the emissions caused by EV buses using Proterra Catalyst XR battery. In this paper, two LCA processes have been investigated: WTP, related to fuel production and supply to the automobile. The other is the operation part of the vehicle (PTW). Fig.7 Shows the LCA of both processes. The results show that the GHG during the WTP is 211gCO2eq/ km for EV buses; on the other hand, the GHG of the diesel buses is 227.4gCO2eq/ km, which shows that diesel buses emissions are more than the EV busses. A vast difference in GHG emissions occurs at the PTW process where the values were 0gCO_2eq/ km, 1626 gCO_2eq/ km. for EVs and diesel, respectively.

To summarize, electric buses consume less energy and emit fewer pollutants than diesel buses. However, there is an important factor that needs to be mentioned is that there is a problem related to EVs, which is the driving range. To provide a more truthful and practical environmental assessment, the author mentioned that it would be necessary to assess fuel efficiency under actual operating conditions.

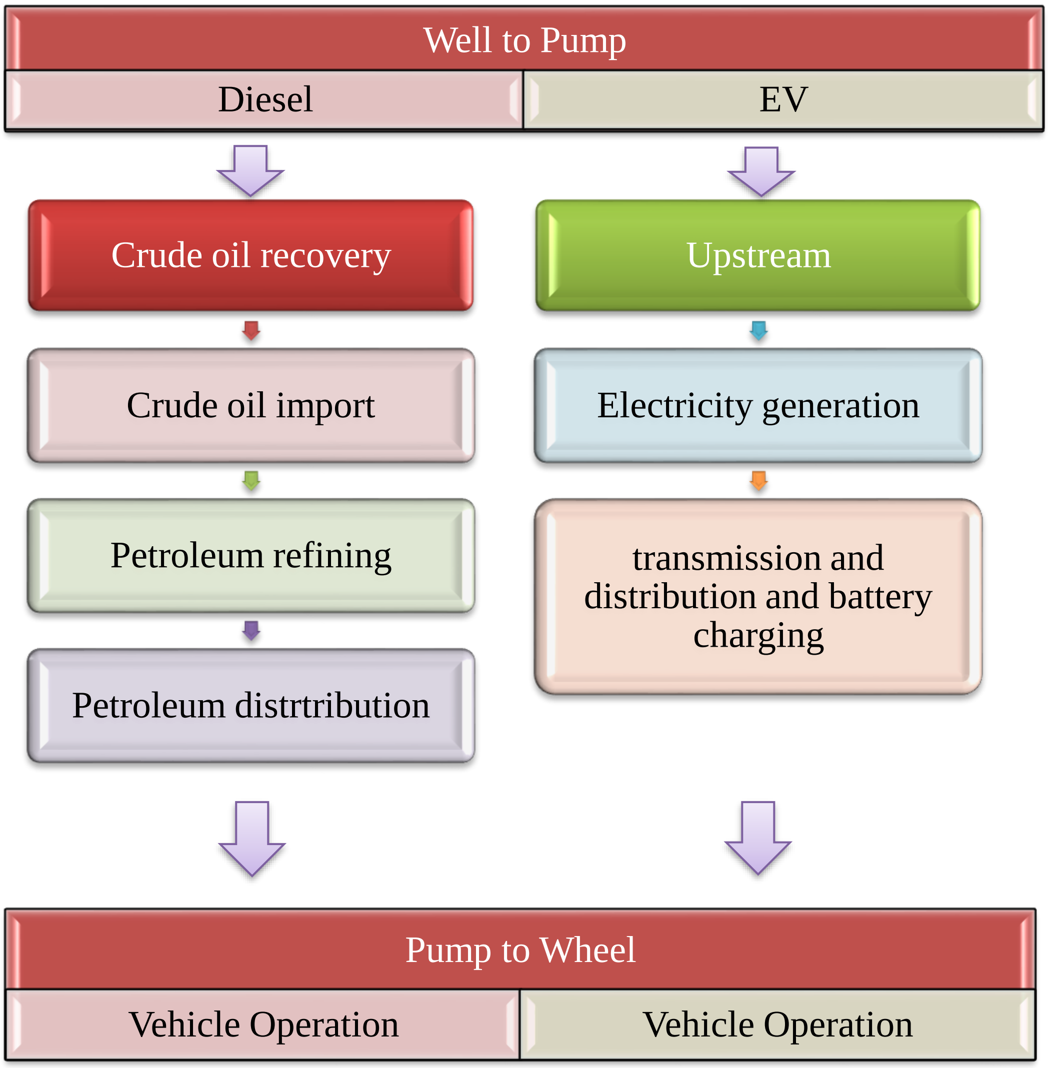


Figure 7 LCA of fuel for EV and disiel

(Nordelöf et al., 2019) Explore the LCA of the city buses using industrial data used to analyze and explore the environmental impact of each bus. The same model series of buses have been used in this study with various options depending on first, electrification level, second, the production of electricity to charge the batteries, after which there's the last step in operation, reflecting the alternate drive mode's liquid fuel type, diesel or HVO. Biodiesel has recently piqued the curiosity of those in the bus transportation industry, and it offers promising environmental performance. Electric buses, plug-in hybrid electric, hybrid electric, and conventional buses were all used in this investigation. The study was conducted based on primary bus information offered by Volvo Bus Corporation, including the bus design, composition, production of components, driving, and maintenance. Also, Additional sources have been used for other processes. Other life cycle stages in various bus alternatives include mining and manufacturing of materials, energy generation, fuel production, and processing of materials resulting from end-of-life (EoL). The study shows that the use stage in conventional buses caused around 90% of climate change, while the key effect for the other three types lays in the production and EoL stages.

2.3. LCC

Using LCC, vehicle manufacturers and operators can compare the prices of various powertrains. It also allows you to pick between several types of buses based on their drivetrains. The LCC calculation separates costs from the manufacture of buses to their use and operation, as well as their entire depreciation during their economic or financial lives and technical life. The cost of ownership is included in the Life Cycle Cost method, such as purchasing, registering, and infrastructure improvements (Szumska et al., 2020). Table 2 will show all of the papers related to LCC, including the cost component, study methods, and study outcomes.

Table 2 LCC literature review

Study Reference	Alternative fuel buses options	Cost Components	Study Methods	Study outcomes
(Compressed et al., 2014)	Diesel, CNG, hybrid-electric buses.	Purchase, fuel, O&M excluding fuel refueling stations and garage costs.	Best Value traditional approach and the Lowest Cost, Technically Acceptable model	Describe how CNG buses compared to diesel and hybrid buses in terms of reliability, on-road performance, and emissions.
(Ercan et al., 2015)	diesel-electric hybrid, battery-electric (BE), liquefied natural gas (LNG), propane (LPG), CNG, and biodiesel	health damage costs, Fuel purchase, Maintenance and Repair, Battery replacement, Infrastructure, Insurance	hybrid life cycle assessment, Multi-objective linear programming (MOLP), Pareto-optimality	The study recommended a variety of options to address environmental concerns and improve Life Cycle Costs. The greatest alternative fuel combinations for public transit buses are BE (Battery Electric) and Hybrid.
(Tong et al., 2017b)	conventional diesel bus, diesel HEB, CNG, LNG, B20, B100, BEB (slow charging), and BEB (fast charging)	bus purchase costs, Fuel costs, bus operation and maintenance (O&M) costs, Infrastructure costs, and health and environmental damages	Life cycle GHG emissions estimates, Social cost of carbon (SCC), Integrated assessment models, GREET model, AP2 and EASIUR model,	The finding showed that BEBs save 17–23% in ownership and external costs when external finance covers 80% of vehicle purchase price compared to diesel. BEBs can significantly reduce CAP emissions while only generating 1% of mobile source emissions.

Study Reference	Alternative fuel buses options	Cost Components	Study Methods	Study outcomes
(Rijal & Paudyal, 2019)	Electric and Diesel Buses	Initial Capital cost, Fuel cost, Maintenance cost, Environmental cost, Disposal cost, and Overhead and Management costs	The study of Cooney , Potkany, ADB, Anal and GGGI	This study compares the expenses of operating electric buses against diesel buses throughout the course of their expected useful life. Less expensive electric buses save enough on fuel and maintenance to justify their higher purchase price. This research will help the development of transportation corporations and governments make bus purchase and subsidy decisions.

2.4. LCSA

It is critical to expanding the scope of the existing life cycle thinking to integrate the sustainability pillars (i) environmental, (ii) economic, and (iii) social. It entails completing an evaluation that takes into account environmental, economic, and social factors, in other words, undertaking an encompassing life cycle sustainability assessment (LCSA). Integrating the three methodologies, which share comparable methodological frameworks and objectives, enables the development of an all-encompassing LCSA. For decades, life cycle costing has been used to assist decision-makers in procurement by calculating and managing costs, particularly for big expenditures, with a strict focus on private expenses. Prerequisites for improved alignment with the environmental LCA approach are now being investigated, which will aid in the method's ongoing development. As a new approach, S-LCA will be critical in augmenting knowledge about material and energy flows (Ciroth et al., 2011;N. Onat, 2015).

(Nuri Cihat Onat et al., 2014b) Offer a multi-combination of input-output analysis with the LCSA framework to represent the sustainable evaluation of the alternative vehicles. Exposing the macro-level social, economic, and environmental impacts related to alternative vehicle technologies was the main focus of the study. The model construction uses 19 macro sustainability indicators for comparing the performance of conventional gasoline, hybrid, plug-in hybrid, and full battery electric vehicles in the United States. Vehicles and batteries are covered in the study from the extraction of raw materials through the processing, fabrication, and operation stages, all the way to the end-of-life phases. Compared to the former stages of the life cycle, this analysis found that manufacturing has the greatest impact on socio-economic outcomes. In contrast, operations have a greater effect on environmental outcomes and some socio-economic outcomes like human health and the economic cost of emissions. According to the findings of this study, manufacturing seems to have the greatest influence on socio-economic impacts. Electric vehicles emit fewer pollutants and have fewer adverse effects on human health compared to traditional gasoline vehicles.

(Nuri Cihat Onat, Kucukvar, et al., 2016b) Build a framework for evaluating the sustainability of alternative passenger cars. The study integrates the life cycle sustainability assessment with multi-criteria decision-making techniques. There were 16 macro-level sustainability aspects for seven distinct vehicle types to be evaluated. The vehicles are distributed among three main power drives: internal combustion, hybrid electric, and plug-in hybrid electric vehicles. Aside from that, The analysis considered two different battery charging scenarios related to the PHEVs and BEVs. Scenario 1 is related to the current electric power infrastructure. Scenario 2 is an ultimate case where the electricity to power battery EVs and PHEVs is produced exclusively through solar charging infrastructure. The vehicle types are calculated and determined based on the three Triple Bottom Line of sustainability, presenting the environment, the society, and the economy for each scenario, including all vehicle types. The findings from the study could open the path for progress in the state-of-the-art and state-of-the-practice present sustainability research, as well as the development of new methodologies.

(Hoque et al., 2019) Present a methodology for LCSA that includes all of the three mechanisms of the TBL of sustainability that has the ability to be used for examining the long-term performance of fuels from the extraction point to the usage point in transportation. The proposed Life Cycle Assessment framework incorporates methodologies such as Environmental Life-Cycle Assessment (ELCA), followed by

Life-Cycle Cost (LCC), and Social-Life Cycle Assessment (SLCA) methodologies to calculate the performance of environmental, economic, and social of alternative fuels. The framework goal is to identify the fields that need to be enhanced in order to improve the overall sustainability performance. A detailed foundation for alternative fuels is provided by the proposed framework, which takes into account regional variances in life cycle data relevant to alternative fuels. One of the frameworks distinguishing characteristics is its ability to withstand differences in natural resource availability and other challenges such as socio-economic and demographic shifts. The framework has been put through its paces by stimulating the production of canola-based biodiesel.

(Hoque et al., 2020) Used the LCSA model to examine the sustainability goals of many alternative sources of energy the road transportation, including ethanol, electricity, electricity, gasoline hybrid, and hydrogen. The framework used 11 TBL sustainability indicators and corresponding weights for assessing sustainability actions. Several performance indicators were developed depending on the region, following the failure of alternative energy sources to satisfy the sustainability requirement for the determined Key metrics. It is believed that the proposed framework is considered an effective solver method to the issue of interrelationships between the three pillars of sustainable development, which was a deficiency of the previous frameworks. The findings reveal that socially and environmentally sustainable power sources such as E55 ethanol-gasoline blend, electricity, electricity-E10 hybrid, and hydrogen are economically competitive against gasoline. Once renewable energy is used to generate hydrogen, it shows that hydrogen outperforms the environmental and social performance. However, the economic viability of hydrogen fuel is currently fuzzy and questionable at this point due to the huge price of hydrogen fuel cell vehicles (HFCVs)in the future. The proposed framework's resilience justifies its usage in a diverse variety of alternative fuel applications.

(Aboushaqrah et al., 2021b) Promoted a consolidated sustainability assessment by combining the hybrid life cycle sustainability assessment and multi-criteria decision-making, with the aim of advancing decision-making for choosing alternative fuel taxis. Starting by structuring and designing a multiregional hybrid life cycle sustainability assessment model to assess the macro-level sustainability effects of numerous vehicle types, including conventional gasoline, compressed natural gas, hybrid, and battery electric vehicles. Then, the use of the interval-valued neutrosophic sets-based analytic hierarchy approach is proposed to assess the life cycle framework findings to evaluate the importance of certain evaluation criteria. Finally, the TOPSIS methodology has been used in order to rank and assess sustainability performance. The findings showed that solar-powered BEVs have the most significant environmental impacts considering water consumption and land utilization exemption. In terms of human health impact, solar-powered BEVs beat out internal combustion vehicles (ICVs), yet ICVs deliver the highest indemnification and produce the most opportunities for employment. The outcomes from the ranking illustrated that Solar-powered BEVs are at the top of the list, then CNG vehicles will follow it only when we look at all the different indications. The suggested technique gives a realistic and life cycle-based decision-making approach, which will promote and emphasize successful policies for much more sustainable mobility.

2.5. Sustainability Indicators in Public Transportation

Originally, the term sustainability was applied to problems primarily linked to environmental difficulties; however, the concept has since been expanded to include concerns pertaining to energy, the economy, and various sectors of society. By incorporating sustainability into transportation planning, researchers have been working on establishing variables that can be described as metrics, indicators, or indices that represent various aspects of sustainability (Mitropoulos & Prevedouros, 2016;Nuri C. Onat et al., 2016).

(Kwok & Yeh, 2004) Developed a sustainable transport indicator utilizing theories of accessibility and geographic information systems. In this paper, researchers proposed a modal accessibility gap measurement, which would be determined by calculating the change between both the accessibility indices of different modes of transportation. Improving accessibility to opportunities such as the number of people, work opportunities, retail stores, and educational institutions provided by public and private transportation. When energy efficiency is taken into account, public transportation will provide more environmentally friendly transportation than private transportation. An increase in the accessibility gap may result in more long-term, sustainable growth in the long run. A comparison of the accessibility gap in Hong Kong in 1991 and 1996 was accomplished to assess whether or not the city's transportation growth has become more environmentally friendly over time. Furthermore, the study discussed how the accessibility gap indicator might be used to assess land-use and transportation-development strategies and scenarios in order to determine which ones are more ecologically friendly and thus more sustainable.

(Dobranskyte-Niskota et al., 2009) Used transport sustainability indicators to measure and analyze transport activities in the EU. A set of 55 transport sustainability indicators has been produced using international and regional transportation indicator programs. An innovative transport sustainability indicator system is designed and merged into further quantitative sustainability measuring the performance of transport activities. There are three analytical steps of quantitative sustainability. The first one is by using the “Dashboard of Sustainable practices” visual interaction tool and research methodology strategies to establish an aggregate SusTrans index. The second step is to rank and evaluate EU27 transport sustainability performance using the SusTrans index. Finally, the third step is to benchmark EU27 transport sustainability performance using the EEA TERM index.

(Joumard & Gudmundsson, 2010) Helped in developing strategies for integrating environmental considerations into transportation evaluation and decision-making processes. There is a primary goal of helping design coordinated approaches for improved environmental effect indicators drawing on current information and integrating these indicators into decision-making processes. Selection standards for indicators for the combined examination of impacts via accumulation or multi-criteria analysis are critical to achieving these goals. In other words, the authors are interested in figuring out how to quantify transportation's environmental impact, how measurements can be turned into operational metrics, how different metrics can be combined, and how data can be used in decision-making processes.

(Epa & Office of the Assistant Administrator, 2012) Mentioned that if indicators are chosen wisely, they will ensure that the advantages of achieving sustainability can be recognized confirmed and will facilitate the implementation of an adaptive management approach that reacts to changing circumstances. The following are viewpoints that could be taken into account while selecting indicators and how they will be perceived and interpreted:

1- Public Reporting: public reporting is not tied to any specific action; in other words, it is not a decision-related activity but rather assists the characterize the overall state of the environment. Economic, environmental, and social conditions should all be measured at a broad level by the appropriate sustainability indicators, which should be measured primarily at a national level as well.

2- Making Decision: Select major sustainability indicators that will be used to track specific results of the decision as well as being significant to the relevant stakeholders are necessary for the context of particular environmental impacts.

3- Research Planning: Environmental, economic, and social conditions will be investigated in research projects based on the significant indicators utilized in making decisions. Additions to sustainable indicator sets are sometimes unpredictable results of adjustments to the key indicators.

4- Program Analysis: It is vital to utilize systematic review indicators to assess the productivity and effectiveness of study activities to compare the deliverables and consequences with the resources and time involved.

(Mitropoulos & Prevedouros, 2016) Addressed that Sustainability Indicators should be incorporated into transportation planning due to the significant consequences on the environment, the society, and the economy that is related to the transportation system, as evidenced by numerous studies. Alternative fuels and vehicle power generation are two important advancements that are helping to improve the sustainability of transportation. Traditional planning ignores technological advances; as an example, consider the huge differences in performance between conventional, hybrid, and alternative-fuel autos and buses, among other factors. It is projected that the introduction of alternative fuel vehicles would have an impact on the regular transportation planning process since additional attributes will need to be considered when transportation decisions are made. The establishment of a sustainability framework will allow for the examination of the characteristics of transportation vehicles to be carried out more effectively. The indicators of sustainability discovered during the research are divided into five categories: the environment, energy, technology, the financial system, and the clients of the indicators.

(Litman, 2017) Present an investigation into the conceptualization of livable (Resilient) and sustainable transport as well as the development of indicators that are appropriate for policy analysis and decision-making. Sustainability, livability, and sustainable transportation are interpreted in numerous ways. The involvement of indicators in policy development and implementation is addressed in this study. Aspects to consider when selecting specific indicators are also discussed in detail. Additionally, the potential difficulties with conventional transportation planning indicators are recognized and addressed in detail. Finally, some examples of indicators and indicator sets are provided for consideration. In the end, the study outlined recommendations for indicators to be used in a specific circumstance.

(Mitropoulos et al., 2017) Developed an indicator set for analyzing the sustainability performance of chosen public transport systems based on the five components has been established, placed, and incorporated into the use of the sustainability framework, which strives to assist the society in meeting its demands in the ways that include what is necessary to minimize the environmental implications and energy consumption while increasing the economy, user and community satisfaction, and technological performance of the system, and other considerations. There are five aspects represented by the goals for managing transportation systems, which are the environment, technical performance, energy, economy, and users. All of these factors are reflected in the framework for transportation system management.

(Naganathan & Chong, 2017) Proposed SSTP matrices to solve the challenges of "intents" and "quantitative determination" by defining the related to sustainable indicators that are important to the procedures and organizations, then measuring the success of activities through the use of these indicators. From there, SSTP establishes the fundamentals for developing sustainability intentions and quantification approaches. It is possible to use these effectiveness measures to differentiate between the different states' transportation sustainability and, as a result, to help explain the gaps in reduced impacts between what is anticipated and what is actually achieved. SSTP can’t be considered as a scoring approach but rather a matrix that can be used to evaluate the long-term viability of transportation policy and infrastructure.

(Karjalainen & Juhola, 2019) Used the indicator-based method to develop the PTSIL, which is the Public Transportation Sustainability Indicator list that involves the integration of environmental, social, and economic components and consideration of important facets connected to the government and the urban design within the planning and decision-making analyses. This project develops a novel evaluation approach for traffic plans and policies that is both extensive and comprehensible for those engaged in the development and policy-making fields beyond its own designated use. According to the findings from this study, PTSIL can be used in public transit decision-making and policy while also emphasizing the applicability and flexibility of the tool. PTSIL developed to be self-sufficient of pre-existing local circumstances and records connectivity problems and can also be used across both external assessments and internal processes within the public transport sector. It can also be used to re-evaluate, analyze, and establish policies and procedures within core operations inside the public transportation sector.

(Naganathan et al., 2020) Justify the research and development areas utilized by various transportation organizations and also the impact of the three pillars on the creation of sustainable indicators, in terms of how indicators are chosen and clustered, and calculate the statistically significant association between indicators and the actual variable , such as citizenry and GDP. The purpose of this quality standard is to assess the state's and its transportation organizations' sustainable activities by examining their environmental, social, and economic policies. A framework for sustainable transportation is laid out in the article, which investigates the relationship between many sustainable metrics. When additional data become accessible in the future, this framework might be expanded to include more incorporating sustainability indicators.

2.6. Data Analytics and Visualization Tools

There was a massive rise in the amount of data collected and exchanged by corporations, public agencies, a wide range of commercial and non-profit sectors, and scientific studies during the current years (Agarwal & Dhar, 2014). The need for Big Data analysis has recently piqued the interest of both academics and practitioners because of its potential to give better and faster judgments. Data Analytics is a popular strategy that many firms are utilizing to extract value from their data. Organizations and corporations use insights as a way to increase business performance, develop new income prospects, and gain a dominant market position over their competitors (Sivarajah et al., 2017). Dashboards are part of data analytics and can promote accountability and transparency, but achieving these benefits is difficult and risky. With the help of cases and literature, designers and users may better grasp how dashboards create value. Uncertainty of the results and enforcing a predefined position are among the main challenges of creating dashboards. These issues can lead to misunderstandings in the outcomes, generating poor decisions and a lack of transparency. Consumer interaction, data interpretation, governance, and institutional frameworks must be supported by mechanisms that work in concert with dashboards to make it more effective and deliver better understanding (Matheus et al., 2020).

(Kurkcu et al., 2017) Established a web-based platform that is simple to use while also extremely powerful in getting, storing, computation, and visualizing bus trajectory data. The web-based platform that has been established can be considered a user-friendly platform because of the capability of accessing the database and requesting the data without the need for external support or delays that might affect the work progress. Furthermore, the tool allows the user to perform a sequence of data analysis and operational visualization processes, proving the prospects of a web-based platform for future developments. The study used computerized bus tracking and technology that present the recent status of the bus to provide data-driven assessments for evaluating potential areas for improvement and evaluating existing transport systems. When this system is combined with Geographical Information Systems (GIS) technologies, the data collected from the proposed application can be used for both online and offline performance assessments of transit operations. Many users will benefit from this computerized tool since it enables them to integrate current information sources, improve efficiency, and provide them with performance indicators and up-to-date statistics.

(Kalamaras et al., 2018) Introduced a visual analytics platform that enables the examination of the past data as well as the forecasting of prospective traffic via a standardized interactive interface. The platform is supported by analytic data techniques such as roadway behavior visualization and segmentation, incident identification, and congestion prediction. These techniques enable the assessment of standard cognitive features among the roads, the visual recognition of unusual occurrences, the hypothesis analysis, and the predicting of traffic flow in the context of completely hypothetical human-induced catastrophes. The predictive algorithms' reliability is validated by benchmarking, and the suggested toolkit's utility in supporting policymaking is illustrated through a range of application scenarios involving actual congestion and accident sets of data.

(Hollberg et al., 2021) Provide a study on visualization tools, providing a bunch of visualization possibilities, and specifying the best use of each visual to simplify the life cycle assessment data and to demonstrate the critical nature of using Visualization to convey the value of interpretations and decision making. Despite the necessity of including life cycle considerations in the design process and its utility in enhancing non-expert decision-making, multiple studies have shown that stakeholders such as policymakers and decision-makers find it challenging to grasp LCA data. The study developed a well-defined state-of-the-art evaluation in visualizing LCA results and examining recent and potential future changes as the average use of visualization tools for conveying and analyzing data and details. Incorporating those visualizations into environment design, collaborating dashboards, and virtual reality will demonstrate a significant commitment designed for simplifying the perception of LCA findings and integrated strategy methods, as well as placing the foundation for future development. The study's summary and recommendations lay the groundwork for the future expansion of easily understood and design-integrated life cycle assessment data visualizations for improved decision-making.

2.7. Summary of Gaps in The Literature Review

A complete assessment of the literature was carried out in order to compare the extent and the results of numerous research exploring the environmental, social, and economic consequences of alternative fuel buses. The main areas that have been covered in the literature review are the following: Alternative Fuel buses, Decision support systems, public transportation, Life Cost Cycle Sustainability indicators, life cycle sustainability assessment, and Life cycle assessment. According to the analysis of the literature review, there are numerous models, approaches, and frameworks for evaluating the sustainability of the public transportation sector, but there was no research shows or addressing the use of the visualization tool to demonstrate and simplify the LCSA model of AFBs in Qatar or another region and to show how data visualization helps in decision making. Lack of applications that can assist in evaluating and asses the big data and help in providing accurate and fast decisions. A lack of studies considered data visualization platforms as an optimization approach.

CHAPTER 3: METHODS AND DATA

This study aims to provide an LCSA data visualization platform using Power BI software to offer a novel decision-making platform based on the product life cycle. The methodology of this study will be divided into two stages. The first stage will present all of the three main dimensions of sustainability which are environmental, social, and economic impacts, based on the LCSA approach, which is related to alternative fuel buses that could be used in Qatar. The second step is the data visualization platform. It will provide numerous dashboards reflecting many representations that will enable decision-makers to narrow their selections based on the bus type, manufacturing nation, and life cycle cost for each bus type, among other criteria.

The figure below will show the two stages and the main outcomes of each stage; then, we will provide more information regarding each stage.

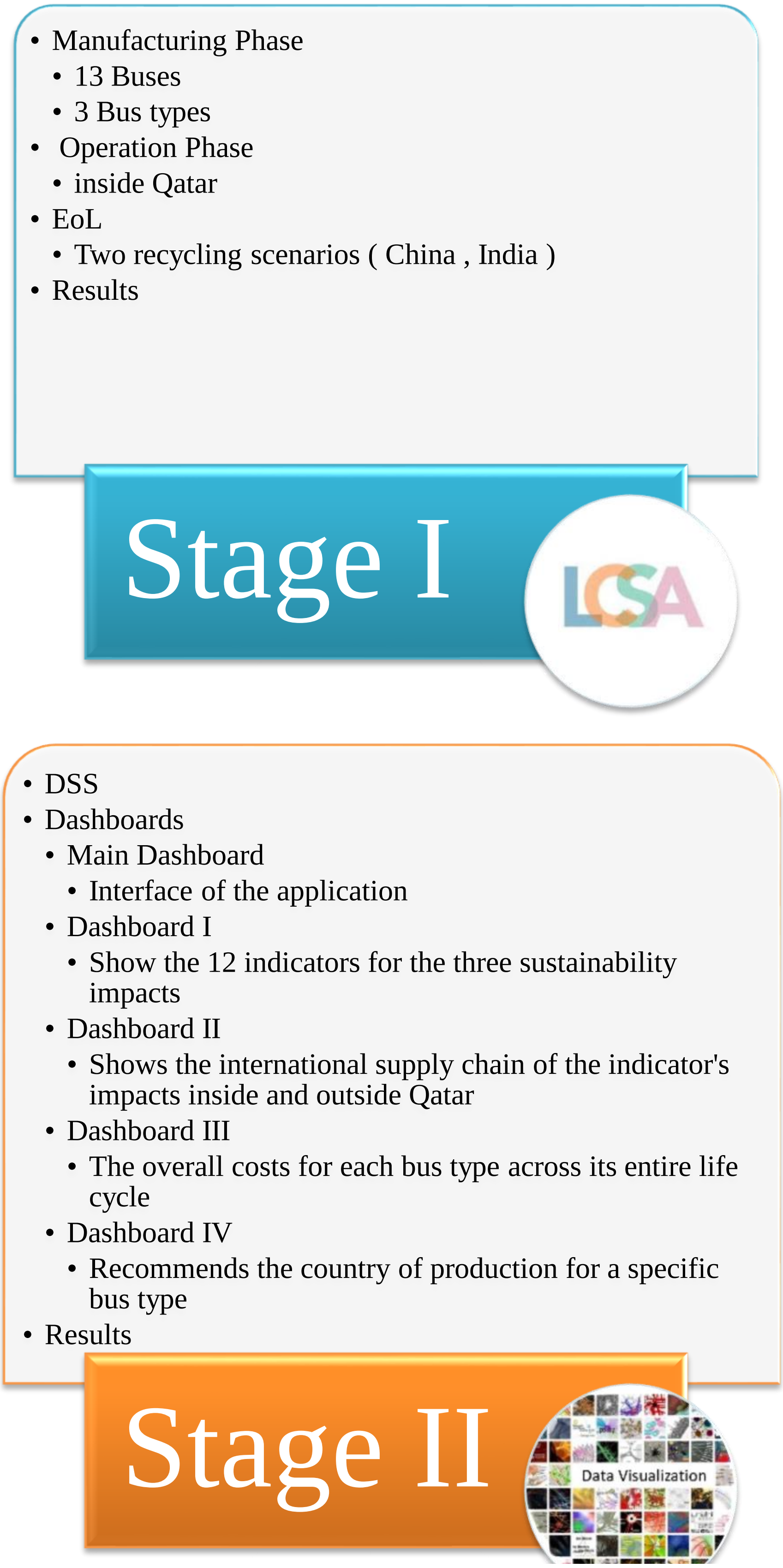


Figure 8 Stage I and Stage II methodology

3.1. Stage I (LCSA)

The data for this analysis was derived from the following study: " Rethinking Sustainable Mobility and Legacy Strategies Towards FIFA World Cup Qatar 2022TM: A Global, Hybrid Life Cycle Sustainability Assessment of Alternative Fuel Buses".

3.1.1. The LCSA Model

The LCSA model was developed and introduced by (J. B. Guinée et al., 2011). The goal of using the LCSA model is to integrate the three components into a single holistic assessment, and this is an indication of extending the metrics to include social and economic impacts as well as environmental impacts. LCSA will be defined by establishing the analysis's objective and scope and identifying the system's boundary (i.e., from the cradle to the grave, including global supply chains, etc.). The main factors taken into consideration in the research were the following:

- A comparison of three types of buses was carried out, including those operating on CNG, EB, and Diesel.
    - Diesel: It has long been the preferred fuel for buses in many regions of the world.
    - EB: Although EBs are a recent development technology, they have been extensively adopted and shown to be effective.
    - CNG: Buses that run on compressed natural gas have lower tailpipe emissions. CNG buses are the most common alternative fuel bus technology option due to their lower life cycle costs.
- A total of thirteen sustainability indicators were used to analyze and compare the three bus models; each indicator represents one of the three pillars of sustainable development (environmental, economic, and social impacts).
    - The indicators of triple-bottom-line life cycle sustainability addressed in

this study were chosen depending on the availability of relevant data and the flexibility with which the data could be integrated.

- Using the thirteen sustainability indicators, the three bus types are compared and contrasted with one another, and the three sustainable impacts are linked to specific indicators, as shown below.
    - Starting with the environmental impacts, the indicators that have been considered in this study include the 1. global warming potential (GWP), 2. particulate matter formation (PMF), 3. photochemical ozone generation (POF), 4. land use, 5. Water Consumption (W.C.), 6. Water withdrawal (W.W.).
    - The indicators used to illustrate the economic impact, 1. Operating surplus, 2. gross domestic product (GDP), 3. life cycle cost (LCC).
    - Finally, four indicators describe the social aspects, which are 1. Human Health (H.H.), 2. Tax 3. Compensation, 4. Employment.

Fig . 9 shows each impact as well as the indications that were evaluated for each impact.

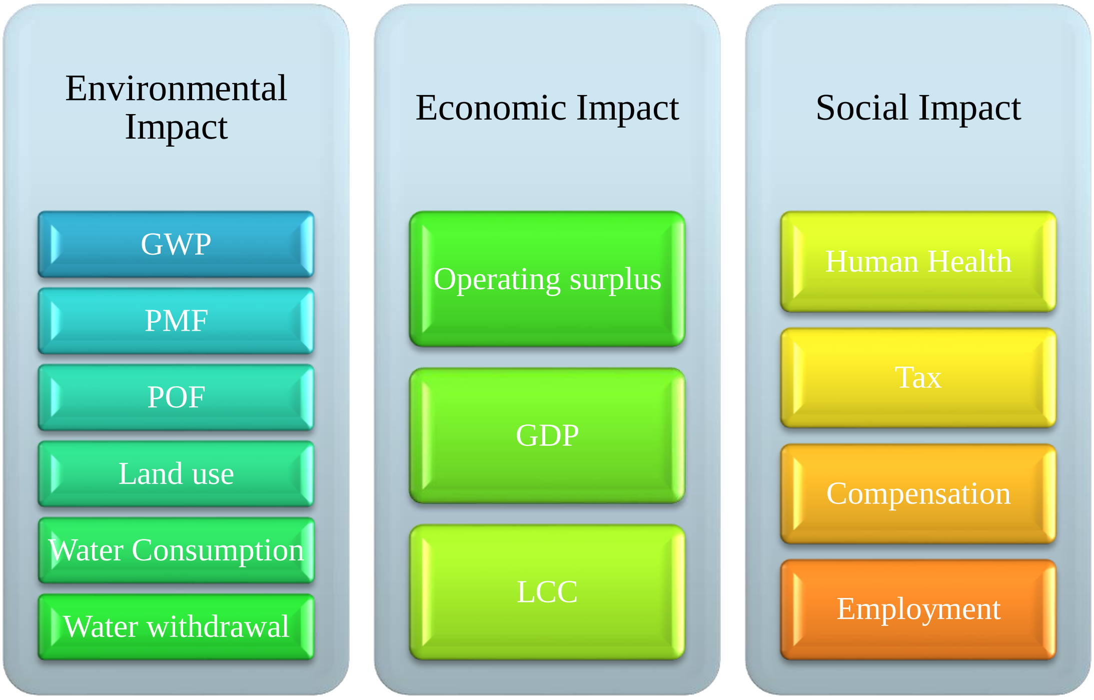


Figure 9 The System Sustainable impacts and indicators

To clarify the units used in the research, The functional unit utilized is one Km of the trips for the bus; more specifically, the sustainability impacts are computed and reported in Kg / Km of a trip by bus.

The calculations took into account a number of different phases that were addressed in the context of the investigation. Each bus type is intended to be considered through three phases, which are as follows: manufacturing, operations, and the final phase, which is the end-of-life (EoL). For each phase, there are specific impacts, represented in Fig 10.

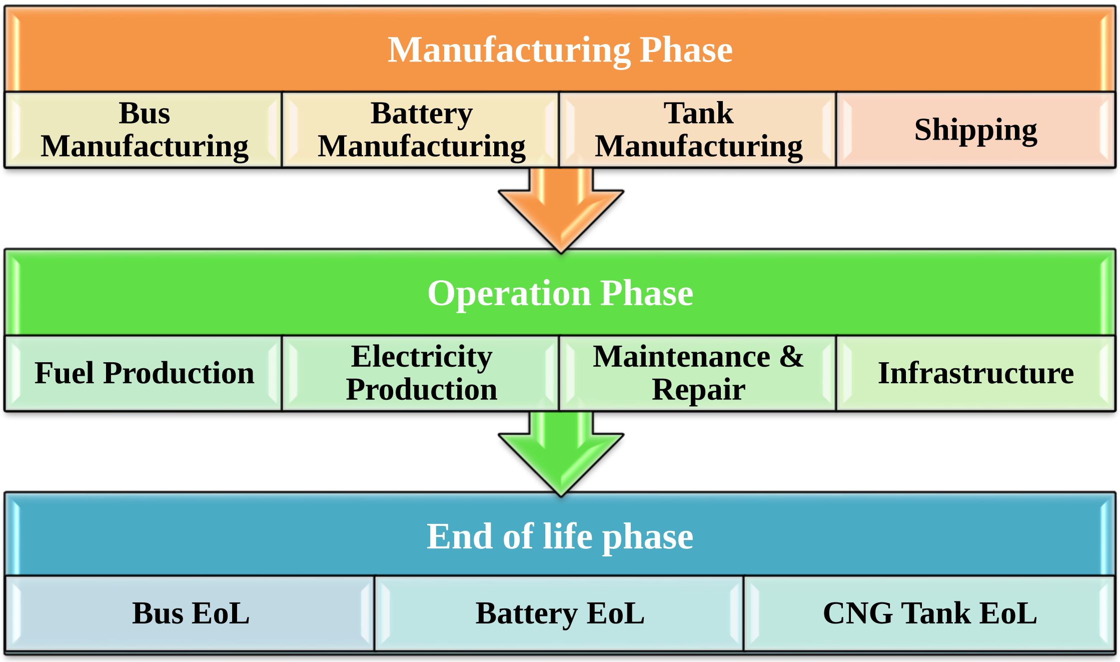


Figure 10 AFB's phases and subphases

By utilizing a global MRIO database, a hybrid MRIO-based LCSA model has been developed that can be used to examine the macro-level sustainability consequences of AFBs. The method of the LCSA and MRIO models are combined to maximize the benefits of both process-based-LCSA and input-output-based LCSA) while minimizing the disadvantages of each technique. The P-LCA model will include all of the life cycle unit processes, whereas the IO-LCSA model will estimate the sustainability impacts across the global supply chain. Using the MRIO database from EXIOBASES 3.4, an industry-by-industry input-output table has been compiled based on pricing, which could be used to support financial transactions throughout the world. After developing the MRIO model, it is possible to compute the three impacts representing the environmental, economic, and social impacts by multiplying the output of each field by the impact category per economic output.

3.1.2. Scope of The Analysis

As stated before, the study aims to examine the environmental, social, and economic impacts using Guinee et al.'s LCSA framework (2011). The study contrasted three bus types: CNG, EB, and diesel (DB). Indicators of sustainability were used to compare the three bus models associated with environmental, economic, and social impacts.

In Fig. 11, the components of the system are presented in greater depth, detailing the various phases that are included in the context of the research. The framework structure is defined in three phases: manufacturing, operating, and end of life (EoL).

During the manufacturing phase, information about the bus manufacturing process is displayed, as well as the additional parts that must be incorporated for the various bus classifications. When it comes to manufacturing buses, the bus manufacturing stage will typically provide an overview of the results of producing buses based on each indicator and each bus category linked with the three specified types and considering the seven countries that manufacture the buses (China, Turkey, India, Germany, Poland Sweden, Spain). Based on an examination of the bus manufacturing stage, it appears that there are additional parts to be manufactured for the EB and CNG buses. To be more specific, this phase includes the fabrication of batteries for electric buses (EBs), as well as the production of tanks for compressed natural gas (CNG) buses. It was necessary to take into account the shipping stage in order to complete the manufacturing phase.

The second step is the operating phase, which examines the electricity and fuel production (WTT and TTW), as well as the maintenance and repair of buses and other vehicles (M&R). Finally, there's the infrastructure of EB's charging station to think about.

The third and last phase is the end of life (EoL) phase that has been included in this framework in order to estimate the impact of recycling each of the three bus types under two scenarios: recycling in Chania, and recycling in India, respectively.

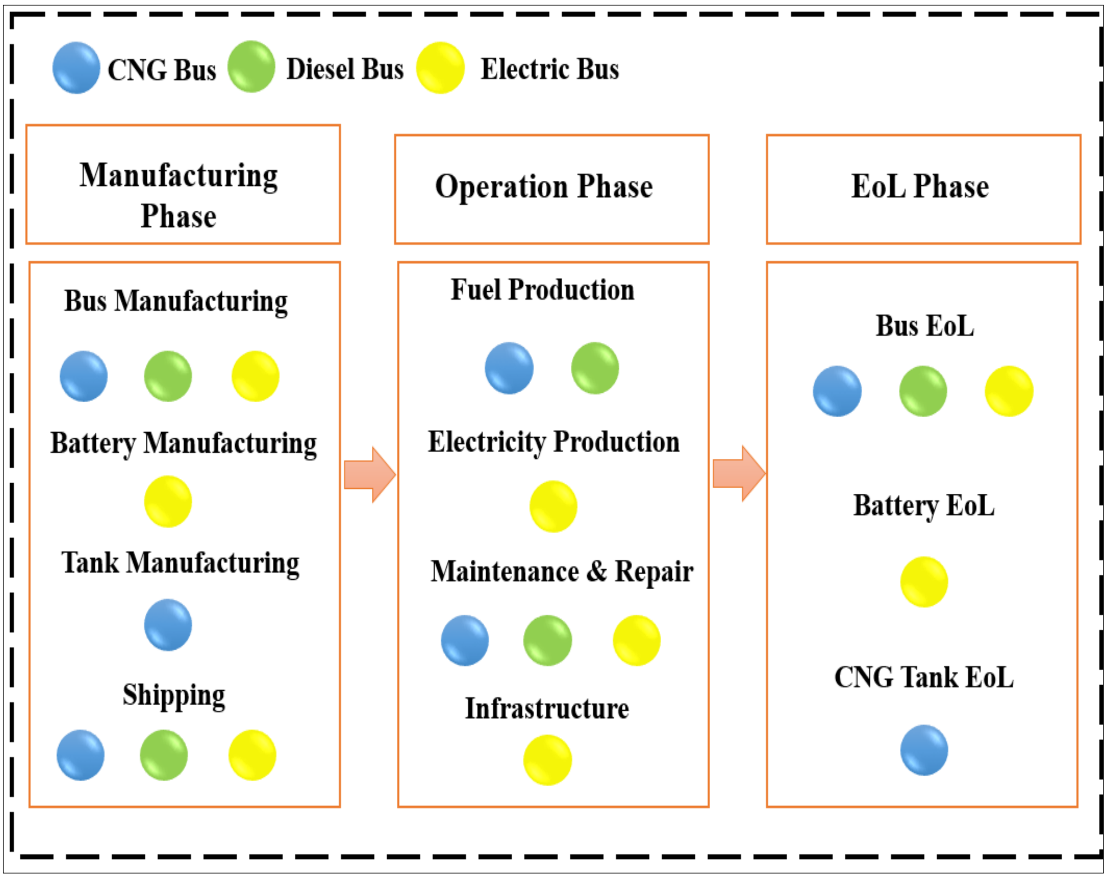
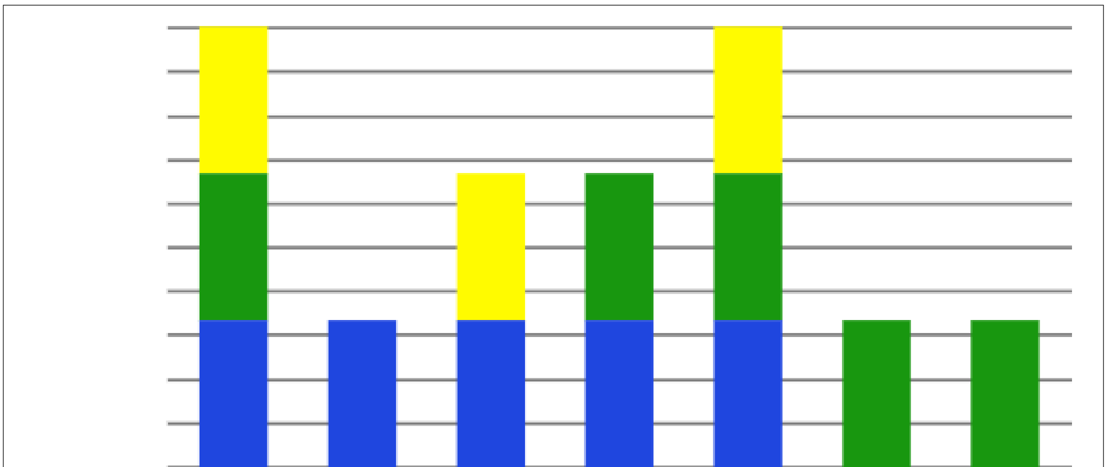


Figure 11 The system boundary for LCSA of alternative buses



	China	India	Poland	Sweden	Turkey	Germany	Spain
CNG	1	1	1	1	1	0	0
Diesel	1	0	0	1	1	1	1
EB	1	0	1	0	1	0	0

Figure 12 EB-CNG-DB-Manufacturing countries

This study assesses a total of thirteen types of buses, as shown in Fig.12. Five types of compressed natural gas (CNG) shipped from China, Turkey, Sweden, Poland, and India. Four EB types are from China, Germany, Spain, and Sweden. Finally, four DB types from China, Poland, and two types from Turkey.

3.1.3. Life-Cycle Inventory

Life cycle inventory (LCI) is a second step or part of the LCA, which we can consider a complementary part of the LCA. It is a method of quantifying the input and the output of the system. Also, it can be defined as the summation of all elementary flows occurring within a production system as a whole (M. Abraham, 2017; Impact, 2019; Klemeš, 2015). There are two major types of analysis taken into consideration in this study, which are as follows: 1- input-output analysis; and 2- MRIO analysis. The goal is to evaluate the environmental impacts of production demand and consumption while considering the international value chain. The calculations will be demonstrated in the following chapter, which will go into greater detail in presenting the calculations for the three phases of manufacturing, operation, and end-of-life considerations.

3.1.4. Calculations and Equations

Each phase's results have been calculated based on the following equations based on the above methods and specifications.

3.1.4.1. Manufacturing Phase

The manufacturing phase was collected to satisfy certain bus specifications, considering the bus length, the bus lifetime, and the bus's annual mileage. The bus length was specified as 12-meter long, with ten years of lifetime and a yearly mileage of around 146,000 Km. Many considerations and assumptions have been highlighted to make sure that the results will be comprehensive and accurate, as the following points represent the main points that have been considered while calculating the results:

- The market of the bus price was considered for the model year 2015, and it was derived by taking inflation rates into account.

- Assume that production costs are 80% of market costs.
- Assume that the price of the EB battery and CNG tank is considered to be 10% of the total cost of production.
- Consider the remaining bus component is 90 percent that of the production price.

According to the MRIO model, the final calculation for bus manufacture was obtained and given as the multiplication of the total price of the bus by the impact factor.

*Bus Manufacturing = Total bus price * Impact factor* Eq. (1)

For the shipping phase, the shipping price has been calculated considering three main elements, which are:

1. The distance between the countries that manufacture and ship the buses to Qatar.
2. The weight of the buses.
3. The price by Euro for each Km.

3.1.4.2. Operation Phase

Bus operation is represented by "well-to-wheel" (WTW) as it is a term that encompasses both upstream and tailpipe emissions. WTW covers two sup-phases, "well-to-tank" WTT and "tank-to-wheels" TTW. Additionally, it covers all costs associated with maintenance, repairing, and charging infrastructures of buses during their service life.

WTT represents the indirect or upstream emissions caused by extraction, production, and fuel delivery.

To calculate the total WTT impact, a straightforward multiplication process can be applied by multiplying the fuel efficiency by the product of adding all impact factors.

The fuel efficiency values are calculated based on the fuel required to travel one kilometer for each alternative bus. The impact factors are represented by three main components inside Qatar fuel supply, inside Qatar sectors, and outside Qatar sectors.

TTW represents the direct or tailpipe emissions caused by the bus fuel combustion.

The TTW impact will be calculated for DB and CNG only as the EB tailpipe emission is zero. The calculation will be a process of multiplying the fuel efficiency of DB and CNG buses with the tailpipe emission factors.

3.1.4.3. End of Life Phase

EoL phase, in general, can be defined as the stage at which the item no more meets the needs of the original owner or first consumer (Rose et al., 1999). The current focus recently emphasizes the end-of-life plans and approaches for the objects and products that maximize the value of the products, also known as the reusing approach. After the product or the item is used and abandoned, an end-of-life plan outlines the method of handling the object once it has been disposed of away (Bauer et al., 2017). It was determined that there would be two recycling scenarios, one for China and one for India, and the recycling process will take place in one of these countries. Among the components that will be recycled are the bus body, EB batteries, and the tank of CNG buses. The computation of the EoL phase is a technique that involves subtracting the effects of the manufacturing process from the impacts of the recycling process.

3.1.4.4. Data Calculations Summary

Following the analysis of each step and the explanation of the data calculation method, Table 3 will provide all of the calculations associated with the phases in order to provide a summary of them.

Table 3 Summarize the calculations for each phase

Phase	Calculations summary
Bus manufacturing	Multiplication of the total price of the bus by the impact factor
Bus operation Well to Tank (WTT)	Multiplying the fuel efficiency by the product of adding all impact factors
Bus operation Tank to Wheel (TTW)	Multiplying the fuel efficiency of DB and CNG buses with the tailpipe emission factors
End of life	Subtracting the effects of the manufacturing process from the impacts of the recycling process

3.1.5. Results

According to the results presented, there will be 26 outcomes for 13 indicators in total. Those 26 outcomes were selected and executed in the data visualization stage, which resulted in creating the LCSA data visualization platform. The outcomes results can be found in Appendix Table 33.

3.2. Stage II (Data visualization)

Stage II represents the data visualization work completed in the study. As the data from the LCSA stage have been imported into the software, dashboards have been created by visualizing the data and structuring it to illustrate the results clearly. In the end, full data analysis and results were discussed to show the outcomes and recommendations.

3.2.1. Data Visualization Scope of Analysis

The purpose of this study is to develop an LCSA data visualization platform utilizing Power BI software in order to give a novel decision-making platform based on the product life cycle. When conducting this research, the LCSA approach is considered to be used to go through the complete life cycle of the alternative fuel buses that were chosen, starting with the manufacturing phase and continuing with the end-of-life phase of the buses. As a result, a full dashboard has been constructed in order to represent all of the results visually.

Each constructed dashboard was structured to convey a specific phase and provide clear outcomes that will help the decision-makers develop their decisions, as shown in Table 4.

Table 4 Dashboard use

Type of the dashboard	Dashboard use
Main Dashboard	The interface of the application
Dashboard I	Show the 12 indicators for the three sustainability impacts
Dashboard II	Shows the international supply chain of the indicator's impacts inside and outside Qatar
Dashboard III	The overall costs for each bus type across its entire life cycle
Dashboard IV	Recommends the country of production for a specific bus type

3.2.2. How the Dashboards Function

The dashboards have been classified and identified for specific uses. Ultimately, a total of four dashboards were created. Each dashboard represented a distinct scenario and highlighted key results to assist decision-makers in understanding and providing the necessary judgments quickly and efficiently, without the need for additional time or resources. All dashboards have been linked to the main dashboard as specific titles that describe the key contribution of each dashboard, allowing the user to navigate to the appropriate title to show and interact with the data with only a single click.

3.2.3. Data Visualization Methodology

This research will use a holistic and novel research method by combining multiple quantitative sustainability assessments and data science methods to adopt sustainability performance assessment and management of alternative fuel buses to be used in Qatar as an importing country. The methodology of the study is presented in the steps below:

1. Preparing and cleaning the data that was taken (data collection stage).

2. Develop a life cycle sustainable assessment (LCSA) model for alternative fuel buses in estimating their social, economic, and environmental implications.
3. Establish multiple visualization platforms to visualize the data in accordance with the provided indicators.
4. Propose a business intelligence model that would assist managers in making decisions and providing sustainability policies for Qatar's public transportation system.

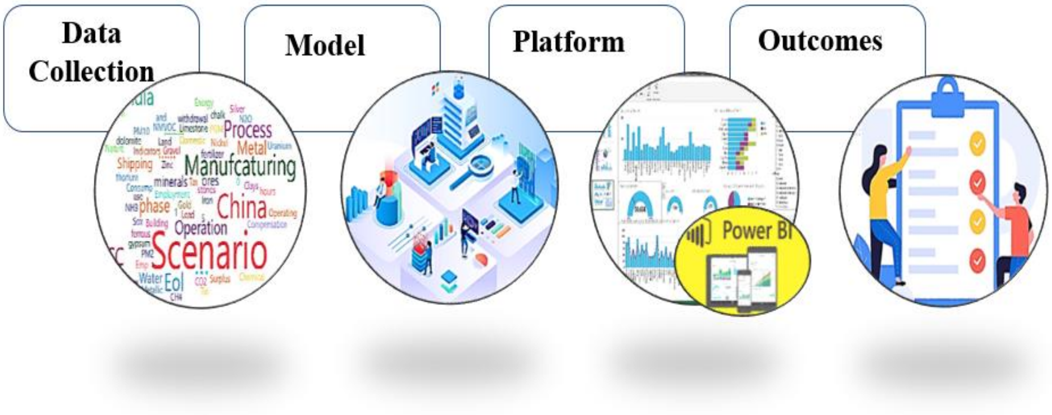


Figure 13 The study methodology

3.2.4. Decision Support System (DSS)

The study approach was divided into three sections:

1. Identifying the main objectives for LCSA during the design phase.
2. Collecting and analyzing the visualization options from the LCSA software tools and the scholarly literature related to the topic.
3. Specifying the categories to classify numerous visualization possibilities that were discovered during the review.

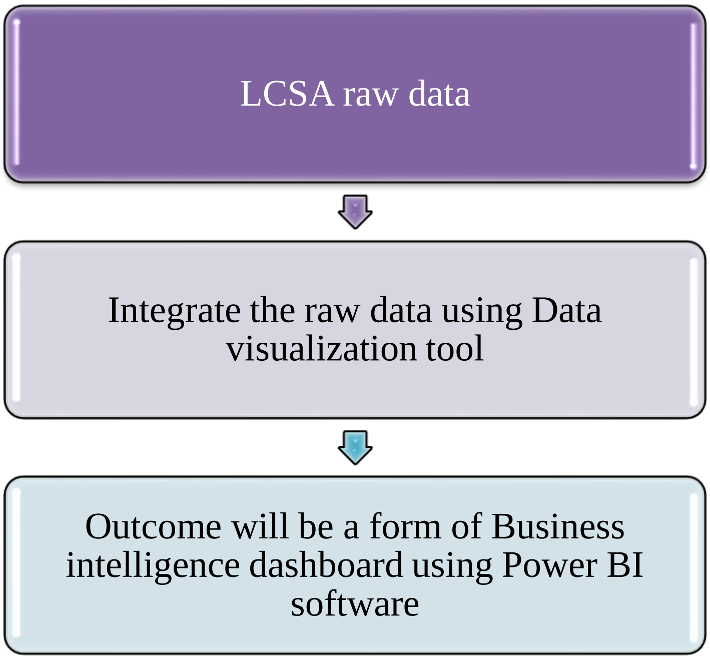


Figure 14 The study approach

CHAPTER 4: RESULTS AND DISCUSSIONS

According to the research (Hollberg et al., 2021), one of the obstacles in the use of life cycle assessments is the difficulty in understanding and explaining the results. Even though earlier research suggests that including life cycle concerns into the design process may help non-experts make better decisions, but still many stakeholders, such as policymakers and decision-makers, are unable to comprehend the results of life cycle evaluations. It is demonstrated that the use of visualization on the LCA results can be beneficial in demonstrating the significance of interpretations and decision-making.

The LCSA approach was applied in this research to go through the entire life cycle of the selected alternative fuel buses, beginning with the manufacturing phase and concluding with the end-of-life phase. Therefore, a dashboard has been created to visualize all of the results. There will be four dashboard classifications that will visualize and analyze specific information related to the three sustainability pillars based on the thirteen sustainability indicators.

4.1. Main Dashboard

Fig. 15 represents the primary dashboard, which is the interface of our application. It was created to assist in reaching other dashboards provided for each indicator and to reflect the analysis that will be valuable to decision-makers. This dashboard has all of the taps that will display each indication, the results of the life cycle cost, and statistics linked to the indicators associated with alternative buses and the country that manufactures them. The user is directed to another dashboard that displays the relevant statistics by clicking once on any of the taps available in the dashboard.

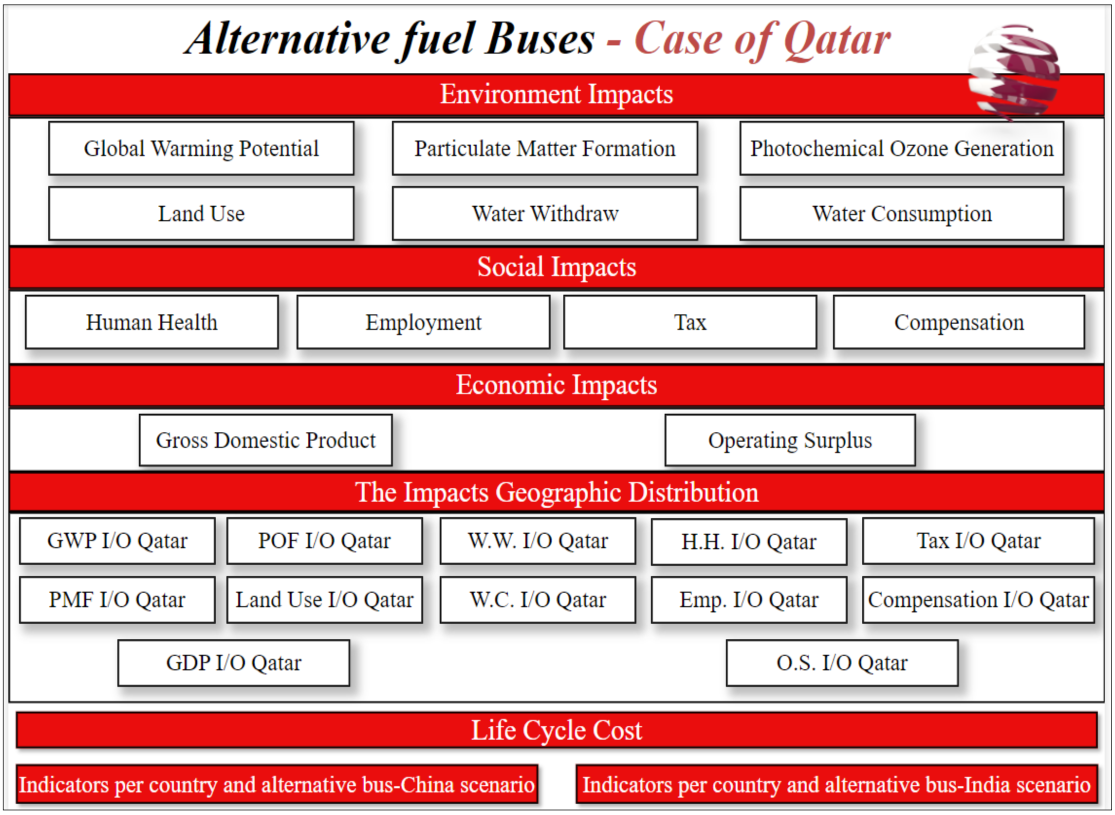


Figure 15 Main Dashboard

The main dashboard or interface has also been intended to be utilized as a mobile application to assist decision-makers in quickly and efficiently obtaining the information they require from their mobile devices. Fig. 15 shows the interface page as it will appear on the mobile device using the mobile application.

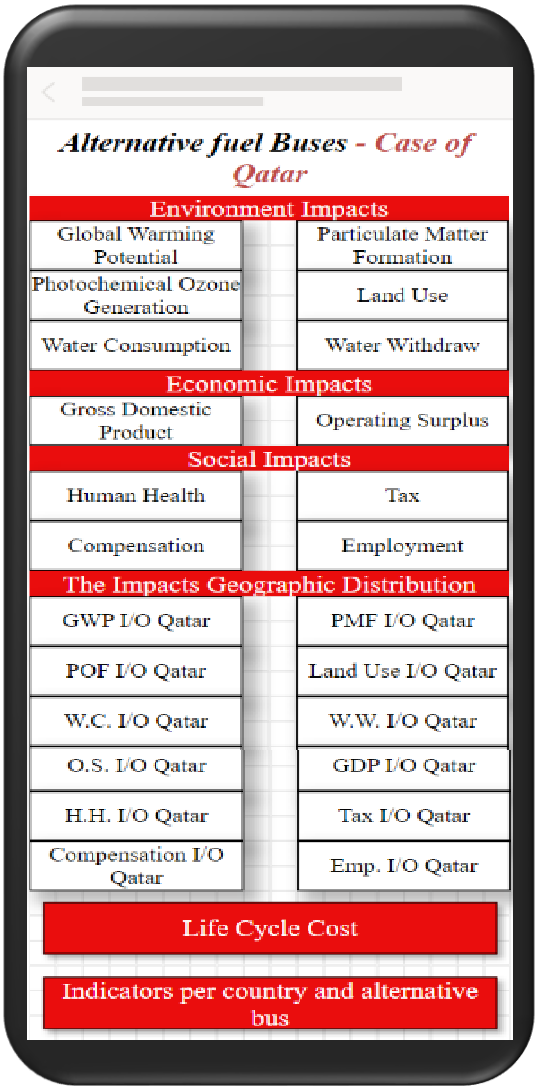


Figure 16 Main Dashboard-Mobile application

Four types of dashboards are linked to the main dashboard as the following:

1. Dashboard (I) presents the results of the 12 indicators impacts of the three sustainability pillars.
2. Dashboard (II) highlights the international supply chain of the indicators' impacts inside and outside Qatar.
3. Dashboard (III) shows the Life cycle cost results and compares them for all three bus types.

4. Dashboard (IV) Shows all indicators with the total value.

In the next sections, we'll go over all of the dashboards in great depth. Each one will have its own analysis of the data.

4.2. Dashboard (I)

Dashboard (I) represents the 12 indicators for the three sustainability impacts as shown in Fig. (17 – 28), which will show the data analysis based on the phases from manufacturing to operation, ending with the recycling phase. This dashboard will allow users to specify the results they need based on two filter options: the alternative fuel bus type and the countries. With the dashboard's alternative fuel buses visual, users can select between CNG, DB, or EB to see the results; they can even select all three to compare the findings. Using the visual that represents the countries will help in specifying each type of AFB can be identified by its country of origin.

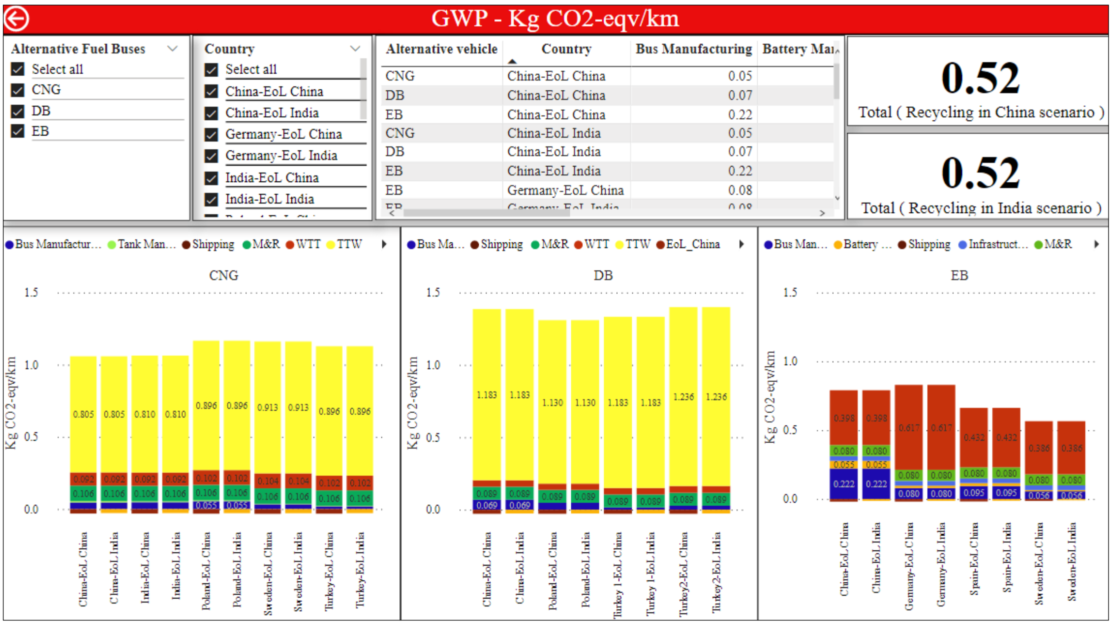


Figure 17 GWP-Kg CO2-eqv/km

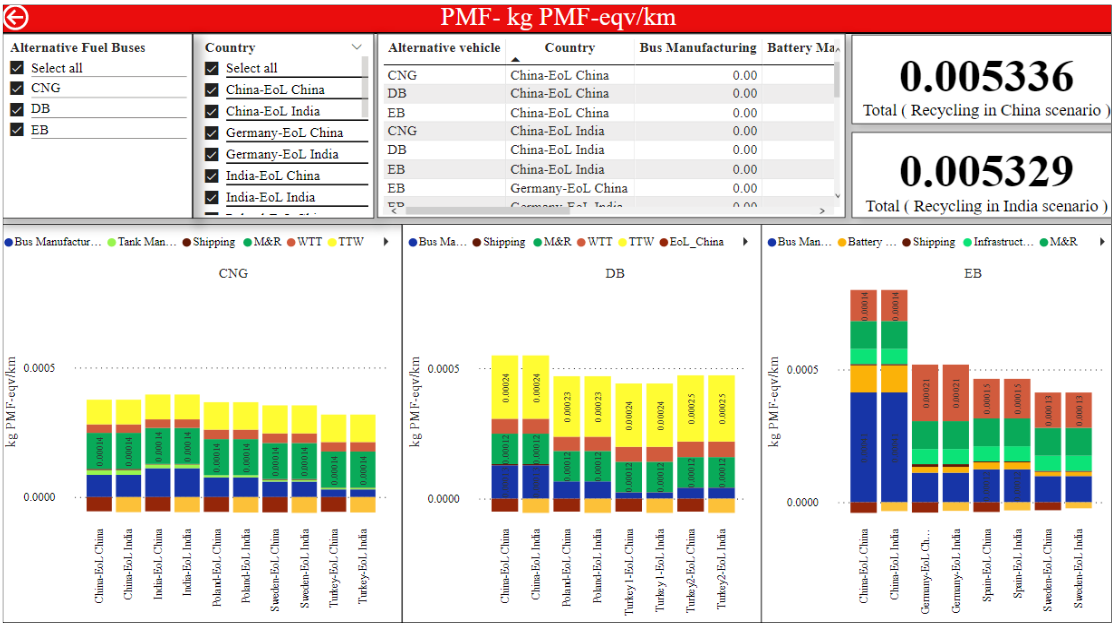


Figure 18 PMF- Kg PMF-eqv/km

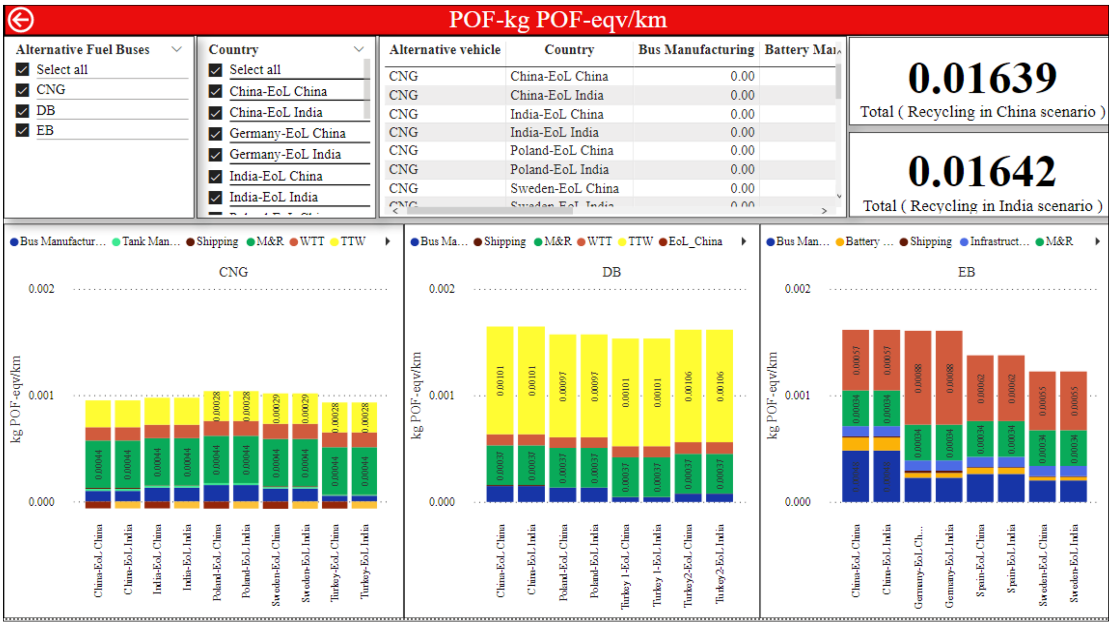


Figure 19 POF- Kg POF-eqv/km

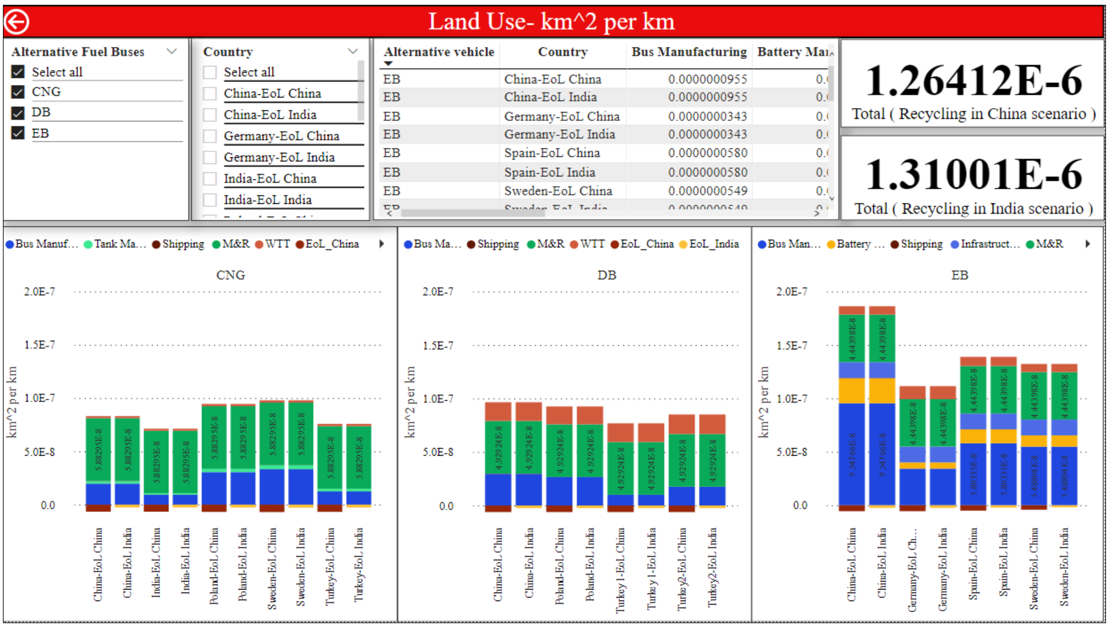


Figure 20 Land Use- Km^2per Km

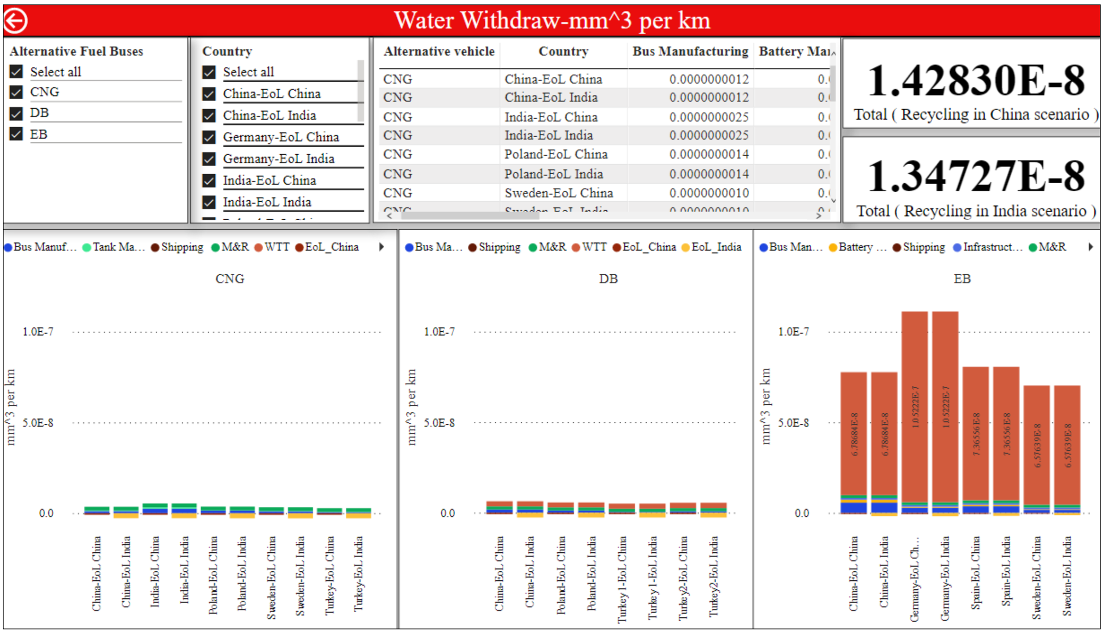


Figure 21 Water Withdraw- mm^3per km

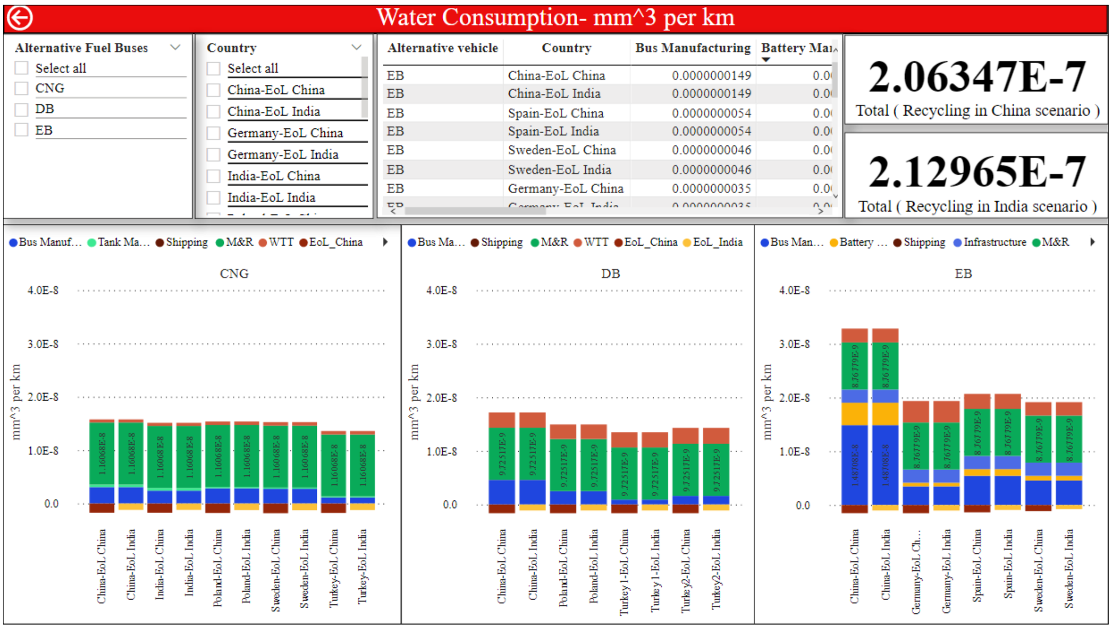


Figure 22 Water Consumption- mm^3 per km

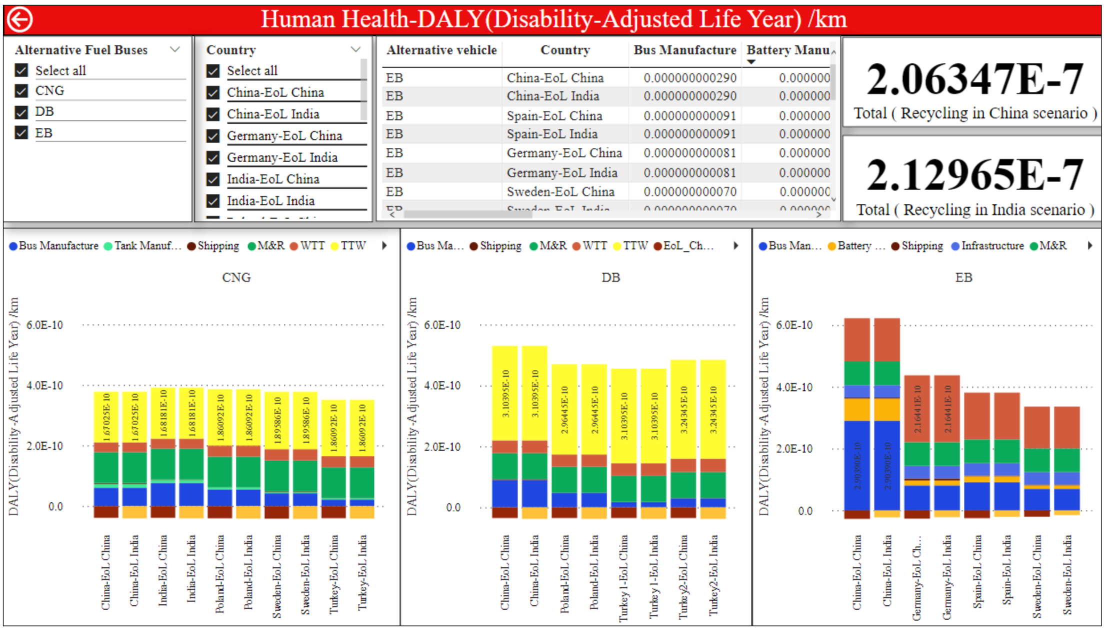


Figure 23 Human Health- DALY(Disability-Adjusted Life Year) /km

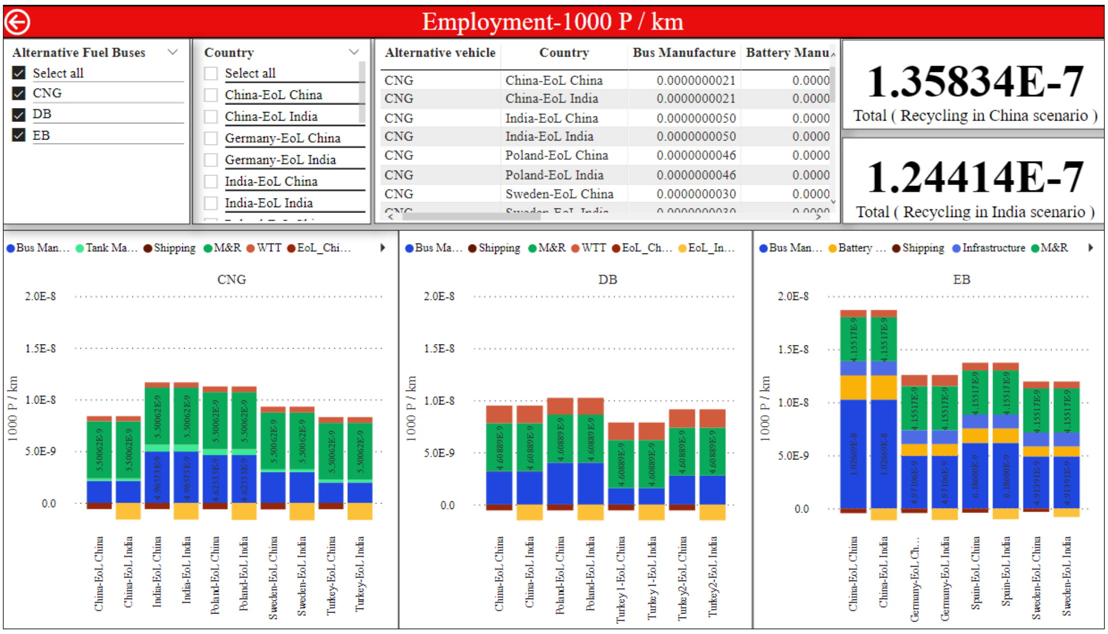


Figure 24 Employment- 1000 P / km

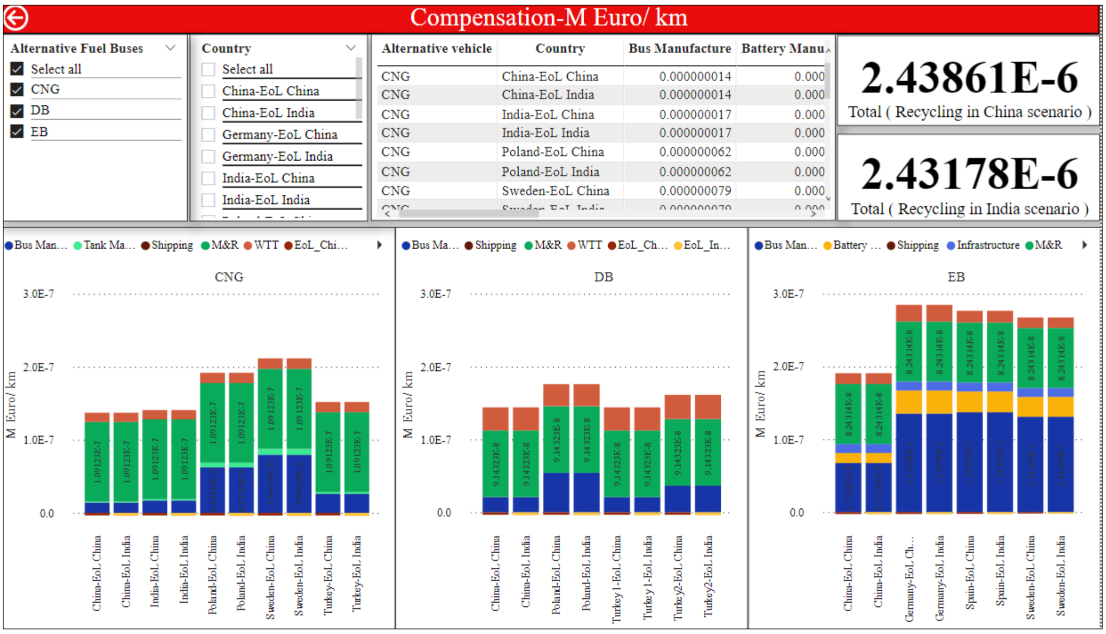


Figure 25 Compensation- M Euro/ km

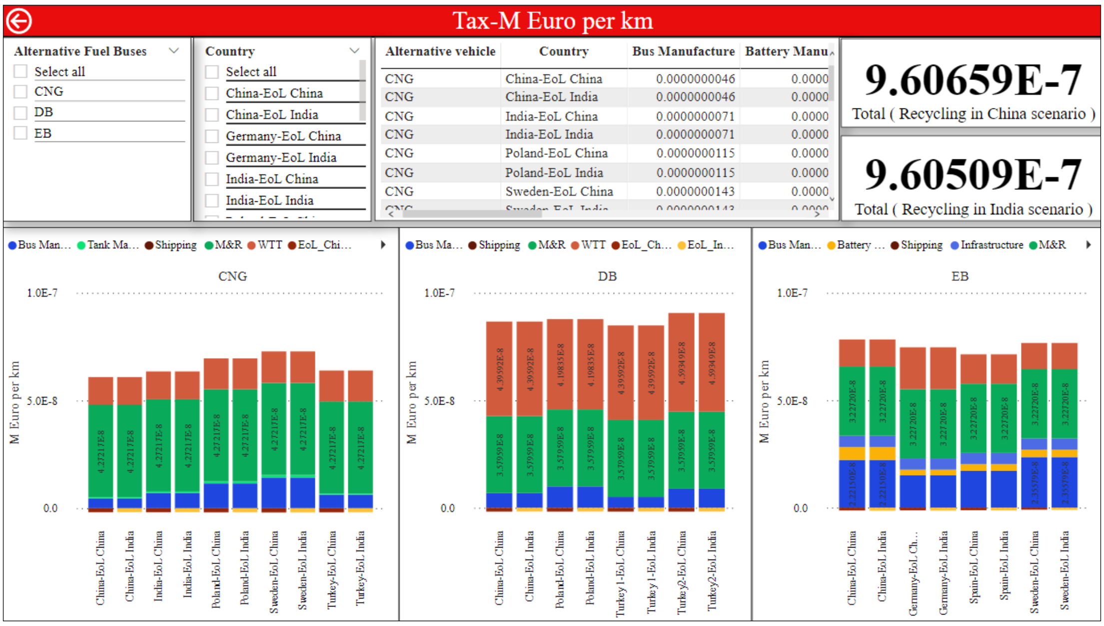


Figure 26 Tax- M Euro per km

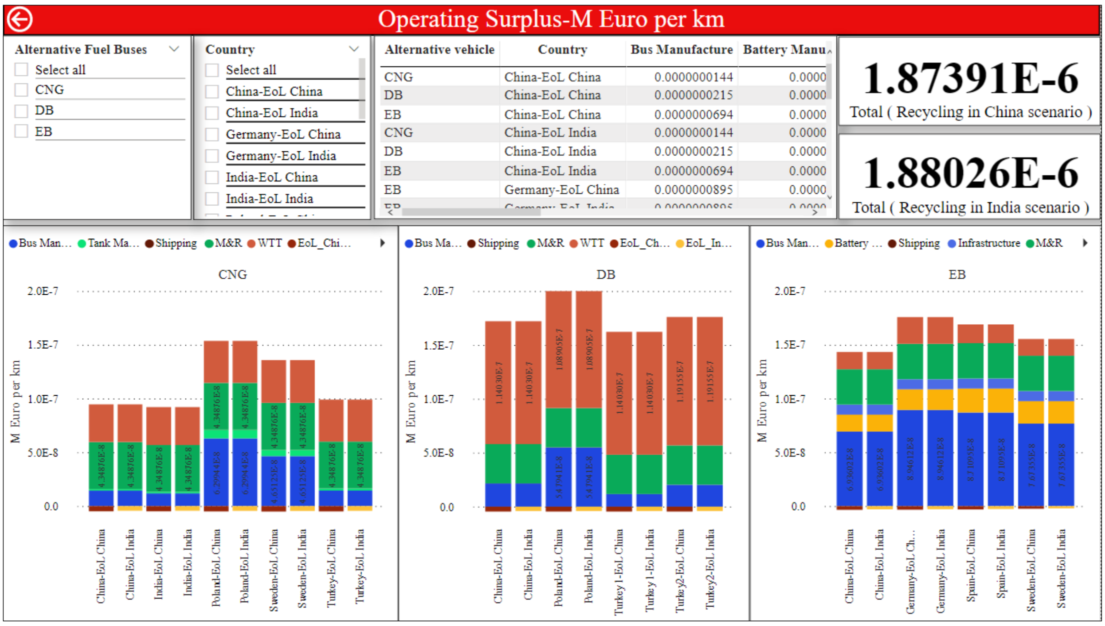


Figure 27 Operating Surplus- M Euro per km

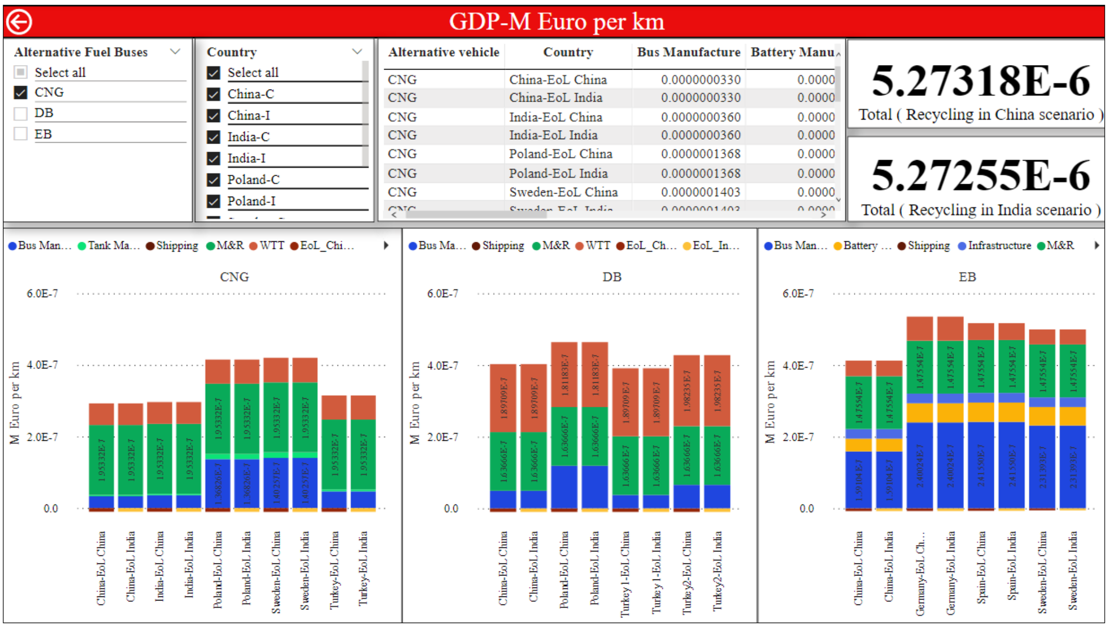


Figure 28 GDP- M Euro per km

The filters are set to show the data for all three AFBs in all countries, with two scenarios recycling in China and recycling in India.

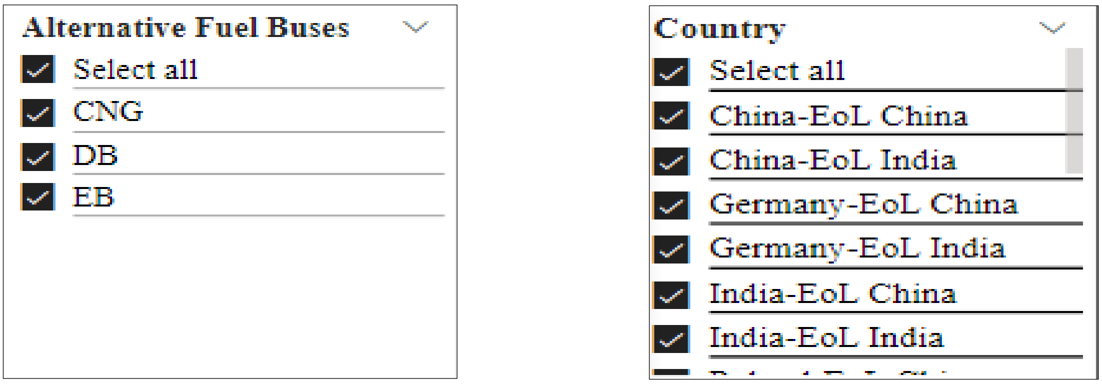


Figure 29 Alternative Buses types and countries manufacture the AFBs

The results visualizations depict the total amount computed for each country and AFB after deducting recycling revenues; the equation is set to be the sum of the GWP results in Kg CO2-eqv /Km minus recycling income. In general, the dashboard's findings have been averaged across all countries. Nonetheless, after the user specifies the required information, the dashboard will display the associated results, as shown in Fig. 30.

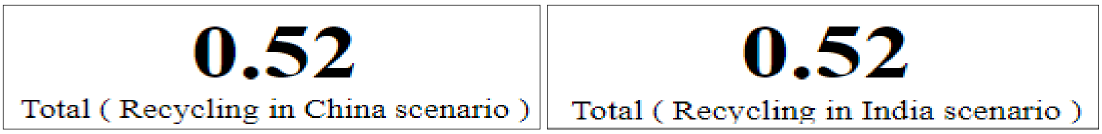


Figure 30 Total value visualization for each scenario (China and India)

Following that, there will be further insights and a more in-depth discussion about the dashboard's use as well as the outcomes analysis.

4.2.1. Environmental Impacts

As mentioned earlier in Fig. 9, the indicators related to Environmental impact are 1. global warming potential (GWP), 2. particulate matter formation (PMF), 3. photochemical ozone generation (POF), 4. land use, 5. Water Consumption (W.C.), 6. Water withdrawal (W.W.). Furthermore, we will examine the LCSA outcomes that are related to the environmental impact, as well as the proposed bus type based on each indicator outcome. In addition, there will be a more in-depth discussion of the dominant factors that influence and increase the effects, as well as justifications for these increases in severity.

4.2.1.1. GWP

Fig. 31 shows the environmental impact on the global warming potential for the three types of AFBs. It illustrates the influence of each process, beginning with bus manufacturing, tank manufacturing (for CNG buses), battery manufacturing (for EB buses), shipping, infrastructure (for EB buses), M&R, WTT, and TTW, and concluding with recycling (China and India).

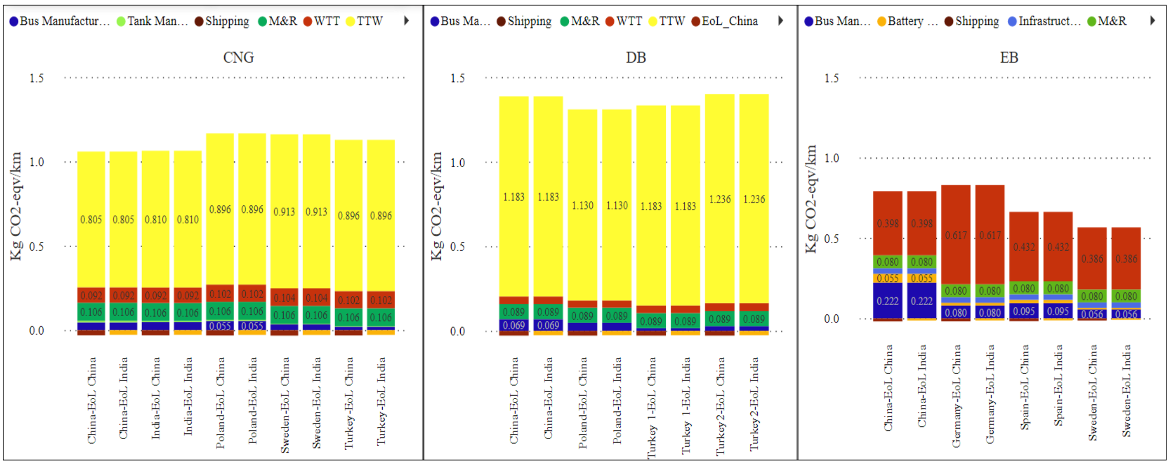


Figure 31 The environmental impact on the GWP for the three types of AFBs

Compared to the EB alternative, which is zero tailpipe emissions, the data demonstrate that the DB alternative, followed by CNG buses, has the most significant overall emissions per km of bus transportation. The most severe negative consequences for DB and CNG buses occur while they are in motion as a result of direct tailpipe emissions (TTW). However, electric power generation in the EB alternatives is considered the source of the greatest amount of EB emissions. As shown in Fig. 32, the DB, which was explicitly made in Turkey, had the highest emissions, emitting 1.4 kg CO_2 equivalent for every kilometer traveled, and after considering the recycling part as a negative value and extracted from the total weight, the total is 1.37 kg CO_2 eqv/ km as shown in Fig. 33.

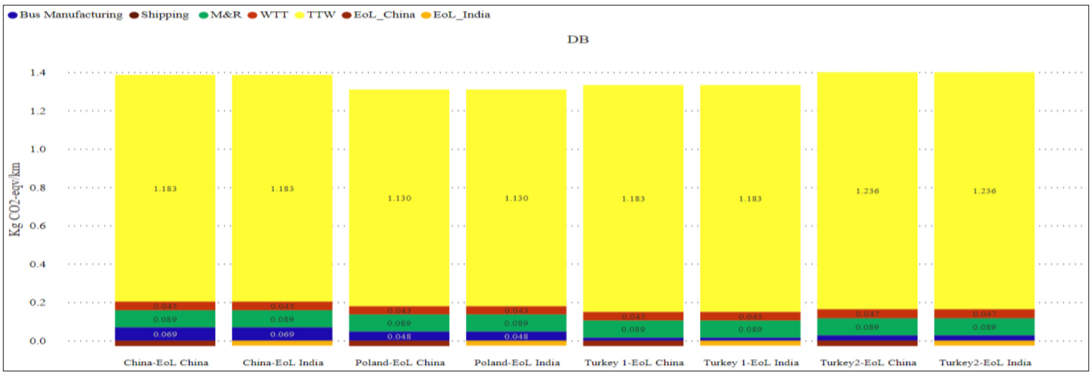


Figure 32 GWP impact for DBs

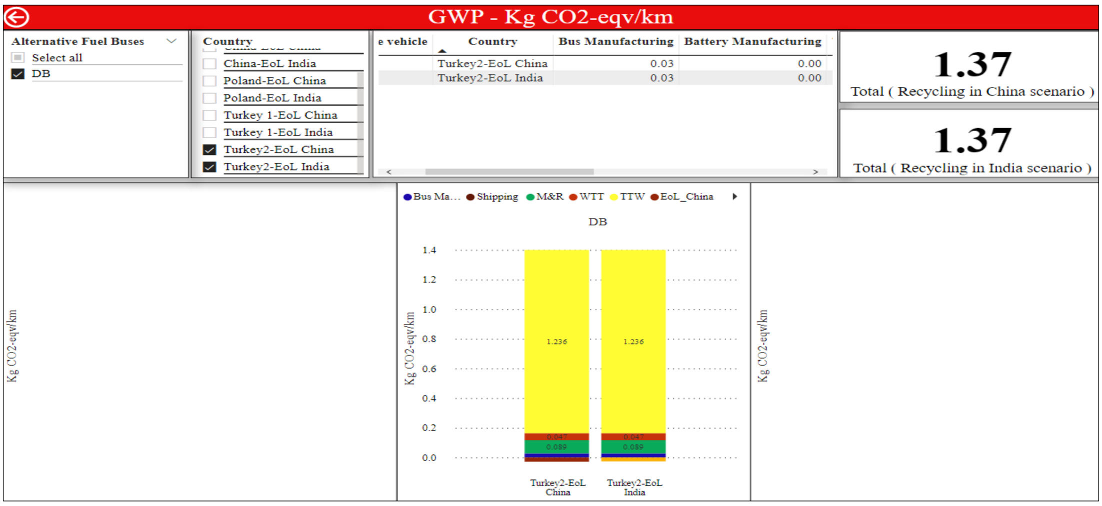


Figure 33 GWP dashboard with DBs highest results

The dashboard indicates that electric buses manufactured in Sweden would have the lowest global warming potential (GWP) impact, with 0.57 kg CO_2 eqv/km, and that the total after considering Chain and India will be 0.55 and 0.56 kg CO_2 eqv/km, respectively. This will demonstrate that electric buses made in Sweden and recycled in China are the most environmentally friendly option when considering global warming potential.

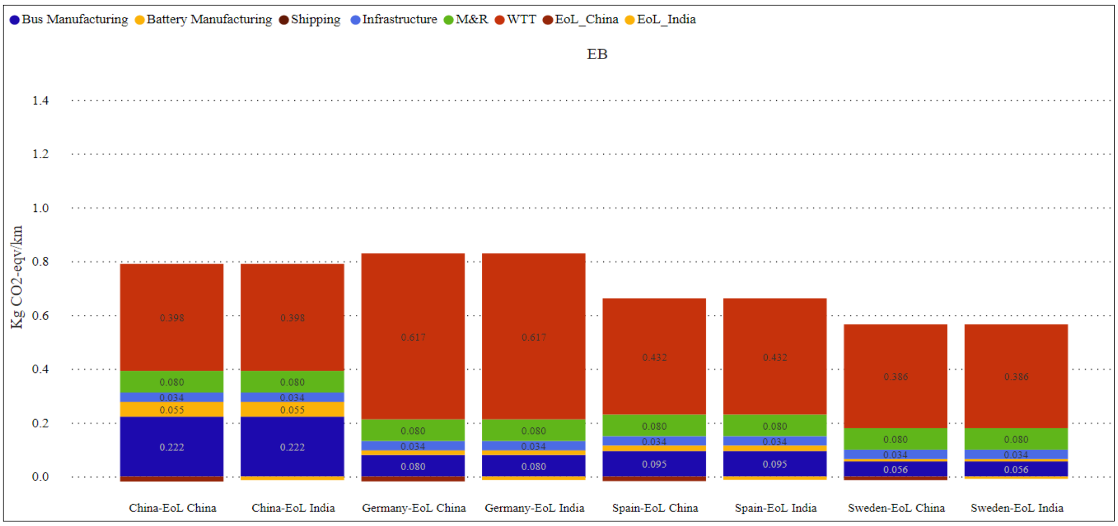


Figure 34 GWP impact on EBs

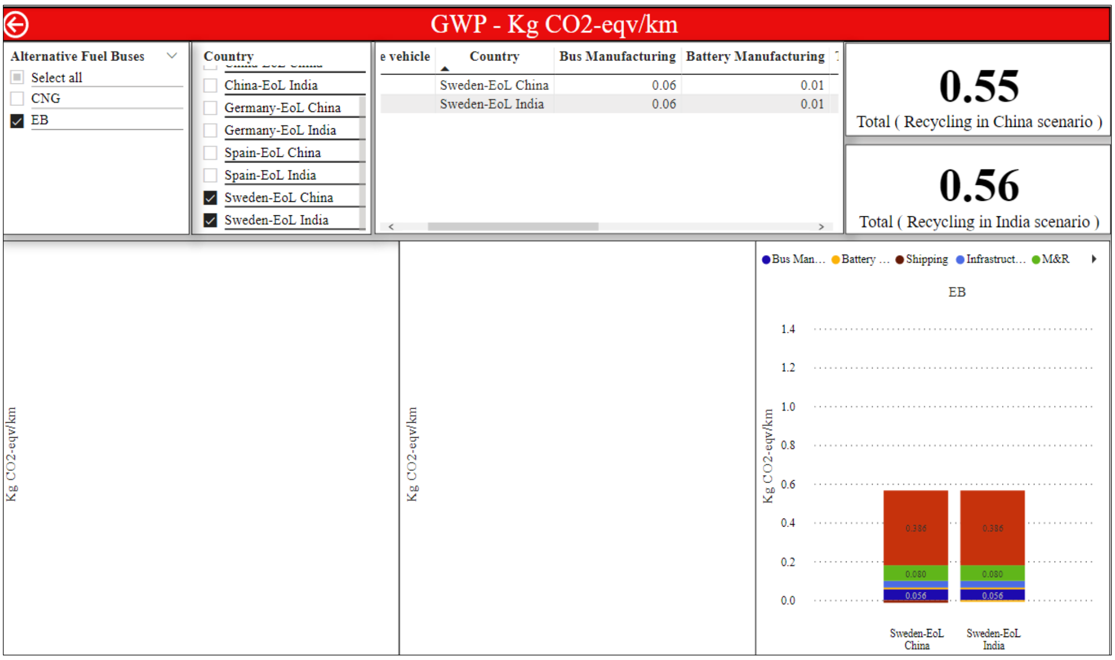


Figure 35 GWP dashboard with EBs lowest results

4.2.1.2. PMF

Fig. 36 presents the three different types of buses, as well as the results of the PMF's environmental impact study. In addition, it can be seen that the electric buses and diesel buses have the greatest environmental impact, with values ranging between 4.00E-04 kg PMF-eqv / km as the lowest range and 6.00E-04 kg PMF-eqv / km as the highest range; it can also be seen that the electric bus manufacturing phase in China has the greatest environmental impact, accounting for approximately half of the total impact, as shown in Fig. 37.

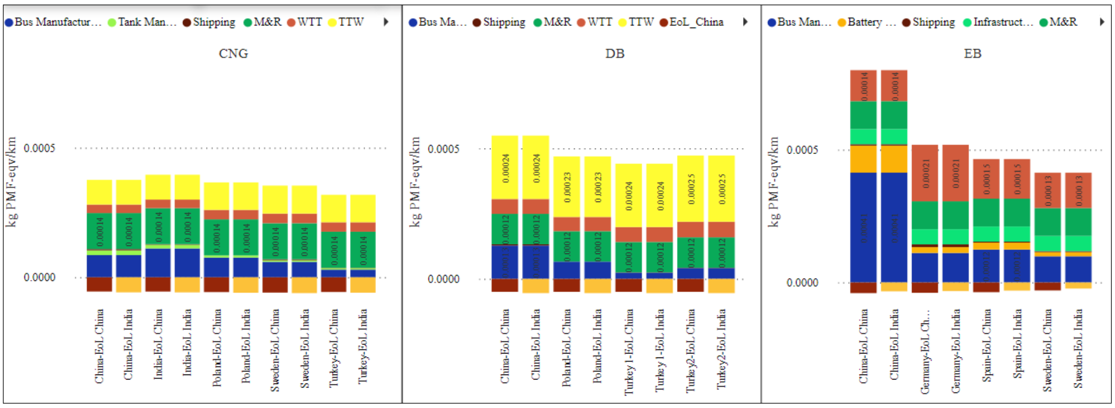


Figure 36 The environmental impact on the PMF for the three types of AFBs

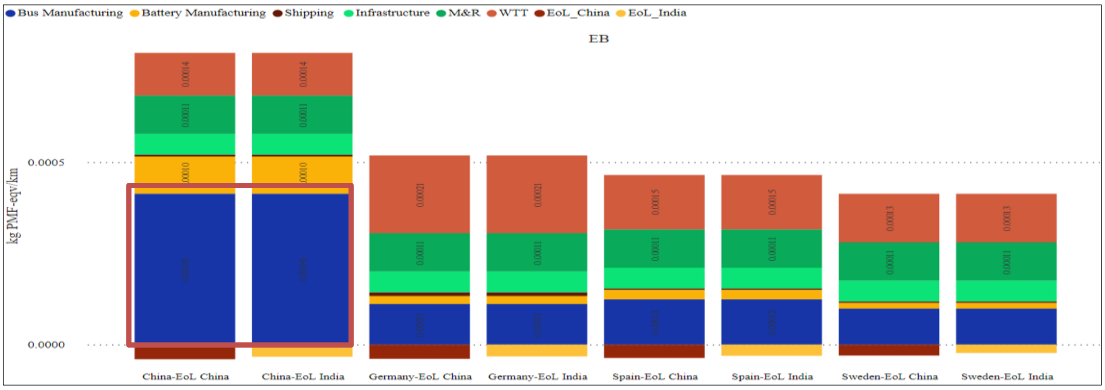


Figure 37 PMF impact for EBs

The results above clearly show that CNG buses are the best option if the decision-maker considers the PMF impacts a significant concern. The dashboard shown in Fig. 39 indicates that CNG buses manufactured in Turkey would have the lowest PMF impact, with 3.19E-04 kg PMF eqv/km. After considering the Chain and India recycling phase, the total will be 2.62E-04 and 2.59E-04 kg PMF eqv/km, respectively.

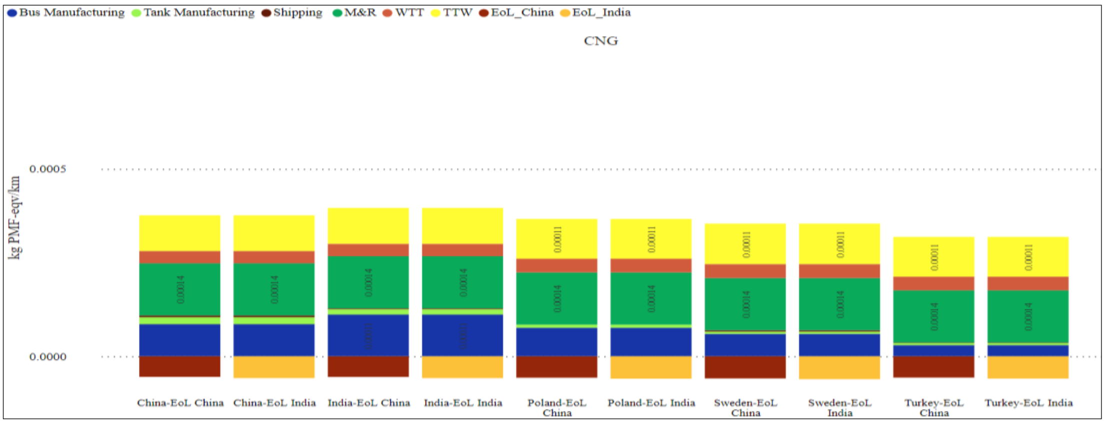


Figure 38 PMF impact for CNG buses

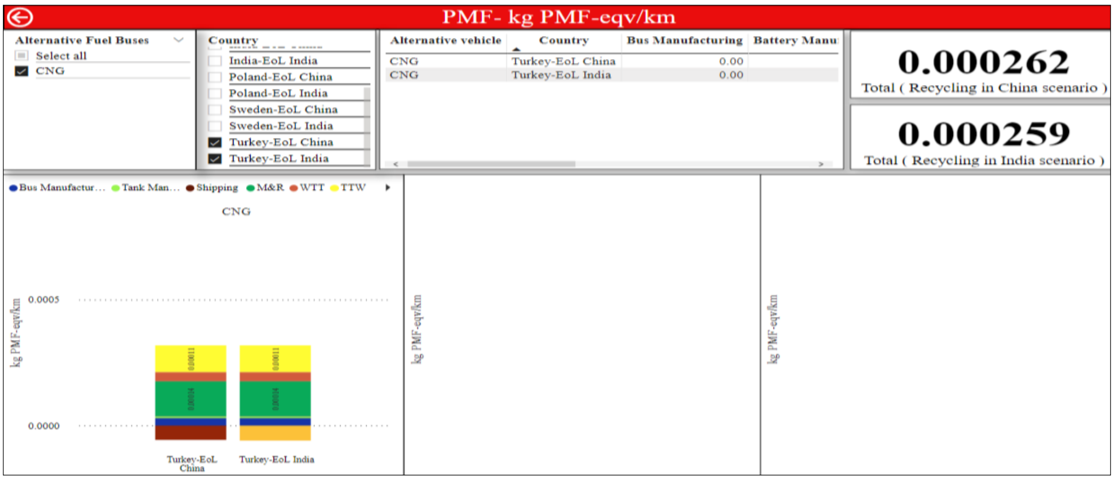


Figure 39 PMF dashboard with CNG buses lowest results

4.2.1.3. POF

From Fig. 40, CNG buses have the best performance and the lowest impact on POF. Similar to the PMF results, it is the lowest for the CNG buses imported from Turkey, with 9.32E-04 Kg POF-eqv/ km; however, when considering the recycling in Chain and India, the amounts will be 8.66E-04 and 8.663E-04 Kg POF-eqv/ km respectively, as shown in Fig. 41.

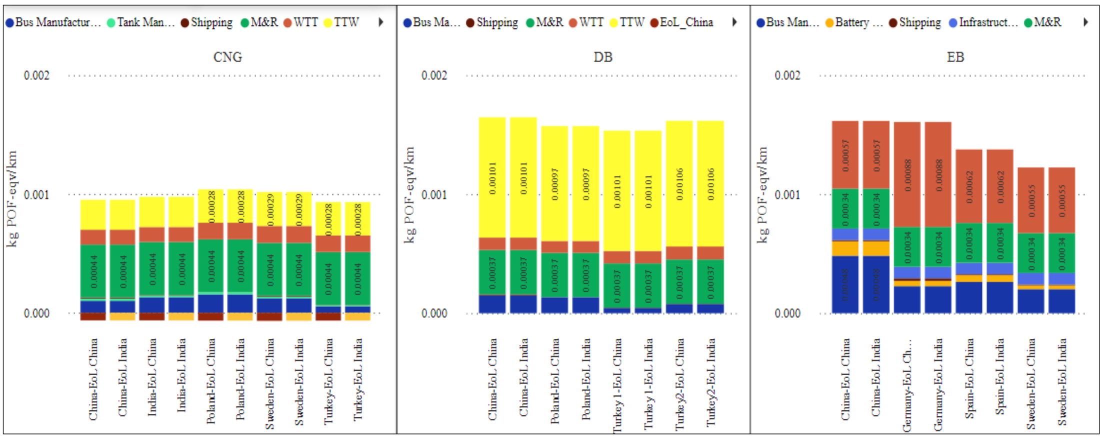


Figure 40 The environmental impact on the POF for the three types of AFBs

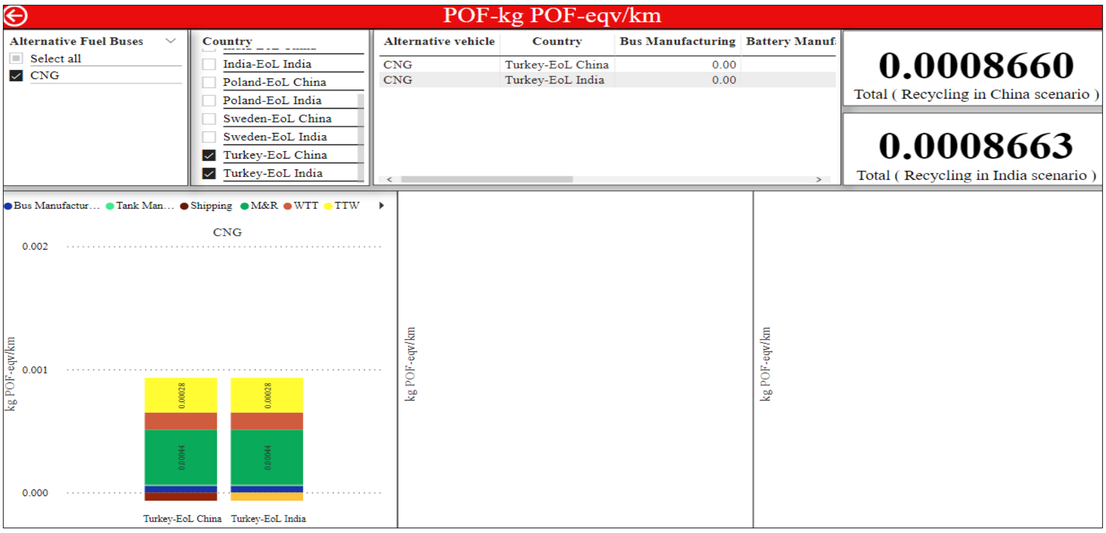


Figure 41 POF dashboard with CNG buses lowest results

It’s important to illustrate and discuss the main reasons for having a high POF impact on the DBs and EBs. Where it’s reaching a minimum of 1.53E-03 Kg POF-eqv/ km for imported DBs from Turkey and a maximum of 1.65E-03 Kg POF-eqv/ km for imported DBs from China; this increase is due to the high TTW impacts as presented in Fig. 42. While for the EBs, a minimum of 1.23E-03 Kg POF-eqv/ km for imported EBs from Sweden and a maximum of 1.62E-03 Kg POF-eqv/ km for imported EBs from China, the prominent increase comes within the WTT impacts caused by the electric generators, as shown in Fig. 43.

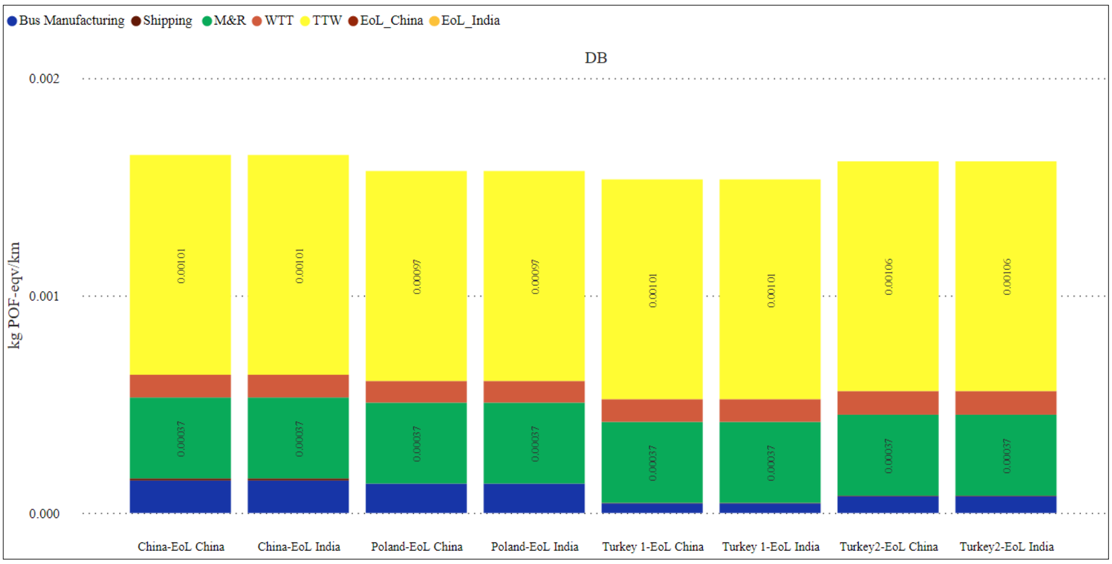


Figure 42 POF impact for DBs

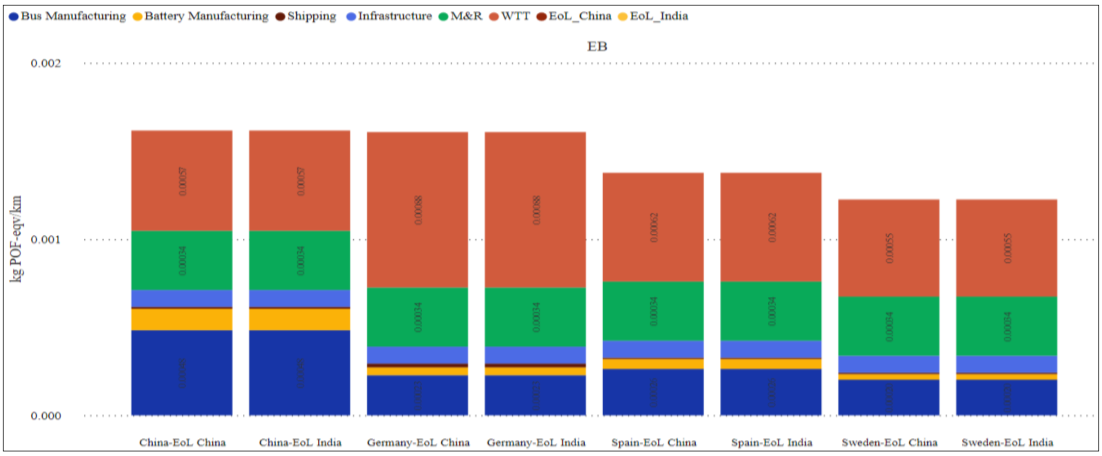


Figure 43 POF impact for EBs

4.2.1.4. LAND USE

From Fig. 44, The three visuals clearly demonstrate that CNG and DB buses have the lowest Land Use impact and are close in terms of the total value. However, Indian CNG buses have the lowest impact on land use, with a 7.13E-08 km^2 / km. By considering the recycling phase, the total will be 6.47E-08 km^2 / km for recycling in China and 6.86E-08 km^2 / km for recycling in India, as presented in Fig. 45. Recycling in China has given a significant advantage over recycling in India since it has substantially decreased land use.

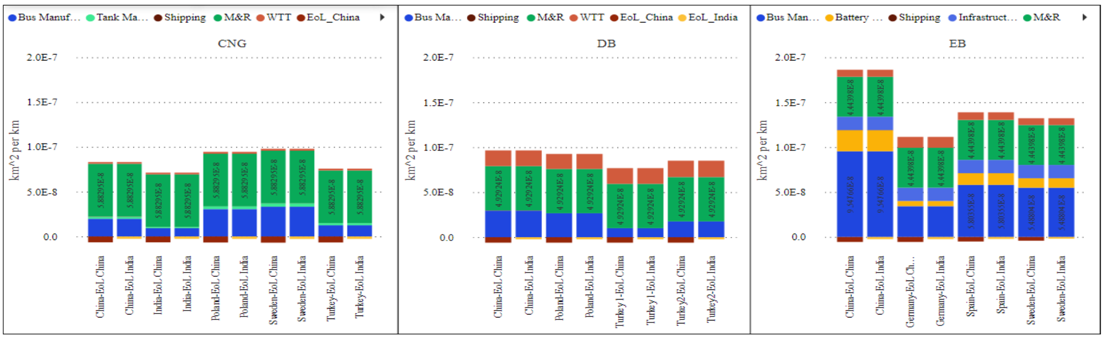


Figure 44 The environmental impact on the Land Use for the three types of AFBs

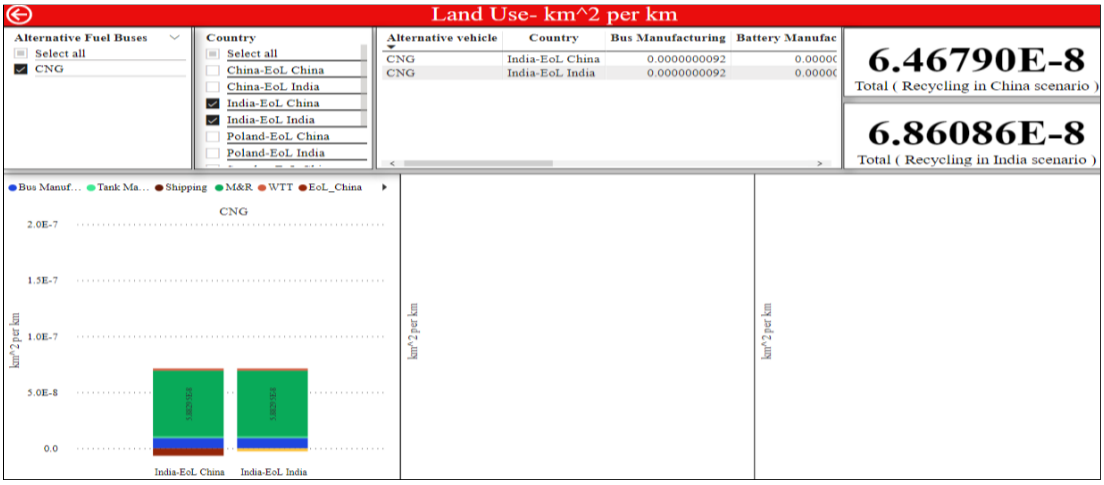


Figure 45 Land Use dashboard with CNG buses lowest results

What is also realized from the visualized results is that the influence of maintenance and repair is affecting the total impacts. On the other hand, Bus Manufacturing is the primary influence that affects the total impacts in the EBs results.

4.2.1.5. Water Consumption

Presented visualizations in Fig. 46 of the Water Consumption impacts represent that DBs and CNG imported from Turkey have the lowest impacts with 1.35E-08 mm3 /km for DBs and 1.36E-08 mm3 /km for CNG buses, and when it comes to considering the end of life face based on the two countries, CNG buses will have the precedence in terms of the total impact as it is 1.1831E-08 mm3 /km compared to 1.1876E-08 mm3 /km for DBs for recycling in China. Also, CNG buses are preferred considering recycling in India as it is 1.238E-08 mm3 /km while it is 1.239E-08 mm3 /km for DBs.

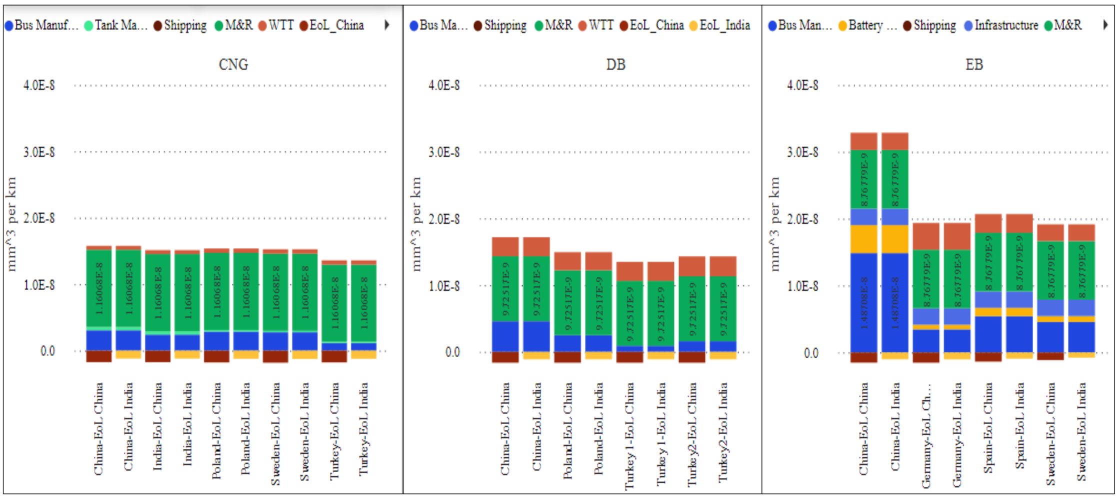


Figure 46 The environmental impact on the Water Consumption for the three types of AFBs

4.2.1.6. Water Withdraws

Upon first glance at the visuals in Fig. 47, the most notable feature is the enormous disparity in the distribution of results between CNG and DBs when compared to the EBs. Fig. 48 demonstrates that the high values of EBs in all countries that import them are influenced by the dominant factor, which is WTT. This could be attributable to the large volume of water that will be extracted for the purpose of generating energy through the use of electric generators, which is expected to be significant. Looking at the best bus types that have the best performance related to the Water Withdraws impact, the visuals show that the CNG buses for the five brands are very close in terms of the impact, but the best among them is the Turkish CNG buses with1.95E-09 mm^3 / km considering EoL of China, and 3.56E-11 mm^3 / km considering EoL of India.

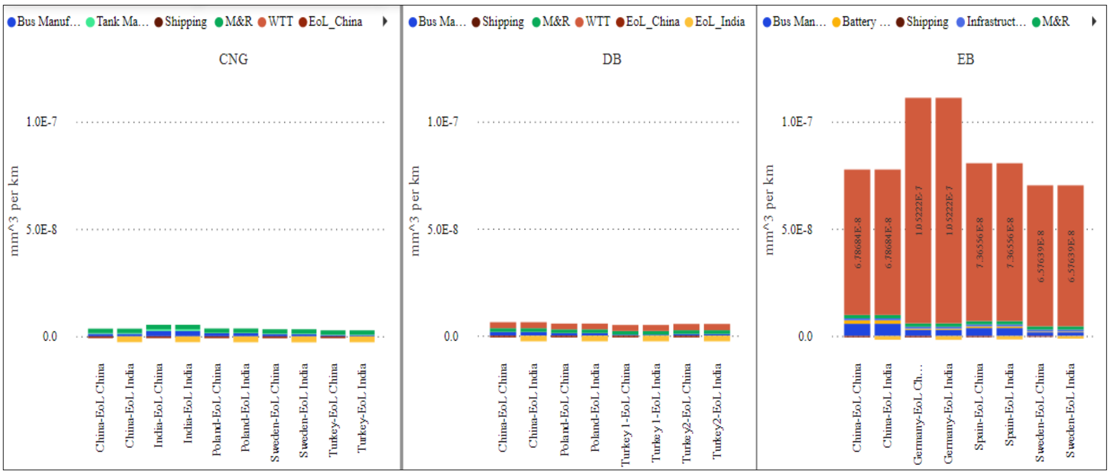


Figure 47 The environmental impact on the Water Withdraws for the three types of AFBs

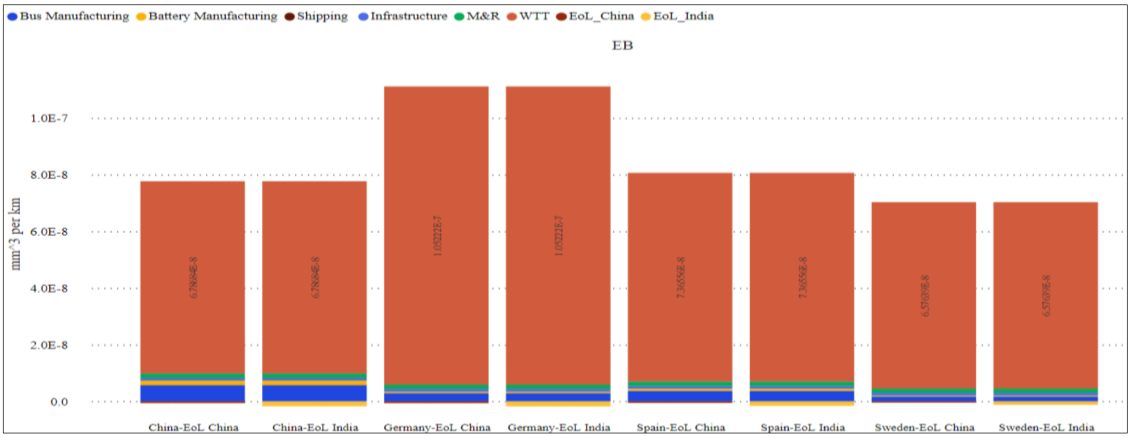


Figure 48 Water Withdraw impact on the EBs

4.2.1.7. Environmental Impacts Results and Discussion

To sum up the overall results for the last six environmental aspects, CNG buses were the most recommended type of buses, where it was the dominant type among five out of six aspects that have been studied. The EBs showed promising results when the study indicated the GWP emissions, as it is a zero tailpipe emissions.

The use of data visualization assisted in the identification of the key elements that contributed to an increase in the results for specific bus types in specific nations. The significance of this increase has been highlighted, and the reasons behind it have been explained. Examples include the fact that direct tailpipe emissions (TTW) from diesel and natural gas buses cause the most severe negative impacts while the buses are in motion, as seen in GWP.

The indicators are included in Table 5 below, along with the buses recommended as having the best performance, the dominating contributor that increases the environmental impact values for each bus type.

Table 5 Environmental impact results

Sustainability indicator	Recommended bus type	Country	Dominating contributor
GWP	Electric buses	Sweden	CNG, DBs : (TTW) Direct tailpipe impacts EBs : (WTT) the emissions associated with power generating
PMF	CNG buses	Turkey	CNG and DBs: (TTW) Direct tailpipe impacts EBs: Bus manufacturing
POF	CNG buses	Turkey	CNG and DBs: (TTW) Direct tailpipe impacts EBs: (WTT) the emissions associated with power generating
Land Use	CNG buses	India	Maintenance and Repair
Water Consumption	DBs and CNG buses	Turkey	Maintenance and Repair
Water Withdrawal	CNG buses	Turkey	(WTT) the emissions associated with power generating

4.2.2. Social Impacts

As mentioned earlier in Fig. 9, the indicators related to Social impact are 1. Human health, 2. Employment, 3. Compensation, 4. Tax. The outcomes of the LCSA that are related to social impact will be discussed in further detail in the following sections, along with the recommended bus type that is based on each indicator outcome. A more in-depth explanation of the major elements that influence and increase the effects, as well as arguments for these increases in severity, will be included as part of the presentation.

4.2.2.1. Human Health

The human health impact for DBs is illustrated clearly in Fig. 49, cased by the tailpipe emissions; the TTW emissions represent more than 50% of the total impact value. In general, EBs outcomes present less human health impact, especially for the Sweden EBs, which is 3.36E-10 DALY (Disability-Adjusted Life Year) /km in total. But also, the Turkish CNG buses provide low human health impact with 3.51E-10 DALY (Disability-Adjusted Life Year) /km. It’s necessary to mention that the EoL factor is higher for CNG buses, then once we look at the results considering the EoL of China and India, the best and the recommended type will be the CNG buses as it is around 3.11E-10 and 3.10E-10 DALY /km for China and India respectively, While for the EBs, the total considering the recycling cases will be 3.15E-10 and 3.20E-10 DALY /km for China and India respectively.

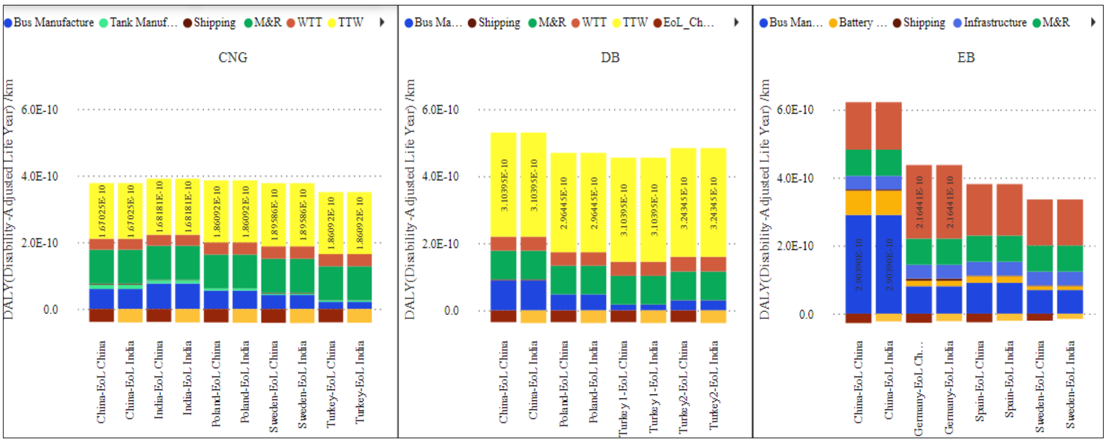


Figure 49 The social impact on human health for the three types of AFBs

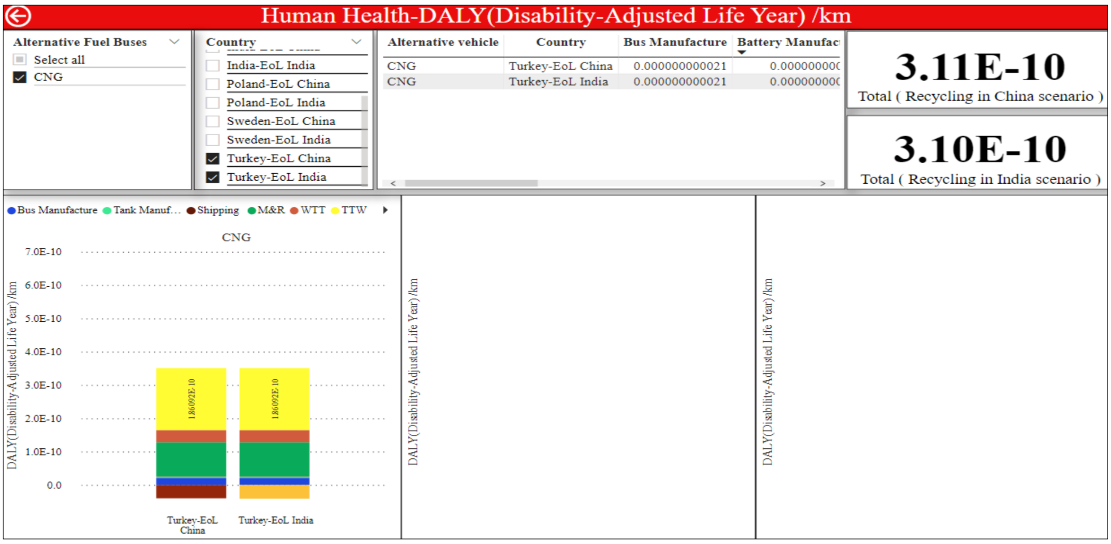


Figure 50 Human Health dashboard with CNG buses results

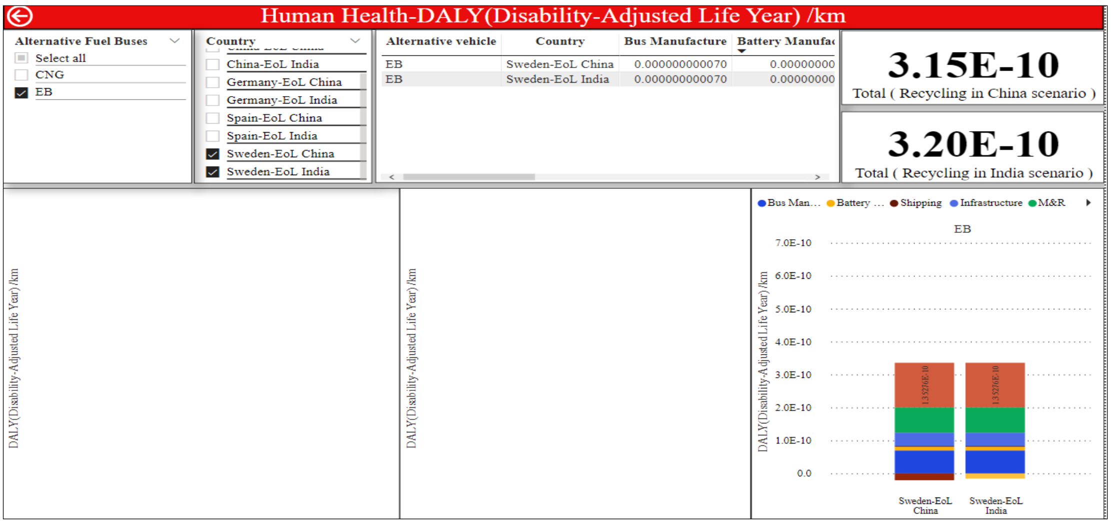


Figure 51 Human Health dashboard with EBs results

4.2.2.2. Employment

Higher scores in this section translate into more benefits in terms of employment impact. EBs have the most significant employment impact, particularly for factors associated with the manufacturing phase, such as bus manufacturing (which is related to bus parts) and battery manufacturing (which is related to battery parts), and present around 67% of the total impact. According to the findings, China's EBs have the greatest impact, with a total impact of 1.87E-08 1000 P / km. Considering the two scenarios of China and India, the results show the following 1.83E-08 and 1.76E-08 1000 P / km respectively. For the other two types of buses, it has been realized that the dominant factor was the maintenance and repair factor, which represents between 47% to 66% for the CNG buses and 44% to 54% of the DBs impact. Also, it represents a recognizable impact for the EBs with a range between 22% to 34%.

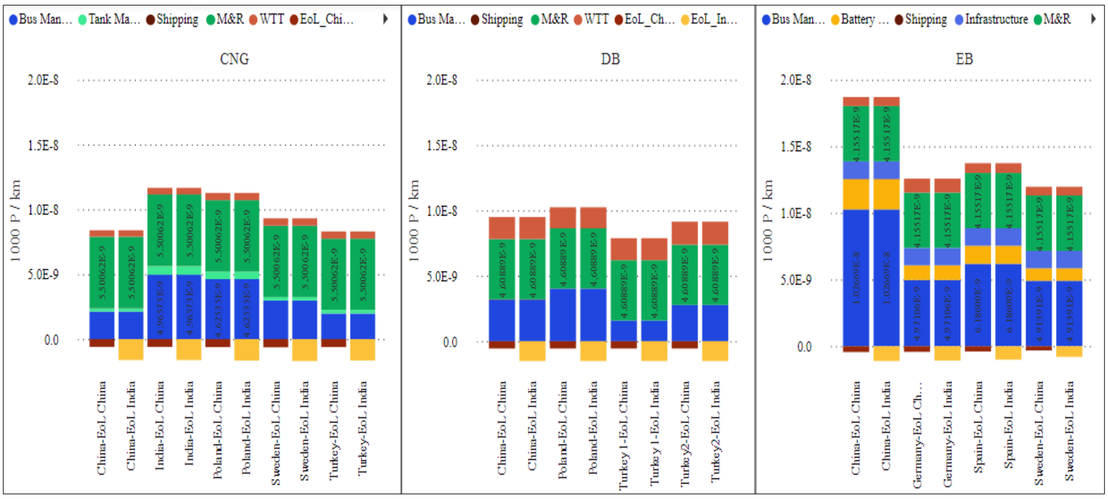


Figure 52 The social impact on Employment for the three types of AFBs

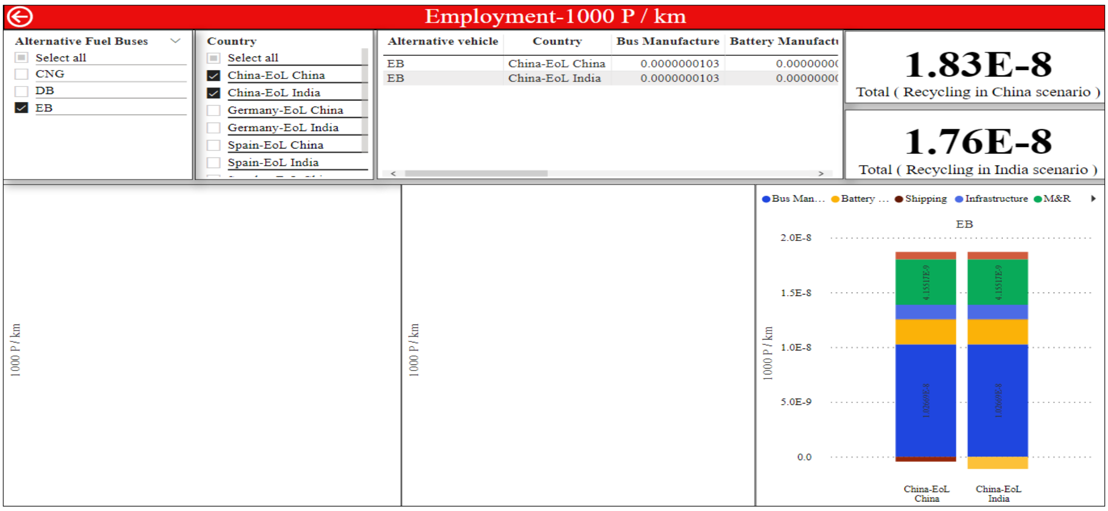


Figure 53 Employment dashboard with EBs results

4.2.2.3. Compensation

The same as the employment impact, Compensation impacts showed the highest results for the EBs. Germany EBs had a total impact of 2.85E-07 M Euro/km, the recycling phases had a slight effect, and the reduction was slightly low. After considering the recycling in China, the total effect was 2.823E-07 M Euro/km and 2.820E-07 M Euro/km for India. The main contributor is the Manufacturing process, including the bus manufacturing the battery manufacturing for EBs. The CNG buses and the DBs show that maintenance and repair are the dominant factors.

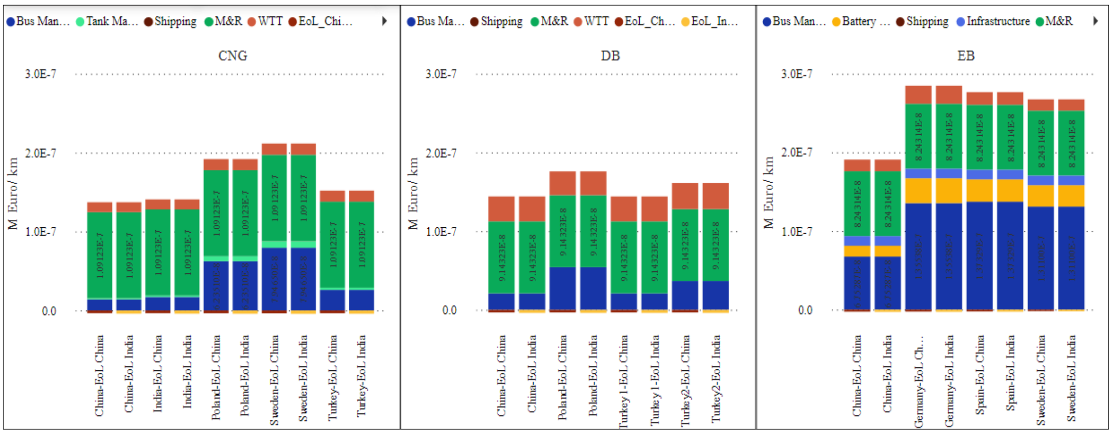


Figure 54 The social impact on compensation for the three types of AFBs

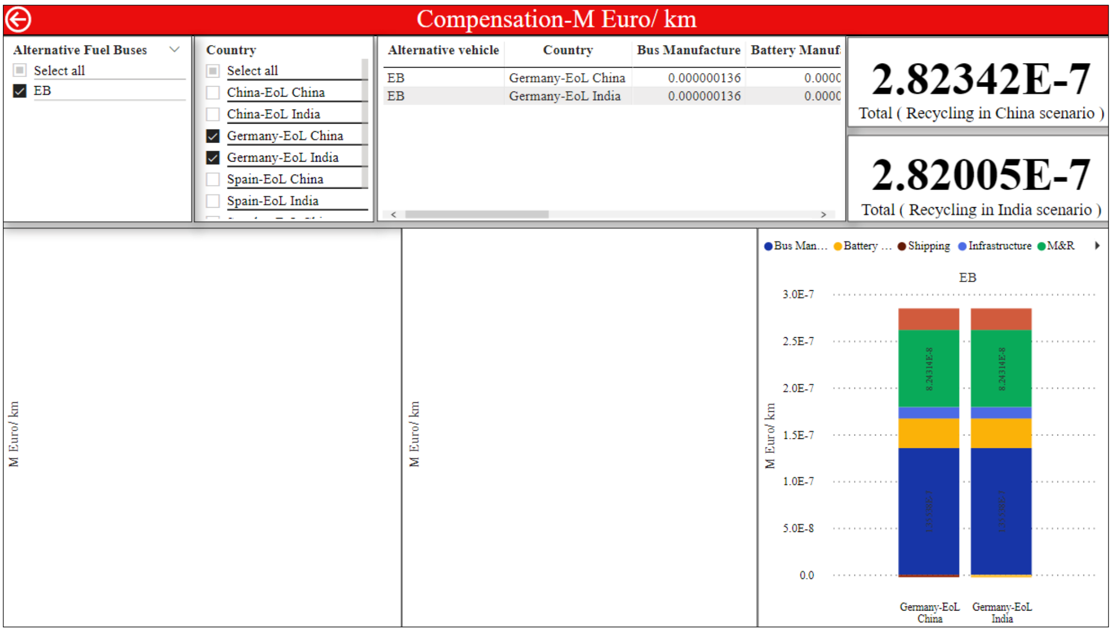


Figure 55 Compensation dashboard with EBs results

4.2.2.4. Tax

The tax in this study is considered to be a positive source of income for the country as it shows the whole LCSA results for each bus type. In general, the higher the tax benefits, the better bus type to consider for decision-makers. According to the findings from Fig. 56, DBs are estimated to hold the largest total tax benefits of all the tested bus types. The outcomes show that the Turkish DBs have the highest tax benefits with 1.13E-08 M Euro/km, and by considering the recycling process. On the other hand, the

Chines CNG buses show the lowest tax benefits, with a total of 6.09E-08 M Euro/km. Within each of the three bus types, the most significant contributors to the total tax benefits impact are factors related to maintenance and repair. For DBs, it also demonstrates that the WTT outweighs the tax advantages.

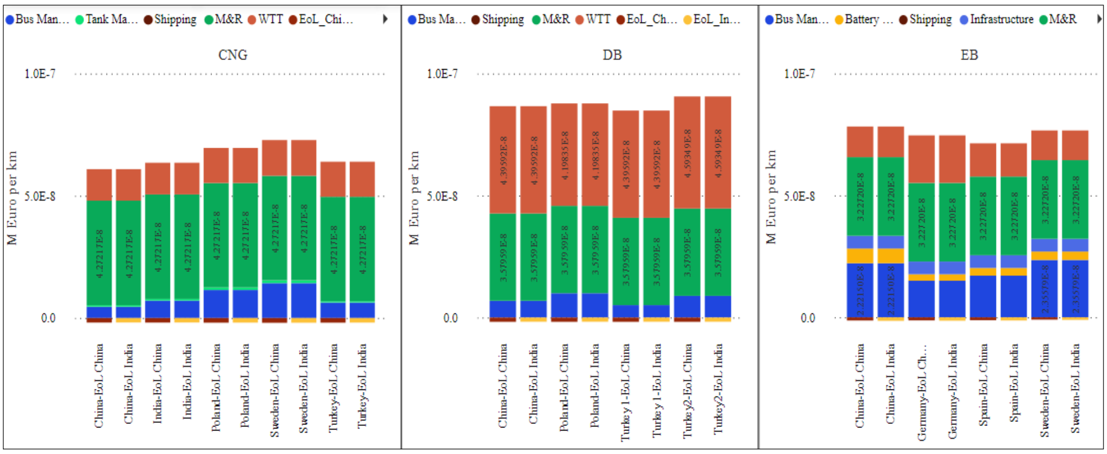


Figure 56 The social impact on tax for the three types of AFBs

4.2.2.5. Social Impacts Results and Discussion

To sum up the overall results for the last four environmental aspects, EBs were the most recommended type of buses where it was the dominant type among three out of four social impacts that have been studied. The EBs have shown encouraging outcomes in terms of human health, employment, and compensation. On the other hand, CNG buses can be considered a close second because they have a lower influence on human health but a greater impact on employment and compensation when compared to diesel buses. Those indicators are shown in Table 6 below, along with the buses that have been recommended as having the best performance, as well as the most significant contributor that increases the Social Impact values for each bus type.

Table 6 Social impact results

Sustainability indicator	Recommended bus type	Country	Dominating contributor
Human Health	CNG, EBs	Turkey, Sweden	CNG, DBs : (TTW) Direct tailpipe impacts EBs : (WTT) the emissions associated with power generating
Employment	EBs	China	Bus Manufacturing, Maintenance, and repair
Compensation	EBs	Germany	Bus Manufacturing, Maintenance, and repair
Tax	DBs	Turkey	CNG buses, DBs, and EBs: Maintenance and repair DBs: WTT (have the highest total tax benefits)

4.2.3. Economic Impacts

As mentioned earlier in Fig. 9, the indicators related to Economic impact are 1. Operating surplus, 2. GDP. The economic impact indicators produced by the LCSA will be addressed in further depth below, along with a recommendation for the bus type that should be used based on the results of each indicator. The discussion will include a more in-depth explanation of the primary factors that influence and enhance the severity of the effects, as well as reasons for why these increases in severity are occurring in the first place.

4.2.3.1. Operating Surplus

As illustrated in Fig. 57, the operating surplus impact on DBs, mainly the Polish DBs, is the greatest, amounting to a total of 2.00E-07 M Euro/km. However, because the EoL will provide a slight reduction of around -4.56E-09 M Euro/km for China and -4.07E-09 M Euro/km for India, the resulting outcomes are 1.958E-07 and 1.963E-07 M Euro/km for China and India, respectively. After considering the EoL of China and India, the results are presented in Fig. 58. The second preferred bus type is the German

EBs, where there is a difference between Polish DBs and German EBs is around 2.46E-08 M Euro/km. When it comes to DBs, the WTT is the most critical component to consider. However, the Bus Manufacturing factor is the contributing factor that has the most impact on the total value for the EBs.

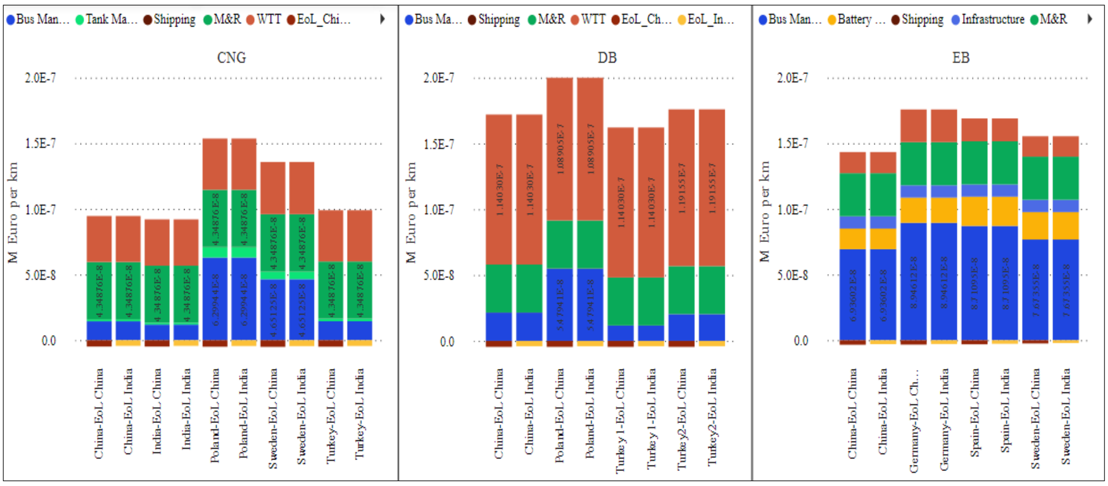


Figure 57 The Economic impact on Operating Surplus for the three types of AFBs

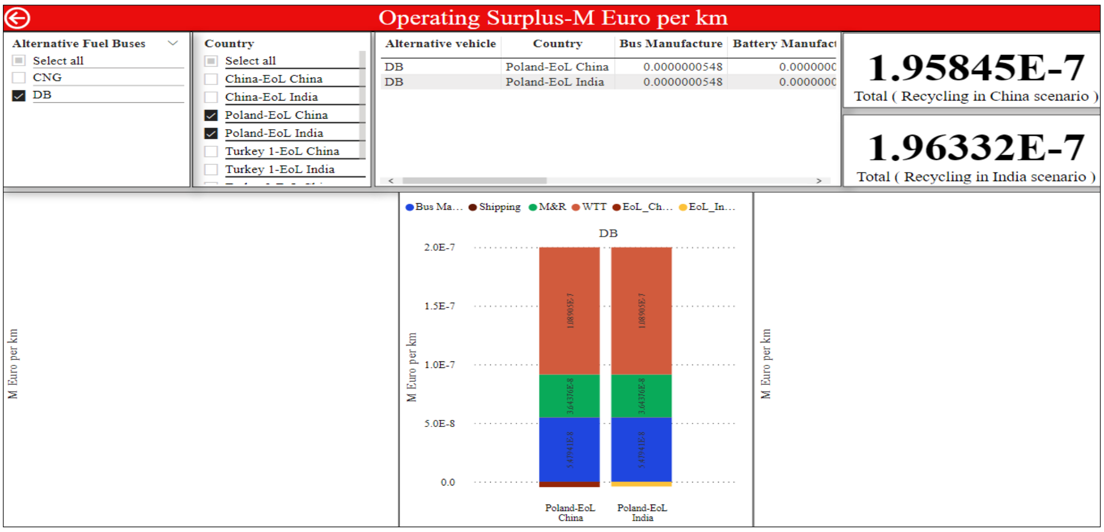


Figure 58 Operating Surplus dashboard with DBs results

4.2.3.2. GDP

According to Fig. 59, the German EBs had the greatest influence on the gross domestic product, with a total value of 5.35E-07 M Euros per kilometer traveled. China's EoL will be approximate -7.11E-09 M Euro/km, and India's EoL will be around -7.13E-09M

Euro/km; the results are shown in Fig. 60, with the ultimate findings being 5.282E-07 and 5.281E-07 M Euro/km for China and India, respectively. EBs are dominated by bus manufacturing factors which is the most critical component. For DBs, the dominant factor is the WTT, and CNG buses are the maintenance and repair factors.

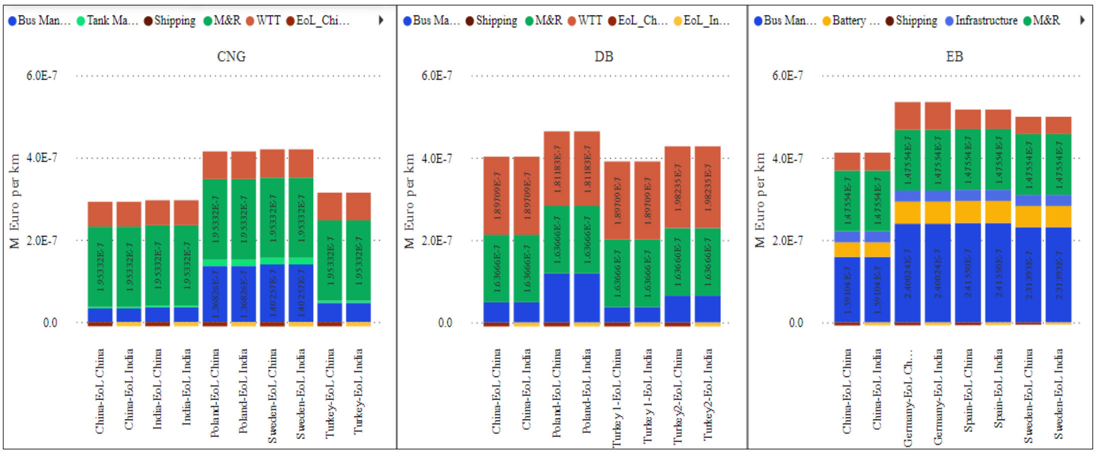


Figure 59 The Economic impact on GDP for the three types of AFBs

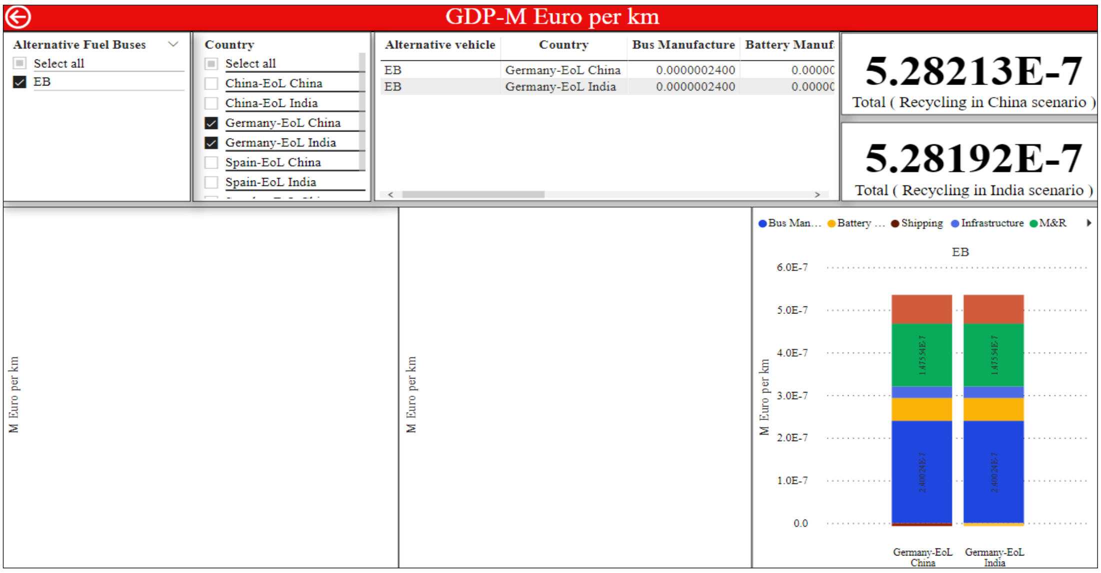


Figure 60 GDP dashboard with EBs results

4.2.3.3. Economic Impacts Results and Discussion

After analyzing the operating surplus and the GDP results, the German EBs were the best economic impact performance. Table 7 shows the Economic effect values for each bus type, as well as the best-performing buses and the most significant contributor to each bus type's Economic impact.

Table 7 Economic impact results

Sustainability indicator	Recommended bus type	Country	Dominating contributor
Operating surplus	DBs, EBs	Poland, German	CNG: Maintenance and repair DBs: WTT EBs: Bus Manufacturing
GDP	EBs	German	CNG: Maintenance and repair DBs: WTT EBs: Bus Manufacturing

4.3. Dashboard II

Dashboard II displays the international supply chain of the indicator's impacts inside and outside Qatar. This section focuses on the impact percentage contribution on a more geographic level of detail. Assessing the extent to which the effects are felt in and out of Qatar. Here, the decision-maker will gain a better understanding of the impact within Qatar and will estimate the magnitude of the effect of picking one type over another over the long term. Given that Qatar is the subject of this study, it will provide additional insight into understanding the direct influence from the standpoint of the factors that have an impact on the country. The sup-phases assessed within Qatar are those associated with the operation phase, as represented by TTW, which is the direct tailpipe impact inside Qatar TTW impact will be counted for the CNG buses and DBs only. The second sup-phase is the WTT, which is associated with the fuel supply inside Qatar, the infrastructure is also included, but it will be counted for the EBs only, and the last sup-phase is the maintenance and repair. The manufacturing phase primarily drives impact evaluations outside of Qatar. The sub-phases pertaining to the external evaluation are bus manufacturing, CNG tank manufacturing, battery manufacture for electric buses, shipping, and the part pertaining to fuel delivery outside the state of Qatar (WTT). This chapter will explain how to utilize the dashboard, the primary visualizations, and how they will portray the data. Based on the dashboard analysis, it will offer the decision-maker the most appropriate bus. The analysis will be divided to cover the three sustainable impacts, the Environmental, Social, and Economic impacts, then each impact indicator will be discussed, and in the end, an analysis of the results will be provided. This dashboard will give the advantage to the decision-makers to prioritize the impacts inside Qatar; also, it will show the results for the indicators for the three sustainable impacts (Environmental, Social and Economic impacts) and assess the decisions based on the prioritized impact. The rationale for considering this dashboard to be noteworthy is that it brings the first dashboard to completion. In other words, the outcomes of the visualizations associated with this dashboard II will be compared to the outcomes of the visualizations associated with Dashboard I. It is also intended that the dominating aspects that we analyzed in dashboard I should link to the results supplied by Dashboard II to provide a comprehensive assessment of the outcomes, including an explanation for the reasons for high and low impacts. It will also provide a thorough analysis and highlight additional critical points that the decision-maker should consider during the decision-making process.

4.3.1. Environmental Impacts

This section will show the results related to the six indicators related to the environmental impacts. The dashboard consists of two filters to specify the results needed: the Alternative bus type and the countries that manufacture the buses. In total, there will be six visuals displaying the percentage results for each bus type; three of them will depict the influence of buses within Qatar, while the remaining three will depict the impact of buses outside Qatar, as described in Fig. 61. While more than one country is selected, the results will be displayed as an average of the rates selected for each country.

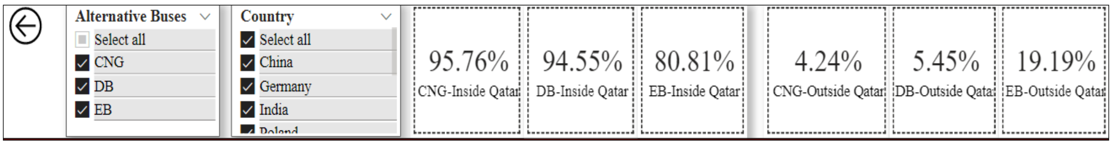


Figure 61 Visual represents the filters and the rates inside and outside Qatar

A more detailed explanation will be provided by the column chart visual depicted in Fig. 62, which will also display the impact rates for each bus type in each country.

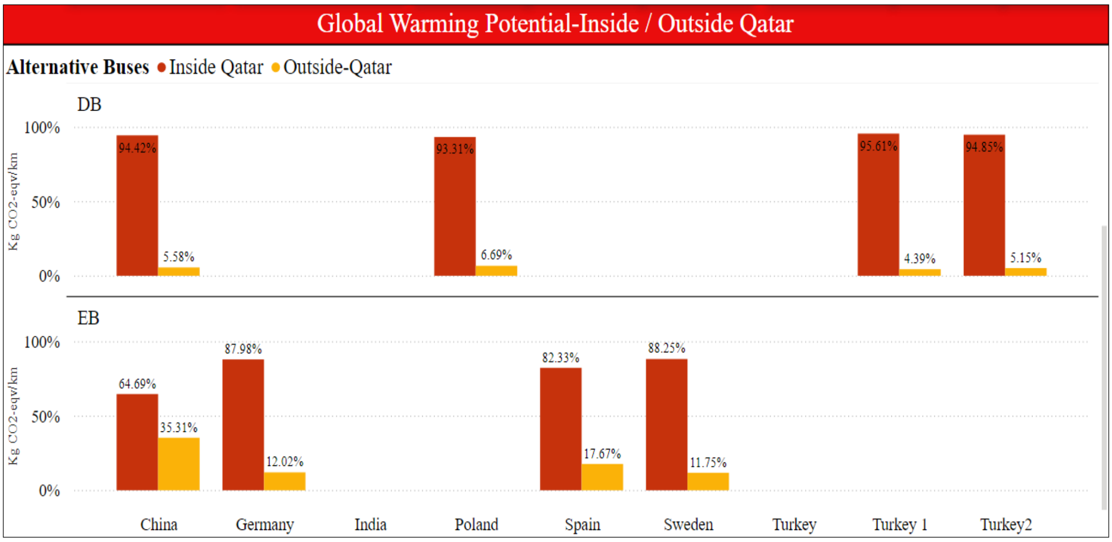


Figure 62 Column chart visual presents the impacts inside and outside Qatar

4.3.1.1. GWP

From Fig. 63, it is instantly obvious that the EBs have the least overall average rate impact within Qatar with 80.81% compared to other bus types, 95.76%, and 94.55% for CNG buses DBs, respectively. The increase in CNG buses and DBs is most probably reflected in the high direct tailpipe emissions (TTW) that have been discussed earlier; the reader can refer to Fig. 19. As a result, EBs have the highest overall average rate impact outside Qatar, with a rate of 19.19%. By selecting the EBs, the column chart will show only the results related to this type of bus. According to Fig. 64, the range of GWP impacts within Qatar was assigned a percentage between 64.69 and 88.25 percent, and the range of GWP impacts outside Qatar was awarded a percentage between 11.75 and 35.31 percent. Accordingly, according to the illustrated results, China's EBs had the lowest percentage, with 64.69 percent inside Qatar and a 35.31 percent rate outside Qatar.

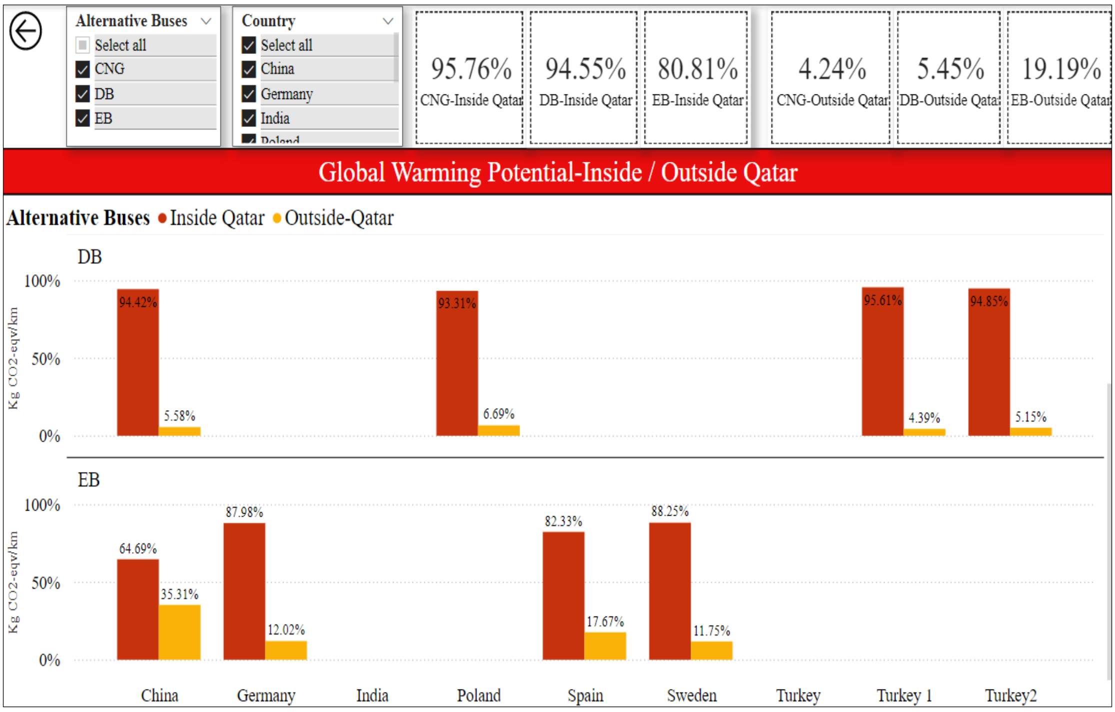


Figure 63 The average rates of GWP emissions inside and outside Qatar

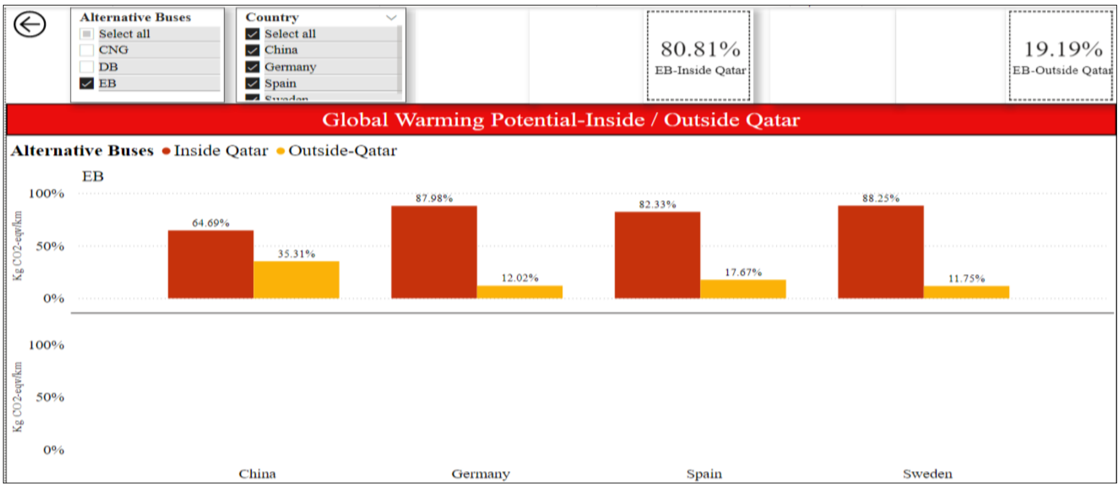


Figure 64 The average rates of GWP for EBs emissions inside and outside Qatar

4.3.1.2. PMF

It can be seen in Fig. 65 that all of the PMF impacts are high on average inside Qatar when compared to the results outside Qatar, excluding one case in which the impact inside Qatar is lower than the impact outside Qatar, which is the case of Chinese EBs, where the impact inside Qatar is 36.25 percent. In contrast, the impact outside Qatar is 63.75 percent, as shown in Fig. 66. In this case, it is reasonable to link that to the high results related to electric bus manufacturing in China. As discussed earlier, bus manufacturing was the major factor among the overall sub-phases in China.

Accordingly, the reader can refer to Fig. 37 for further information if necessary.

Figure 65 All AFBs rated for PMF impact

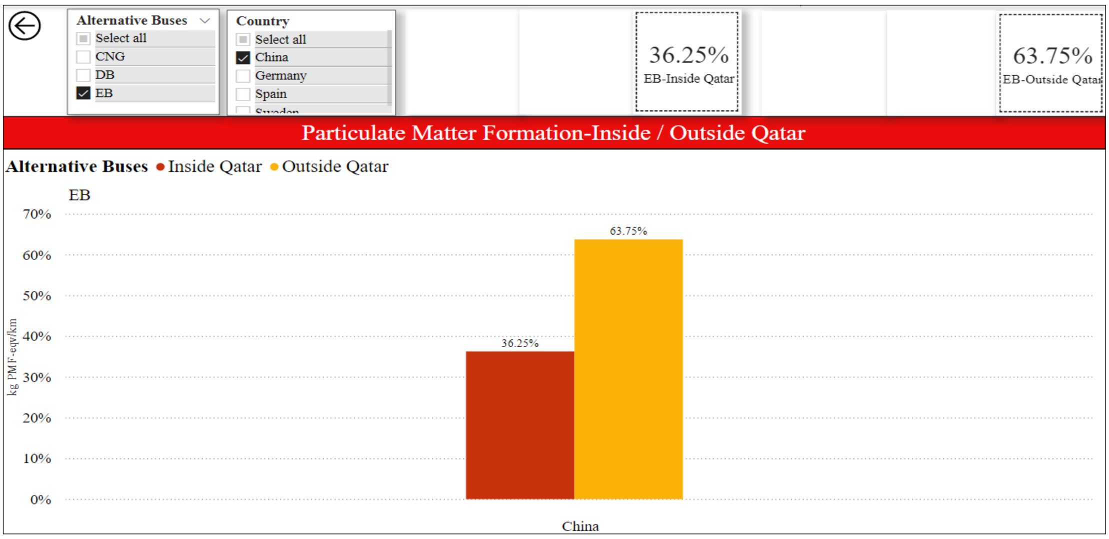


Figure 66 PMF impact for Chines EBs

4.3.1.3. POF

Same as the GWP and the PMF results, POF showed the lowest rates assigned to the EBs, mainly the EBs imports from China with an impact of 61.70 percent inside Qatar and 38.70 percent outside Qatar.

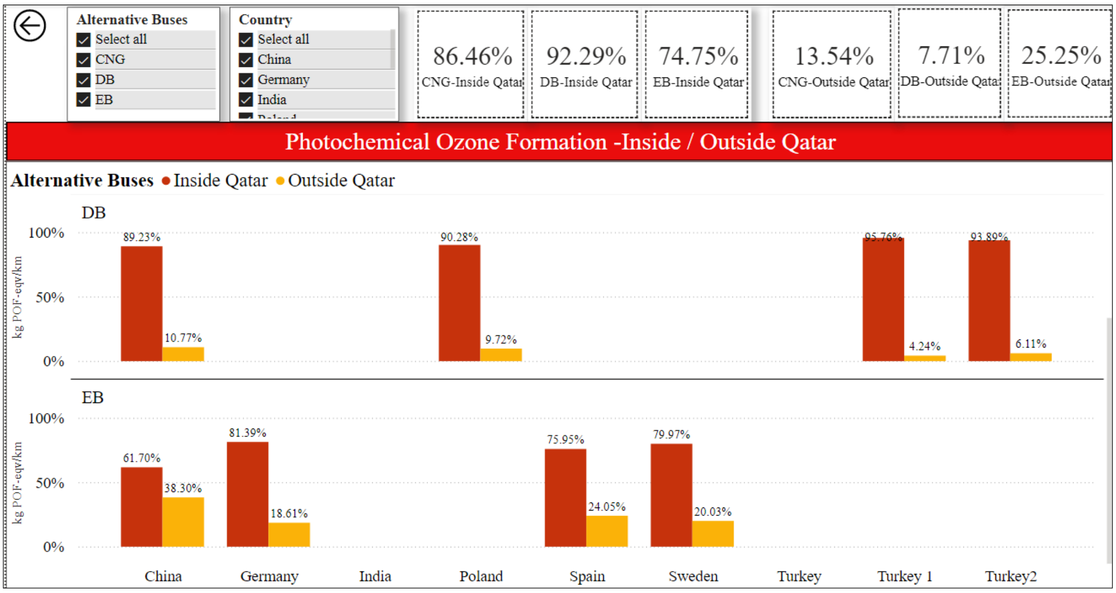


Figure 67 The average rates of POF emissions inside and outside Qatar

4.3.1.4. Land Use

The Land Use sector has the lowest rates of impact when it comes to the overall impact inside Qatar. Referring back to the outcomes of the land Use analysis in Dashboard I, the results in Fig. 44 revealed that M&R for CNG and DBs is the primary contributing factor. As a result, M&R has an impact on the results inside Qatar because it is present during the operation phase; consequently, the visualized results will show a slight increase in the rates of CNG buses and diesel buses. In the case of the EBs, outcomes are different because of the manufacturing phase, which significantly impacts the results. Accordingly, the impact on outside rates is greater than the impact on inside rates.

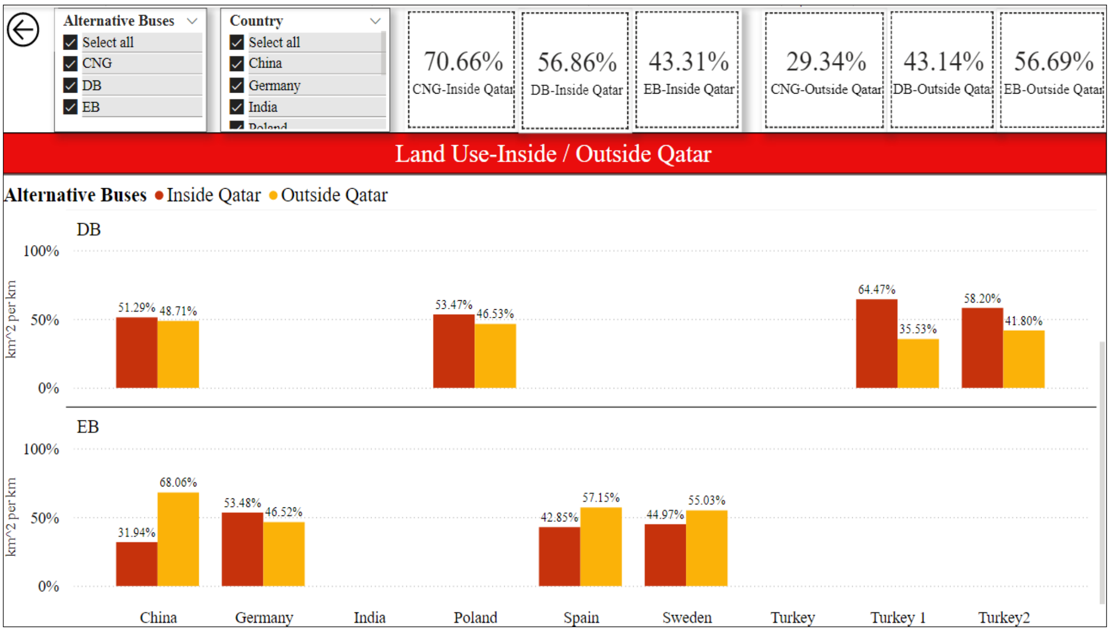


Figure 68 The average rates of Land Use emissions inside and outside Qatar

4.3.1.5. Water Consumption

EBs are also the most environmentally friendly buses in terms of water consumption. It reflects an average rate of approximately 54.95 percent for all four types of vehicles in Qatar; this was the lowest rate especially the Chinese EBs, as shown in Fig. 69. On the other hand, CNG buses had the highest impact inside Qatar, as illustrated in Fig.

[70](#).

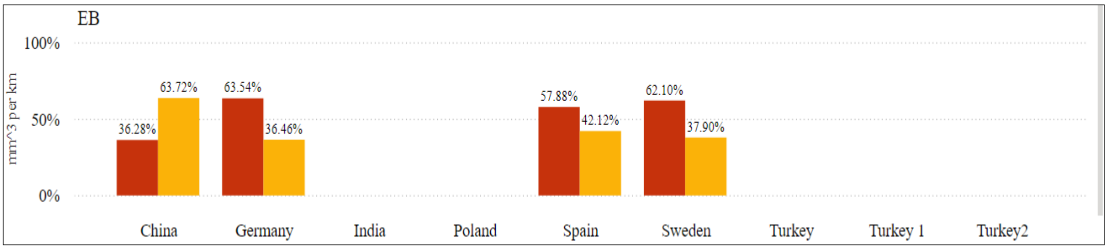


Figure 69 The results of the EBs with respect to the Water Consumption

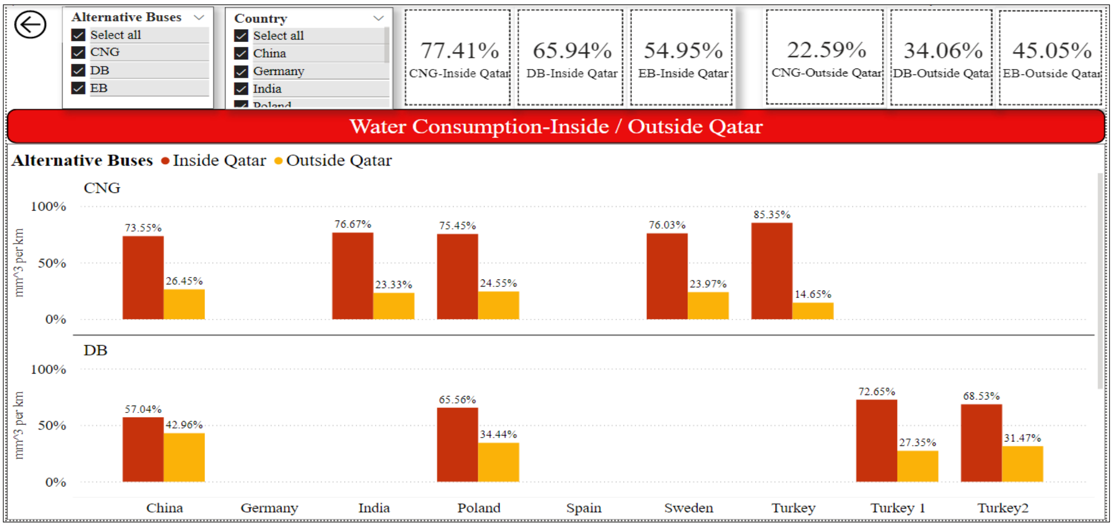


Figure 70 The average rates of Water Consumption emissions inside and outside Qatar

4.3.1.6. Water Withdraws

For the Water Withdraws impact, EBs were not recommended as it represents around 94.49 percent as an average rate of all types inside Qatar; this was the highest rate among the other buses, CNG, and DBs. This could be attributed to the massive volume of water that will be removed for the purpose of generating electricity through the use of electric generators, which is expected to be significant. On the other hand, CNG buses were the lowest, especially the Indian CNG buses with 38.56 percent inside Qatar and 61.44 percent outside Qatar, as shown in Fig. 71.

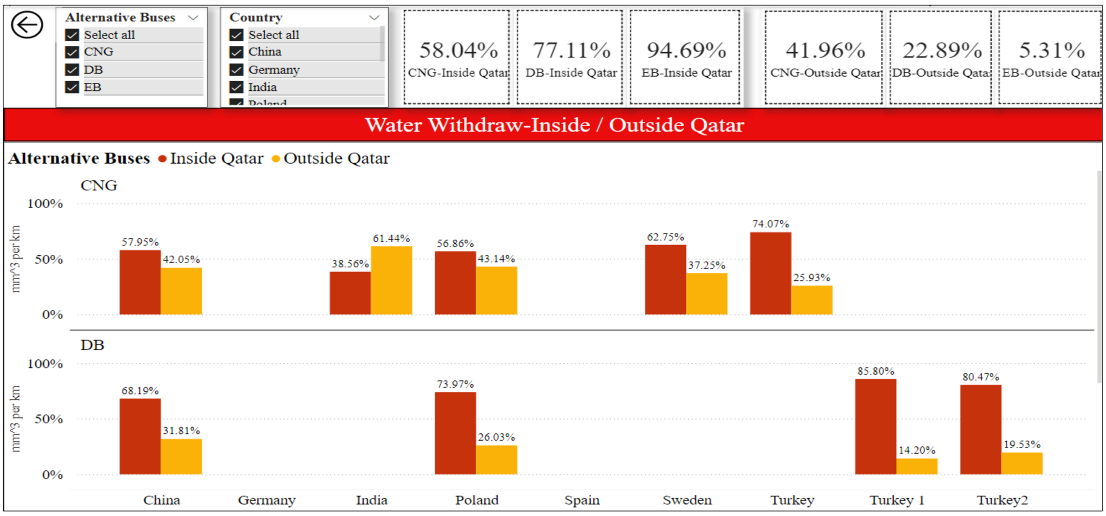


Figure 71 The average rates of Water Withdraw inside and outside Qatar

4.3.1.7. Environmental Impacts Results and Discussion

The results of the six indicators related to the environmental impact for the impacts inside and outside Qatar demonstrate that the Electric buses provided the best performance among the five environmental indicators. Only one incident was found where the EBs were not advised, which was in the Water withdraws indicator. This was related to the large volume of water that will be withdrawn in order to generate energy through the use of an electric generator.

4.3.2. Social Impacts

By examining the average findings of the four indicators in Fig. (72-75), the data reveal that the social impacts of electric buses will be preferred inside Qatar. There will be more detail on the findings in this section, as well as a more specific listing of the countries that manufacture the least social impact bus models.

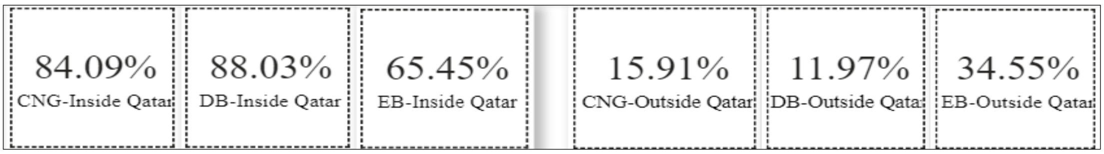


Figure 72 Human Health average results inside and outside Qatar

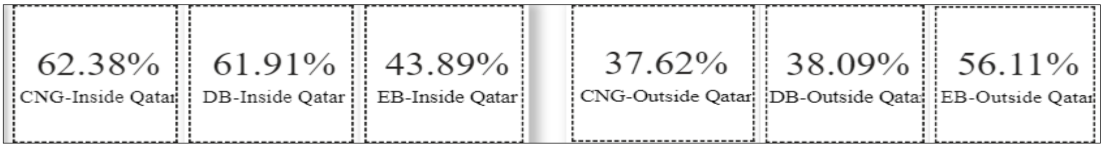


Figure 73 Employment average results inside and outside Qatar

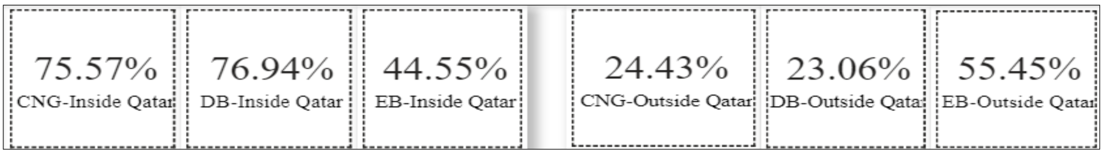


Figure 74 Compensation average results inside and outside Qatar

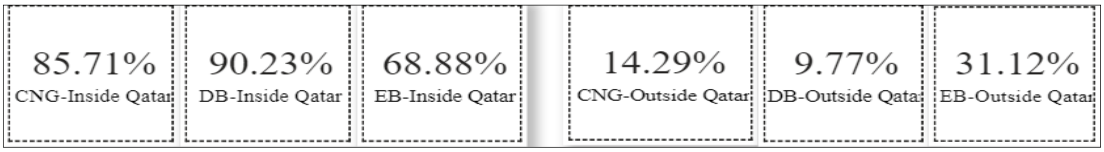


Figure 75 Tax average results inside and outside Qatar

4.3.2.1. Human Health

The Human health impact for the EBs is the lowest inside Qatar, ranging between 41.07 percent to 75.82 percent. Chinese Electric buses, with 41.07 percent inside Qatar, represent the best option.

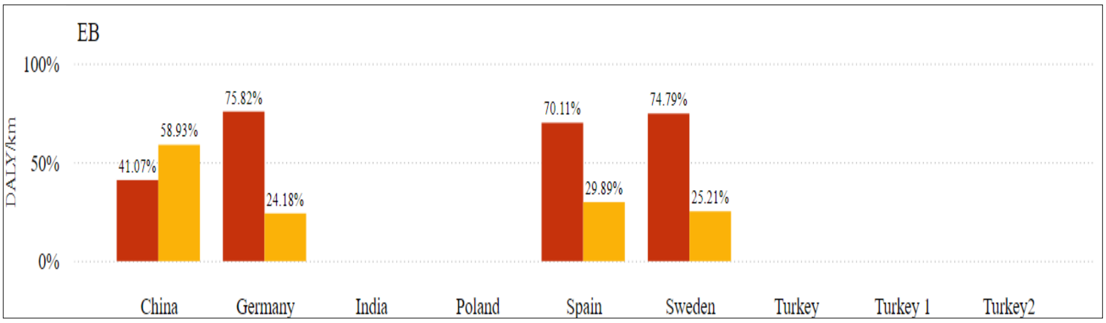


Figure 76 The EBs rates impact on human health

4.3.2.2. Employment

Fig. 77 presents the three types of AFBs and shows the variation among the rates. As mentioned earlier, the EBs represent the lowest impact rate inside Qatar, and it is recommended.

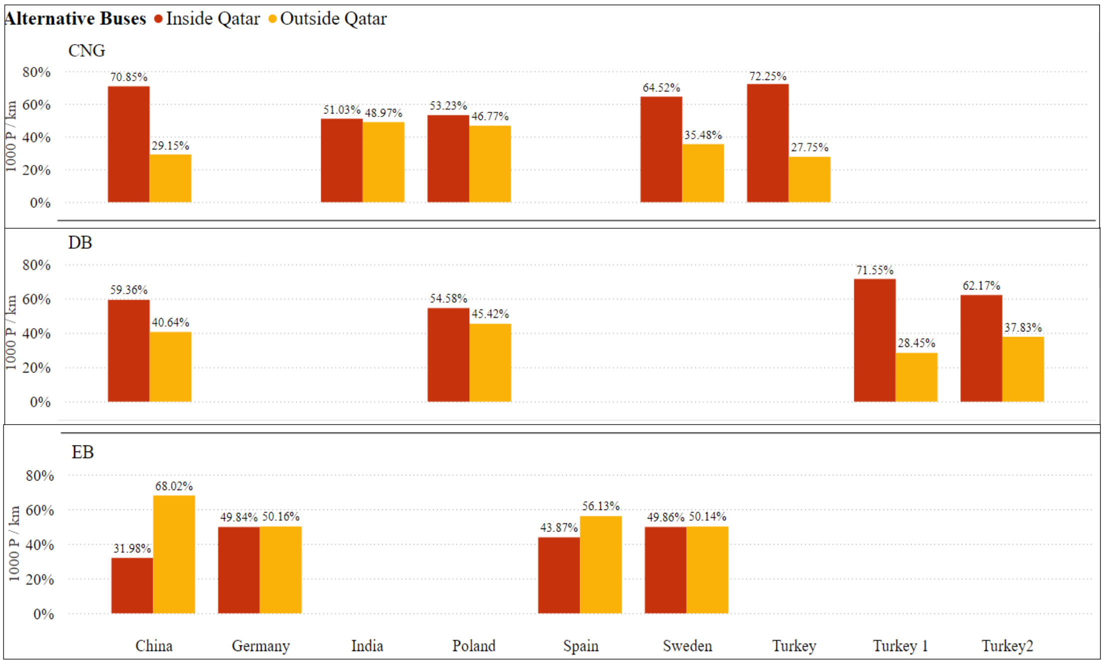


Figure 77 Employment impact rate for the three AFBs

4.3.2.3. *Compensation*

Referring back to the results in Fig. 54, the manufacturing phase for the EBs was the highest factor among the other phases; this was reflected in the rates related to the impact inside and outside Qatar. Since the operation phase is the main contributor to the results inside Qatar, the rates were the lowest for the EBs among the other types.

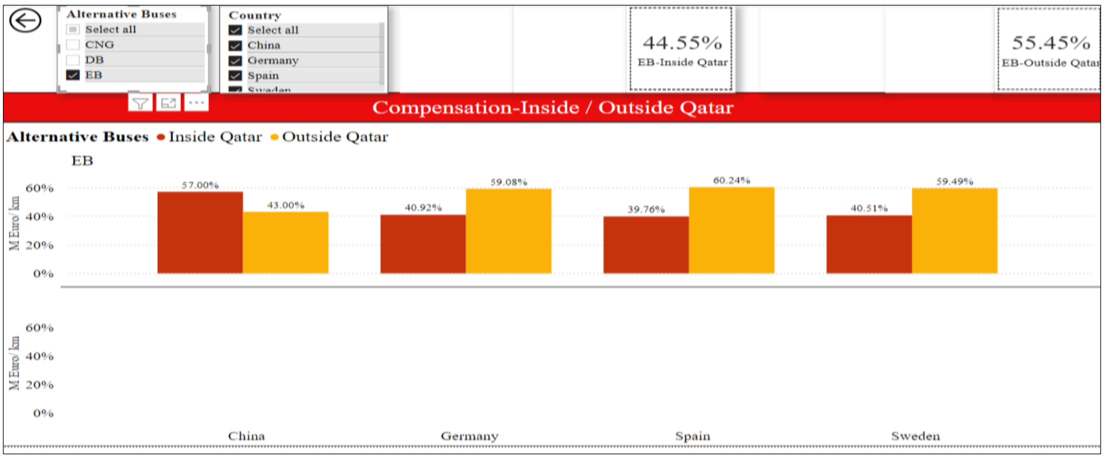


Figure 78 The rates of the EBs

4.3.2.4. *Tax*

For the Tax Impacts, the rates were high in general, even for the EBs, representing the lowest rates within Qatar; the lowest-rated rate was 63.71 percent, which is more than half the entire impact. Outside of Qatar, the results have a less significant impact. Despite the high rates, EBs have the greatest impact compared to the other buses, with 63.71 percent to 75.95 percent in Qatar. On the other hand, it had the lowest influence, with a 7.01 percent rating outside Qatar.

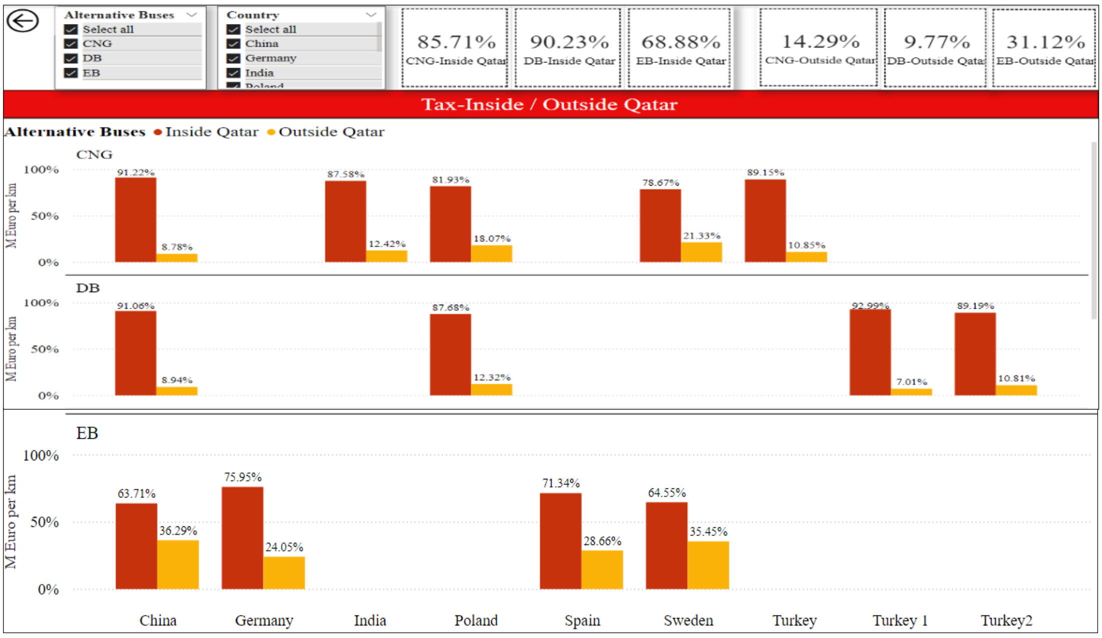


Figure 79 The dashboard of the Tax impact inside and outside Qatar

4.3.2.5. *Social Impacts Results and Discussion*

The social impact showed a high tendency for the EBs to present the lowest rates. The outcomes were close to the results of the Environmental impact; both impacts conclude that the EBs have the best rates inside Qatar, even if it was higher than the outside impacts, but when compared to the CNG buses and Diseal buses, EBs show more satisfying results.

4.3.3. *Economic Impacts*

The operational surplus and the gross domestic product (GDP) are economic impact indicators. For each indicator, further specifics will be presented and explained in greater depth. According to the economic impact factors, the recommended type of buses will better indicate which type to suggest for Qatar with the least impact.

4.3.3.1. *Operating Surplus*

Fig. 80 shows the dashboard of the Operational surplus, where we can clearly view the high difference in the rate between the DBs and the EBs. The EBs present 37.34 percent on average inside Qatar, while the DBs show the highest rate of 83.52 percent on average.

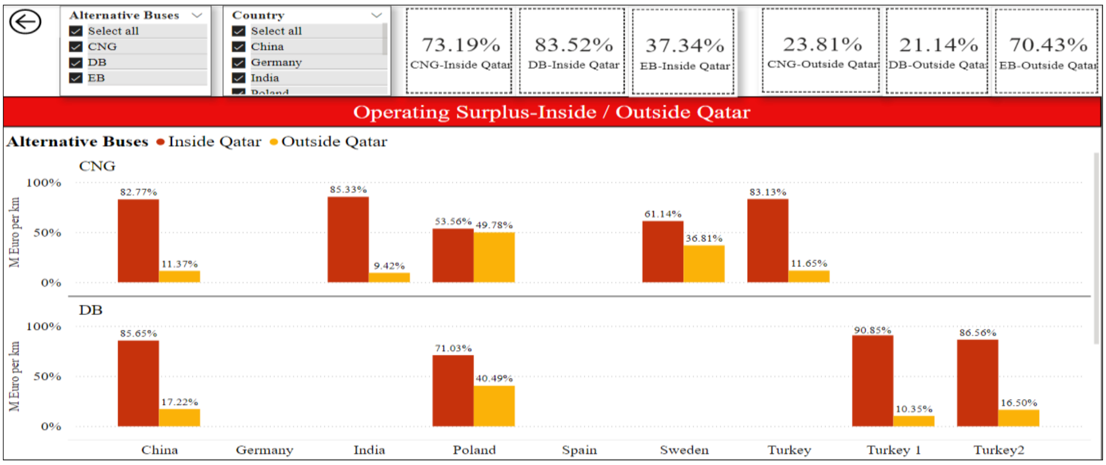


Figure 80 Operating Surplus dashboard

The Electric buses present the lowest rates, which reached 34.86 percent inside Qatar, and 76.79% outside Qatar, as shown in Fig. 81.

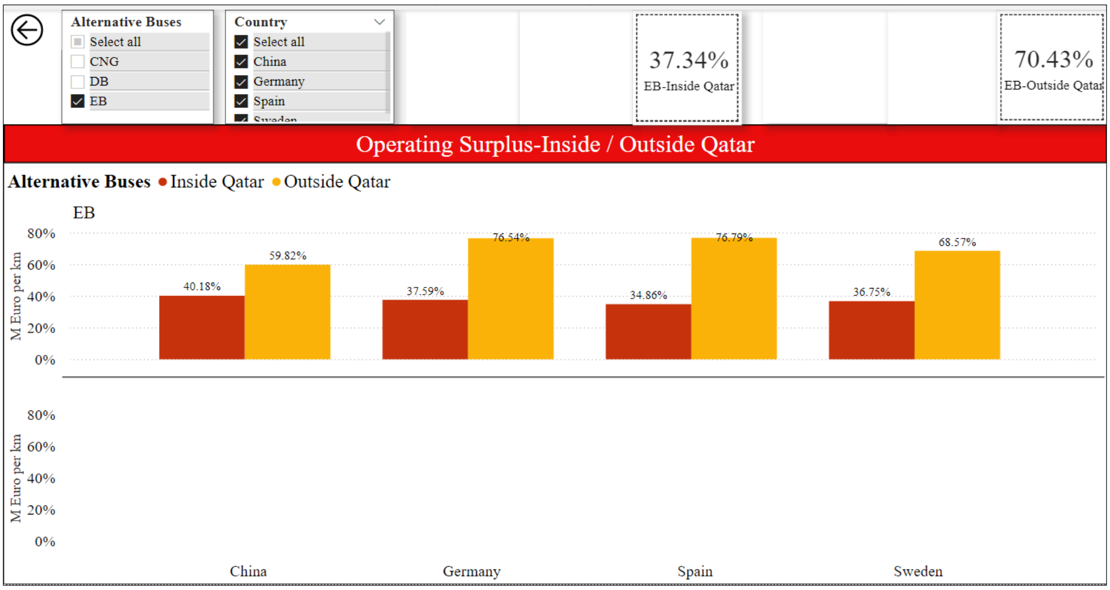


Figure 81 EBs rates for operating surplus indicator

4.3.3.2. GDP

GDP also showed a low impact inside Qatar for the electric buses and high for the Disal buses. The rates were also lower inside Qatar than the rates outside the country for the EBs; Fig. 82 shows the total rates and variation between the rates.

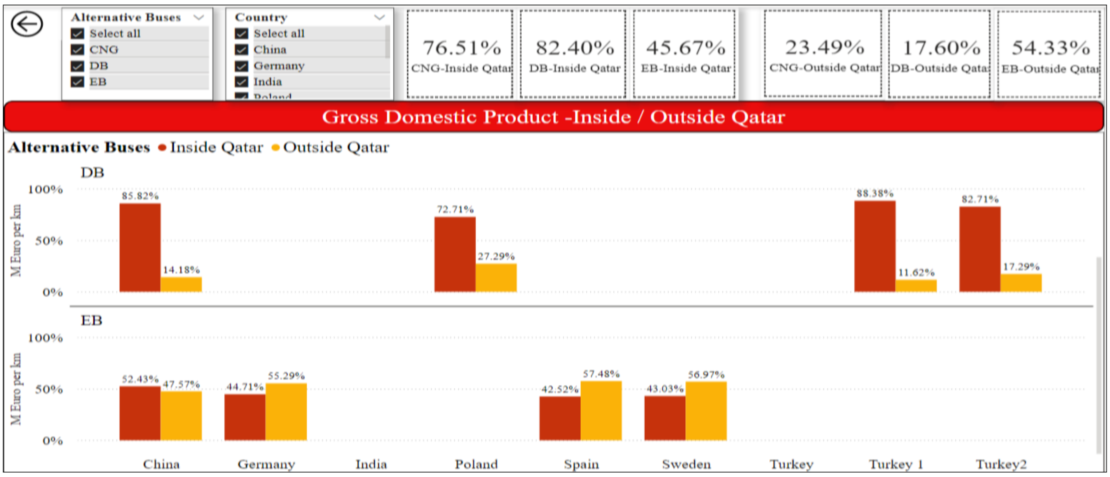


Figure 82 GDP dashboard for the impacts inside and outside Qatar

4.3.3.3. Economic Impacts Results and Discussion

EBs were found to be the most effective and favored form of a bus in Qatar, according to the findings of the economic impact study. Economic indicators were generally more favorable inside Qatar than outside the country.

4.4. Dashboard III

Dashboard III depicts the overall costs for each bus type across its entire life cycle. The LCC was the total cumulative costs of the initial cost, fuel cost, infrastructure, maintenance and repair, insurance cost, and replacement cost; to provide the entire cost, the salvage value was reduced from the expenses presenting the total cost. The overall cost dashboard will be an advantage for the decision-maker to specify the necessary buses that will meet the needs of several stakeholders while remaining within a realistic budget. This dashboard will offer the flexibility of displaying the average total result, using visuals presenting the CNG average total cost, the DB average total cost, and the EB average total cost. The findings reveal that DBs have the highest average cost for the four DB types that could be imported from Poland, Turkey, and China. The average cost of the DBs is $2.5 million, which represents the highest cost for buses throughout a 10-year lifetime. The EB buses are the second most expensive, with an average cost of $1.41 million, a difference of around $90,000 from the DB buses. With an average cost of $1.29M, CNG buses are the most cost-effective option. The filters were available to give the users the capability of specifying each country or alternative bus type to show more cost details for the chosen factors. The chart that shows the results and visualizes them is called the graphomate chart, where it presents the cost of each factor separately, then provides in red the total cost of each bus type.

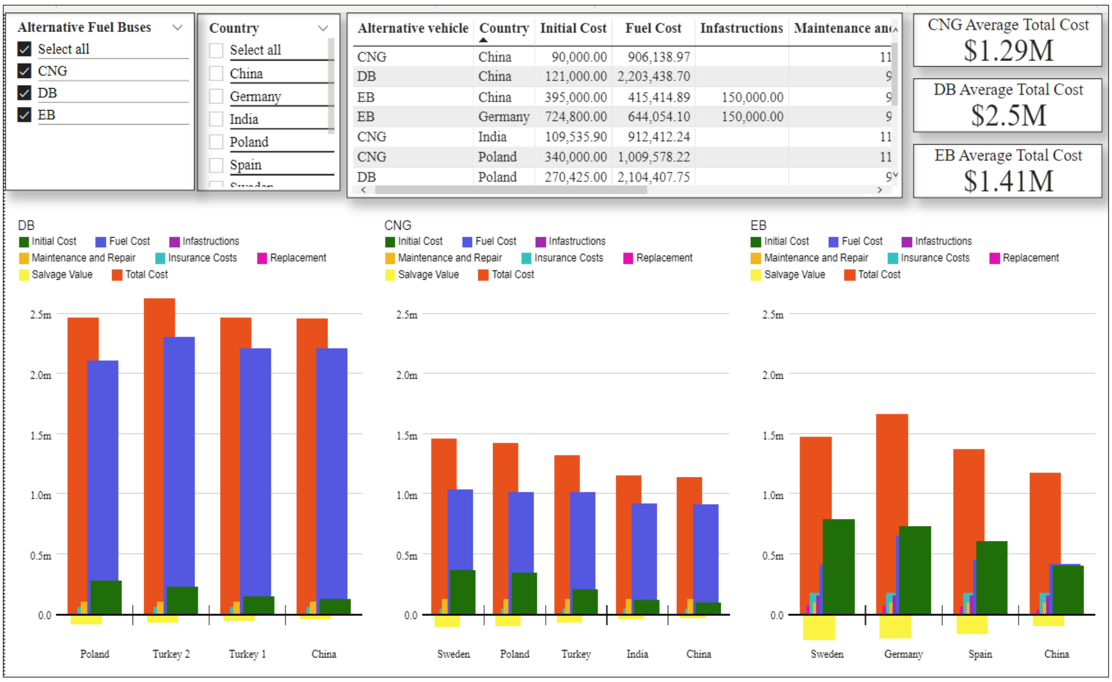


Figure 83 LCC Dashboard (M$)

4.4.1. LCC Results and Discussion

After developing an understanding of how the dashboard functions, we will explore the findings of the dashboard analysis. Fig. 84 demonstrates that the DBs have the highest cost, which is consistent with the findings of the three impacts and their indicators, which indicated that the DBs had the least recommended results. Various costs associated with the DBs ranged between $2.6M and $2.4M. The fuel cost is the most significant contributor to the cost increase, accounting for more than 89 percent of the entire cost. The findings for the EBs were lower than those for the DBs. This fluctuation is mainly a result of factors, including initial and fuel costs; also, the expense of infrastructure contributes to increasing the costs of EBs. It was found that out of all bus types, EBs had the highest salvage value. However, when it comes to cost efficiency, the CNG buses outperformed all other options, with a cost ranging from $1.1 million to $1.4 million. Based on the results of the indicators and the impact on the state of Qatar, the EBs and CNG buses were also suggested as the lowest-impact buses (inside and outside Qatar).

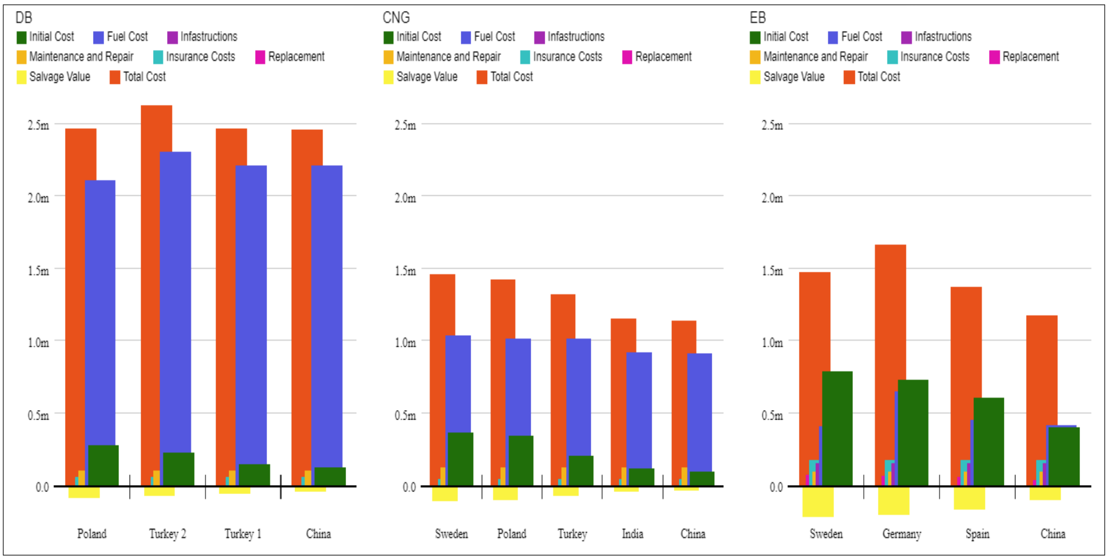


Figure 84 Graphomate chart visualizing the AFBs outcomes

4.5. Dashboard IV

This Dashboard illustrates the indicators of high and low impacts considering the two EoL scenarios and their effect on the total value; it also recommends the country of production for a specific bus type. Our main concern here is the impact of the End-of-life scenarios on each indicator and how the results will reflect on each indicator. Dashboard IV will present the findings of each indicator in each manufacturing country for each bus type; additionally, we will compare the visualizations considering the effect of the two EoL scenarios. Fig. (85-86) shows the results of the China and India scenarios, respectively.

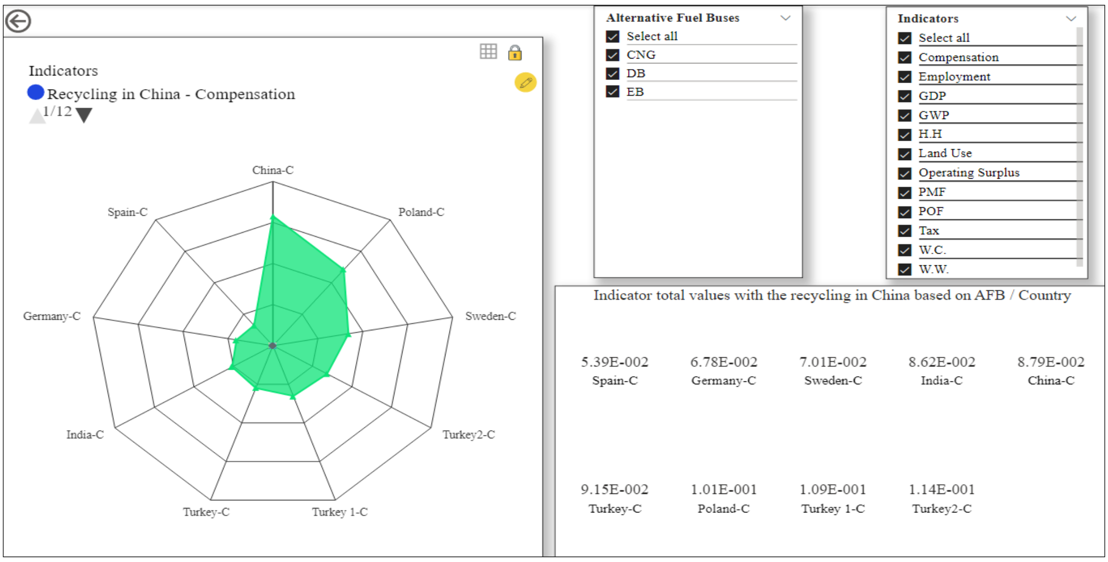


Figure 85 Indicators per country and alternative bus-China

Figure 86 Indicators per country and alternative bus-India

In the coming sections, it is planned to analyze each sustainability impact, with the results of each indicator illustrated in two scenarios. An illustration of the outcomes of each indicator will be shown in all figures from a-k. There will then be a discussion and recommendations that will be offered related to the country that will have the best impact as an importer.

4.5.1. Environmental Impact

The environmental impact of six indicators and three bus types is visualized below. Each bus type is illustrated in two scenarios for each indicator and bus type. Figures (87-92) will show all of the impacts of the six indicators for the CNG buses, DBs, and EBs on the countries of manufacture. The figures below show that the difference in total values between the China recycling scenario and the India recycling scenario is not significant. In some cases, it is not even observable. Still, there are specific indicators where the recycling scenarios have a significant impact on them: land use and water withdrawal. In general, it is noticeable from the visuals the variance in the values, which can be observed in the CNG buses and the DBs. In terms of land use, according to Fig. 90, China has a more significant benefit than India because China's land usage is lower than India's; as a result, the outcomes associated with China scenarios are more appropriate, and decision-makers will consider this more. The difference in values between China and India may be clearly seen in the outcome of the water withdrawal outcomes depicted in Fig.91. India does have better results than China since the outcomes of the India scenario are lower. The results will be disclosed by examining all of the data and comparing them to each alternative bus. The results indicate that most CNG buses are oriented toward the Turkish CNG buses related to the China scenario. Turkish diesel buses outperformed all other diesel buses types, and the results also revealed that India's recycling scenario yielded greater benefits than China's recycling scenario. According to performance, CNG buses were the outperformed type for the best performance bus among all three main bus types and the majority of the indicators. Swedish Electric buses were the best among the GWP indicator results, and the result correlated with the China recycling scenario produced the best returns.

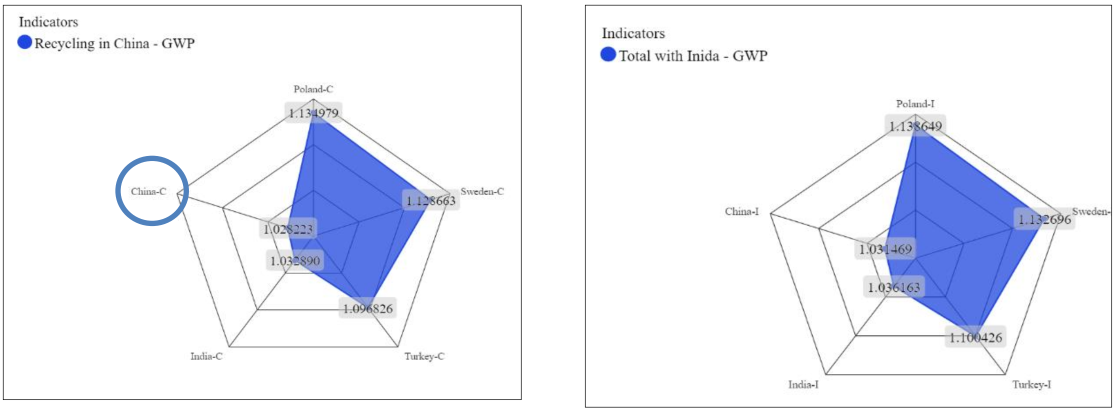


Figure 87 a) CNG bus-GWP impacts in country (China and India scenario)

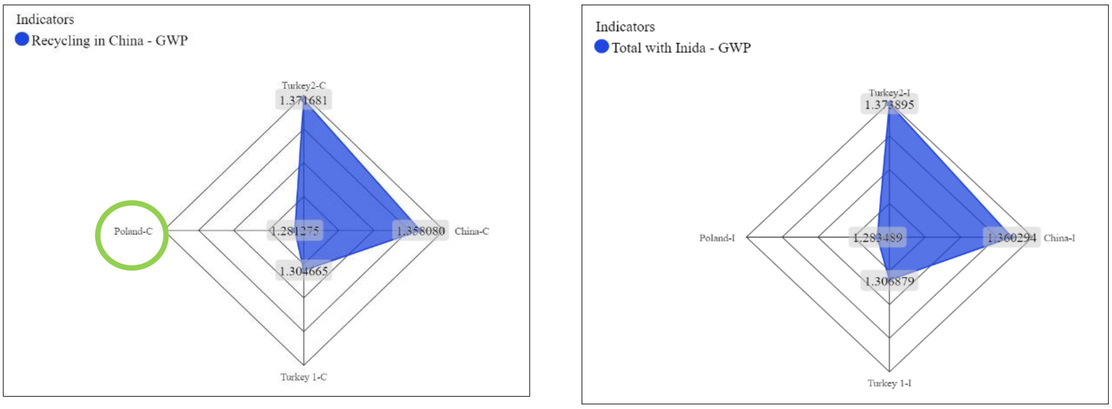


Figure 87 b) DB-GWP impacts in countries (China and India scenario)

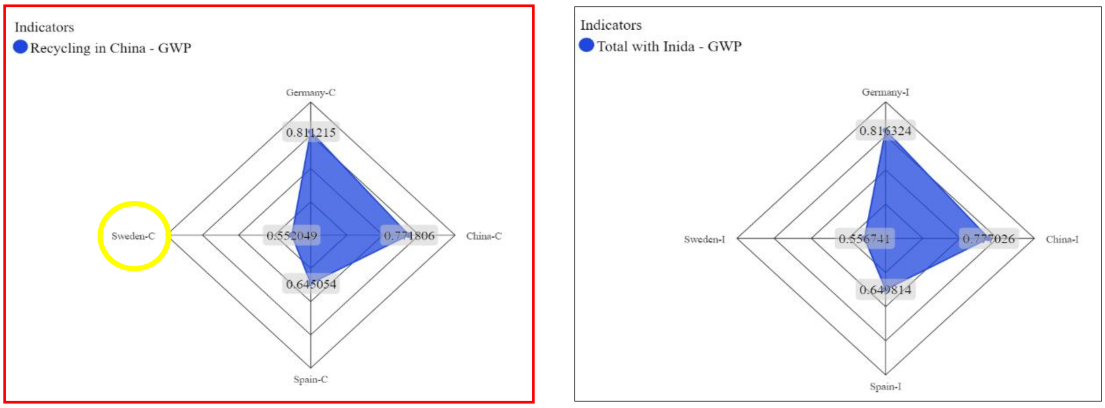


Figure 87 c) EB-GWP impacts in countries (China and India scenario)

Figure 87 GWP impacts in-country for EBs, CNG, and DBs

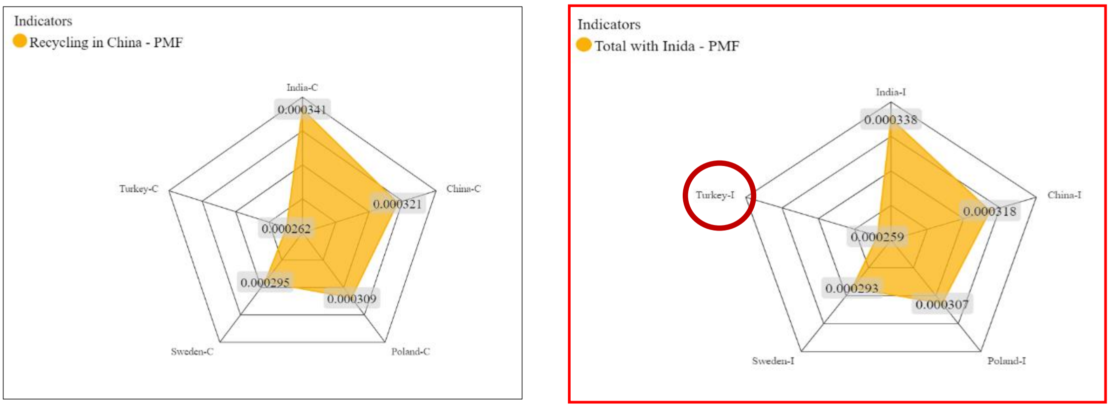


Figure 88 a) CNG bus-PMF impacts in country (China and India scenario)

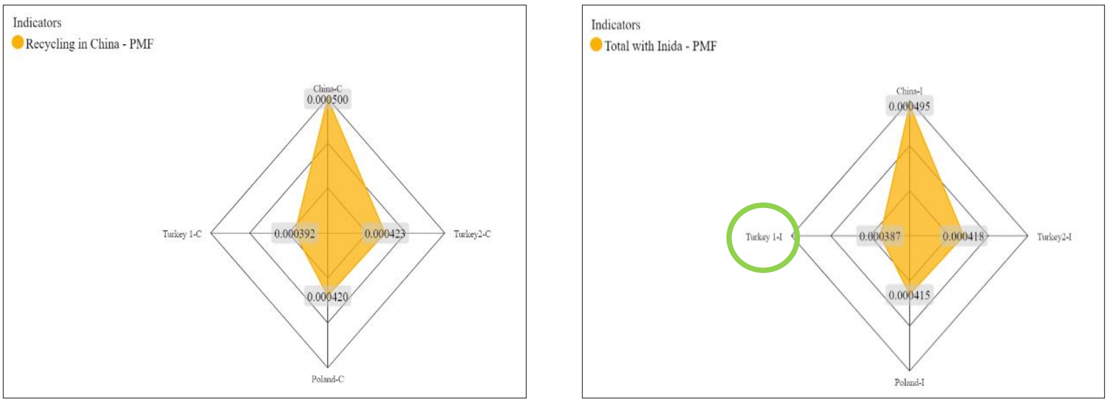


Figure 88 b) DB bus-PMF impacts in country (China and India scenario)

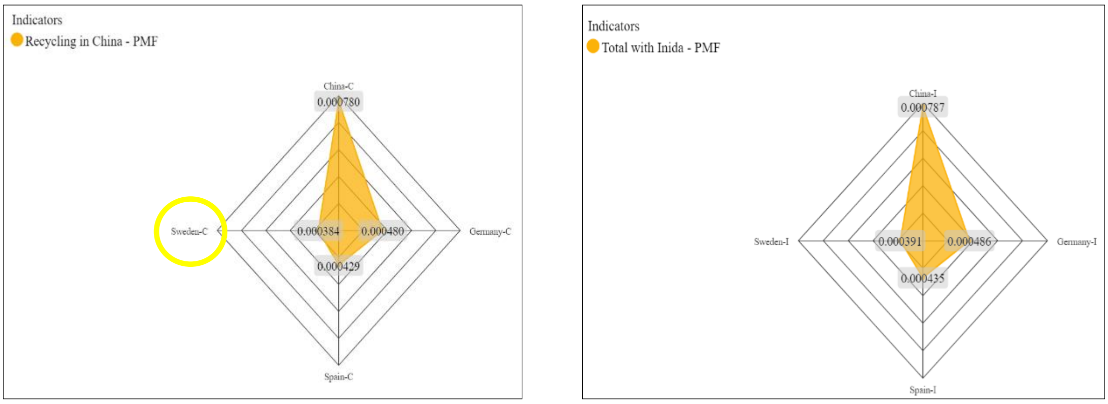


Figure 88 c) DB bus-PMF impacts in country (China and India scenario)

Figure 88 PMF impacts in-country for EBs, CNG, and DBs

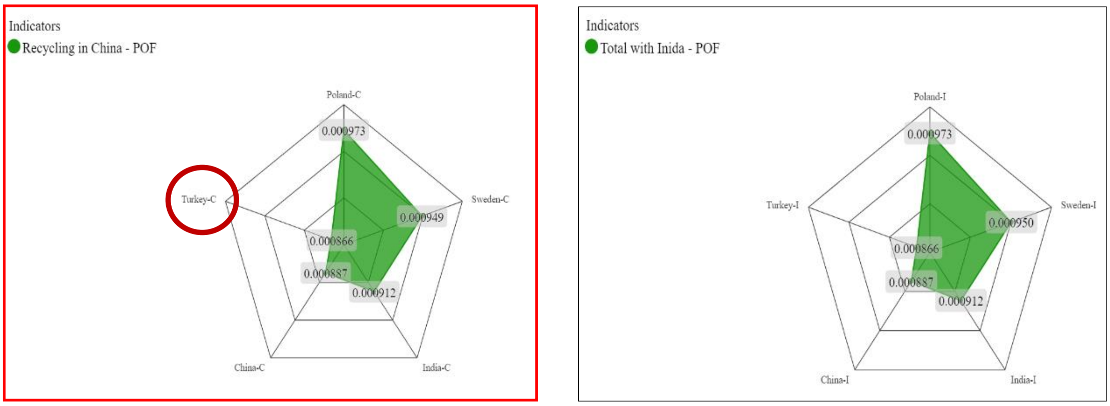


Figure 89 a) CNG bus-POF impacts in country (China and India scenario)

Figure 89 b) DB bus-POF impacts in country (China and India scenario)

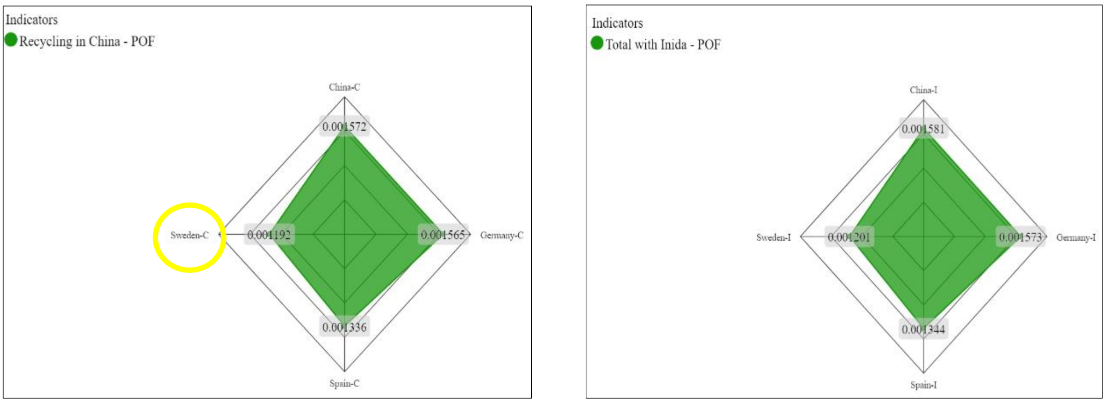


Figure 89 c) EB bus-POF impacts in country (China and India scenario)

Figure 89 POF impacts in-country for EBs, CNG, and DBs

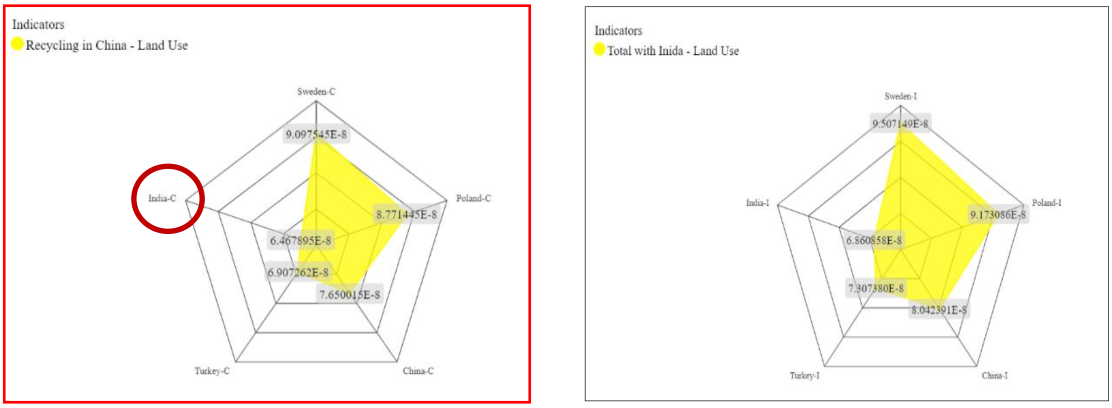


Figure 90 a) CNG bus-Land Use impacts in country (China and India scenario)

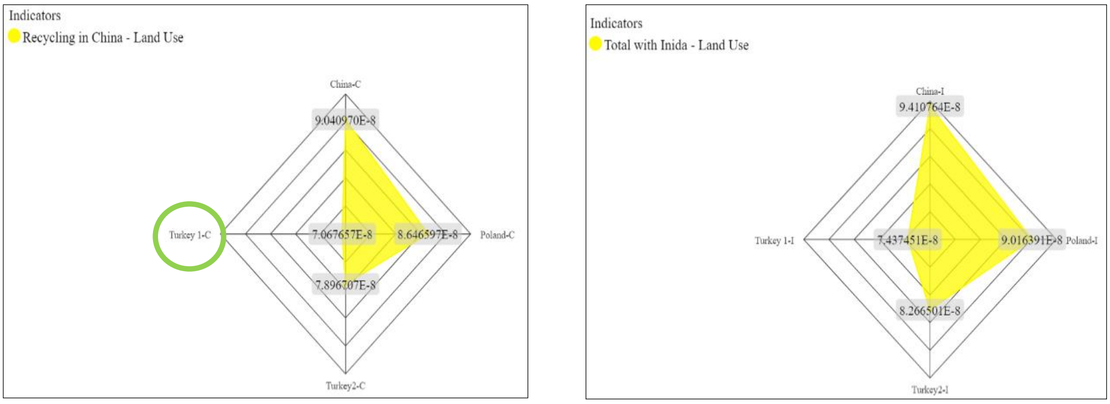


Figure 90 b) DB bus-Land Use impacts in country (China and India scenario)

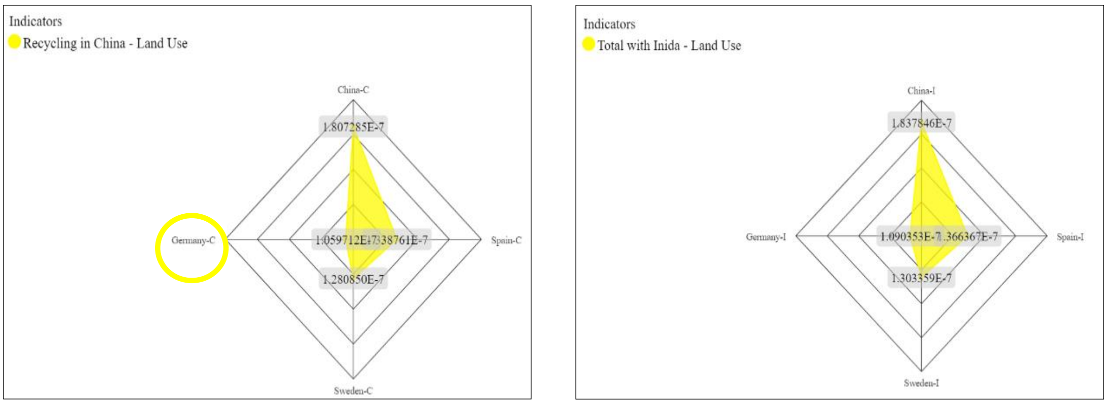


Figure 90 c) EB bus-Land Use impacts in country (China and India scenario)

Figure 90 Land Use impacts in-country for EBs, CNG, and DBs

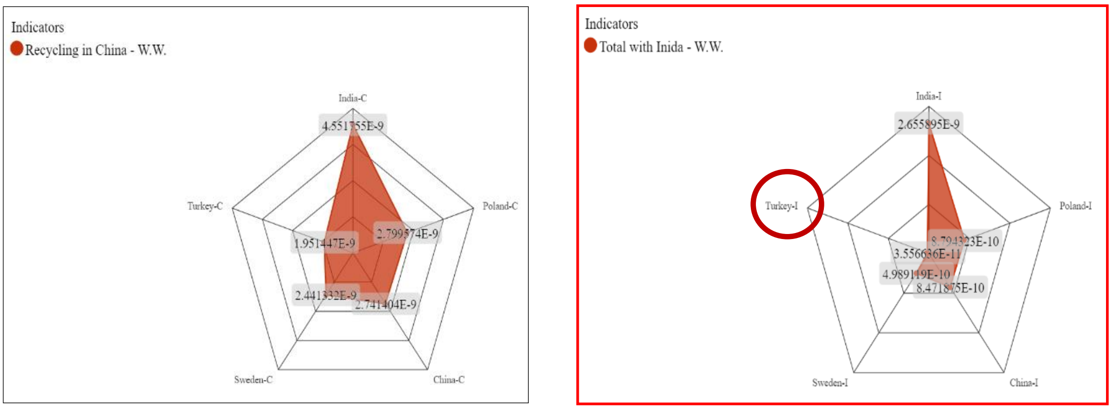


Figure 91 a)CNG bus- water withdrawal impacts in country (China and India scenario)

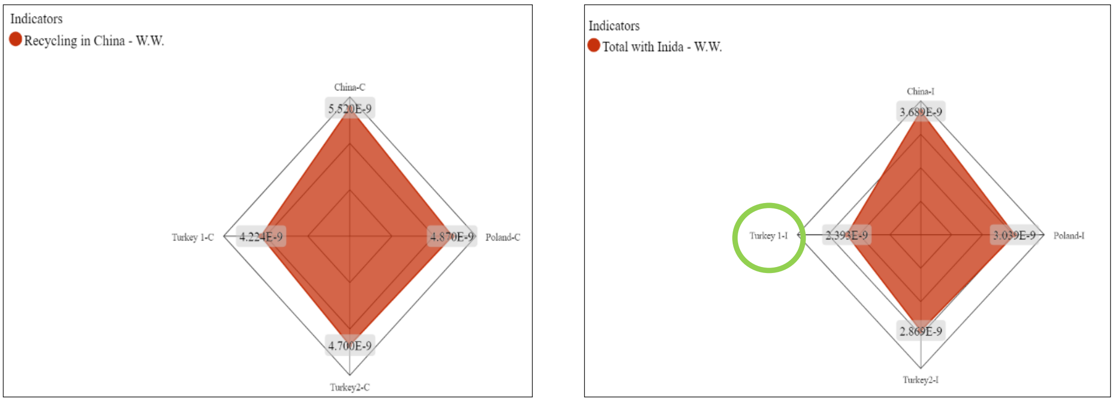


Figure 91 b) DB bus- water withdrawal impacts in country (China and India scenario)

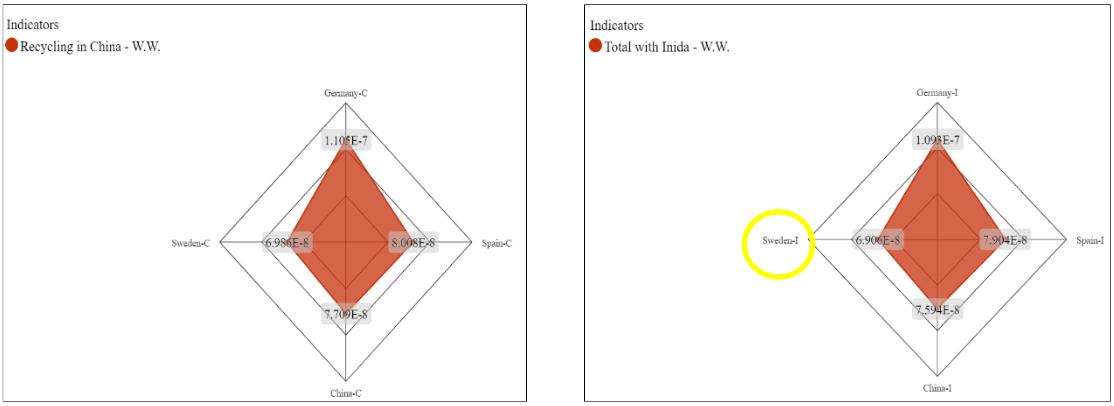


Figure 91 c) EB bus- water withdrawal impacts in country (China and India scenario)

Figure 91 water withdrawal impacts in-country for EBs, CNG, and DBs

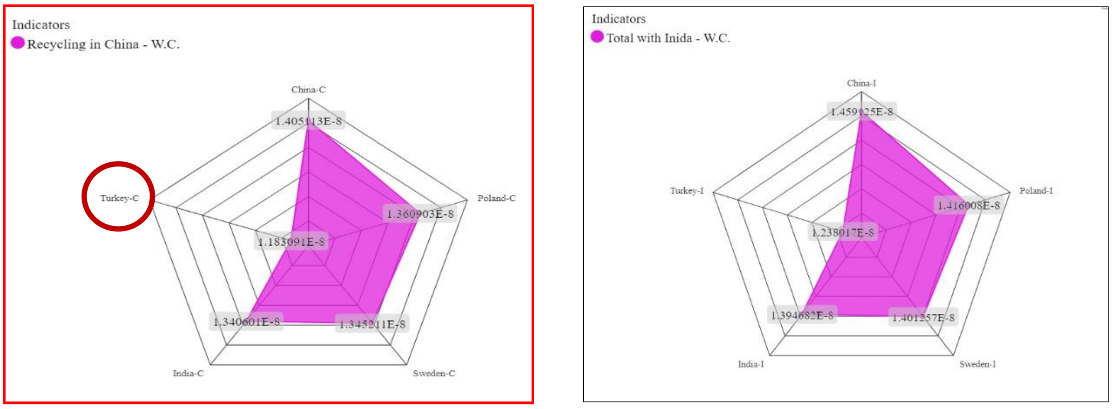


Figure 92 a) CNG bus- water consumption impacts in country (China and India)

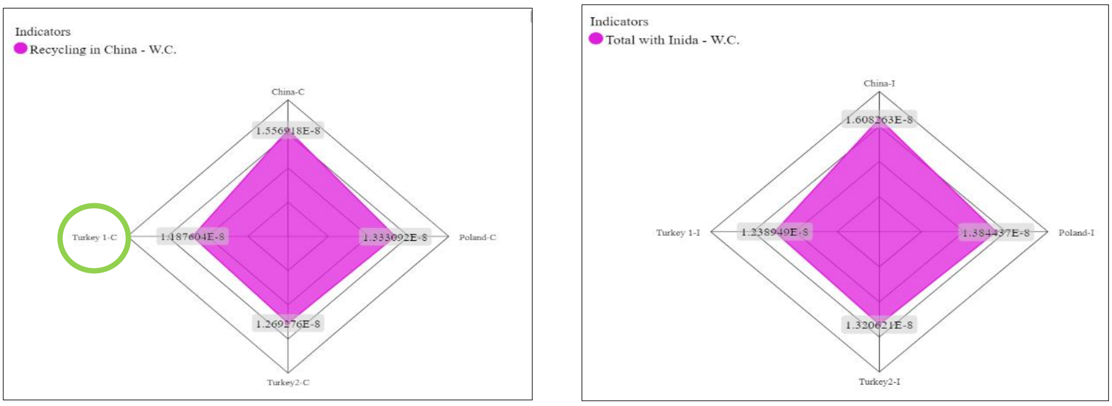


Figure 92 b) DB bus- water consumption impacts in country (China and India)

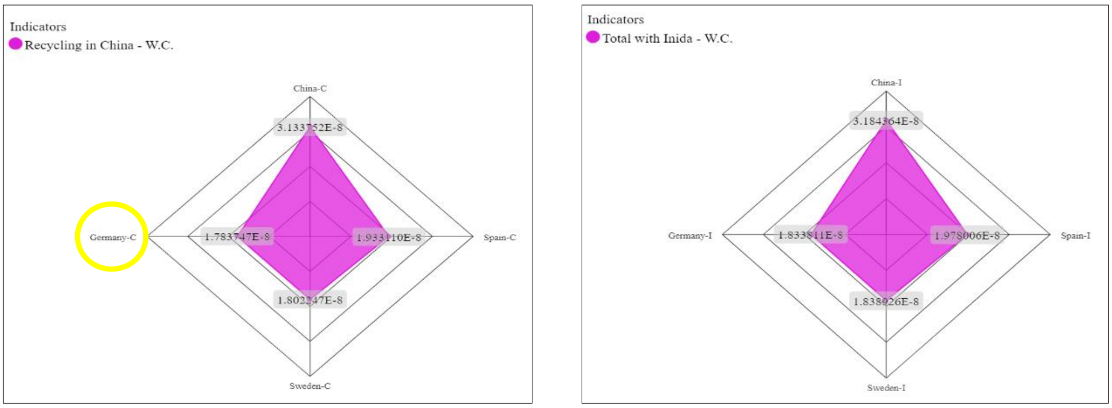


Figure 92 c) EB bus- water consumption impacts in country (China and India)

Figure 92 Water Consumption impacts in-country for EBs, CNG and DBs

4.5.2. Social Impact

The following visual representation of the social impact of four indicators and three bus types. It is presented in two scenarios for each indicator and bus type for each bus type.

Fig. (93-96) will demonstrate all of the impacts of the four indicators for CNG buses, DBs, and EBs on the countries where they were manufactured. According to the figures shown below, the overall value difference between the recycling scenarios in China and India is not significant. By examining all of the data and comparing it to each alternate bus. The findings will show that Turkish diesel performed better than all other diesel bus types in the study.

Additionally, India's recycling scenario did better than China's recycling scenario, indicating that India's recycling scenario is more beneficial. Sweden's electric buses outperformed its competitors in terms of compensation. In general, findings associated with the China recycling scenario gave the best returns. DB's buses outperformed the competition in all three major categories, and the majority of the indications for the best-performing bus come from the perspectives of employment and tax.

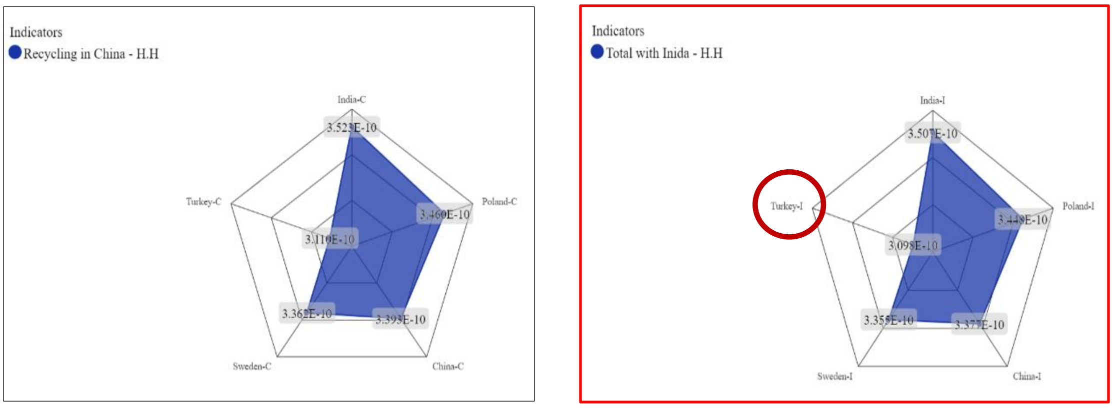


Figure 93 a) CNG bus- Human health impacts in country (China and India scenario)

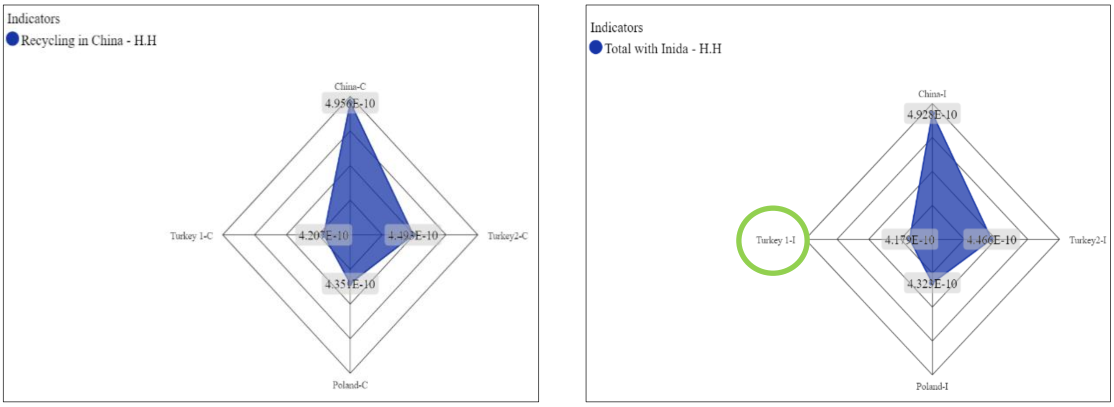


Figure 93 b) DB- Human health impacts in country (China and India scenario)

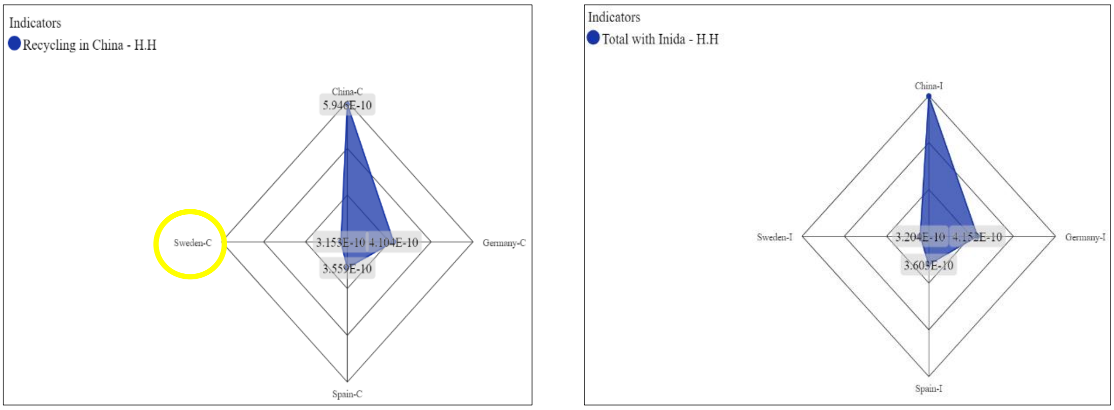


Figure 93 c) EB- Human health impacts in country (China and India scenario)

Figure 93 Human health impacts in-country for EBs, CNG and DBs

Figure 94 a) CNG bus- Employment impacts in country (China and India scenario)

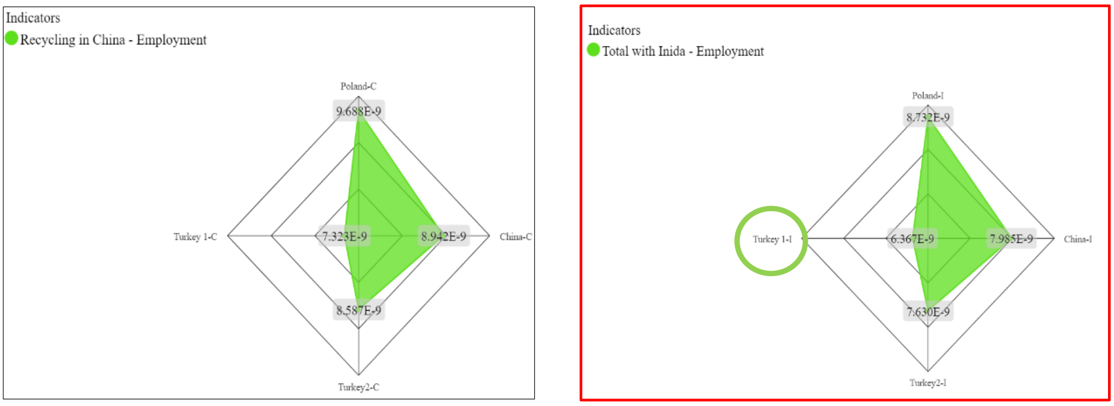


Figure 94 b) DB- Employment impacts in country (China and India scenario)

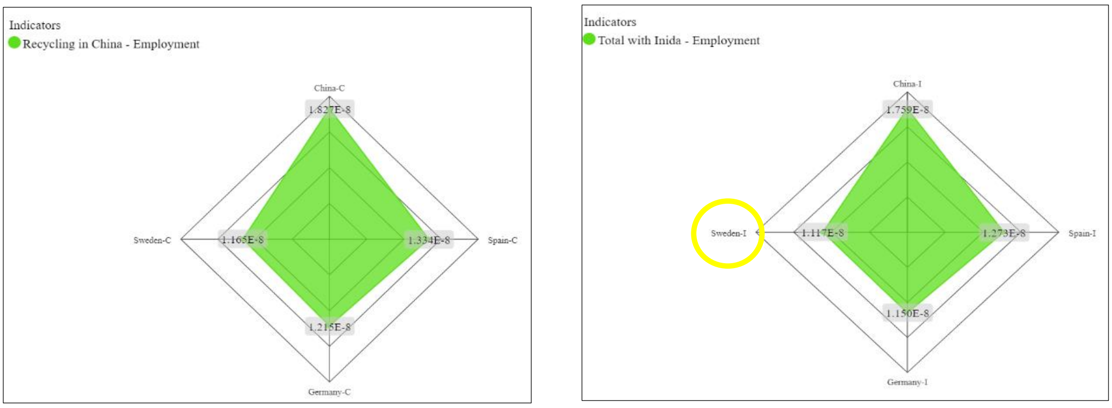


Figure 94 c) EB- Employment impacts in country (China and India scenario)

Figure 94 Employment impacts in-country for EBs, CNG, and DBs

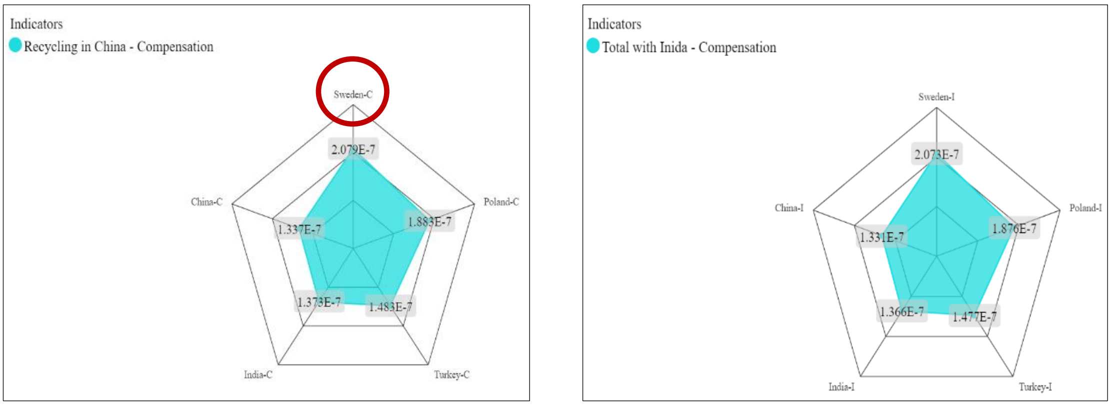


Figure 95 a) CNG bus- compensation impacts in country (China and India scenario)

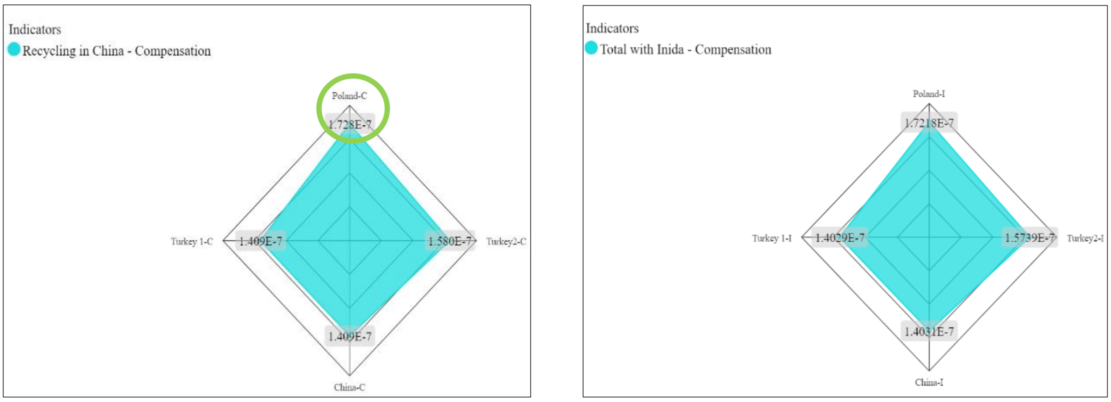


Figure 95 b) DB- compensation impacts in country (China and India scenario)

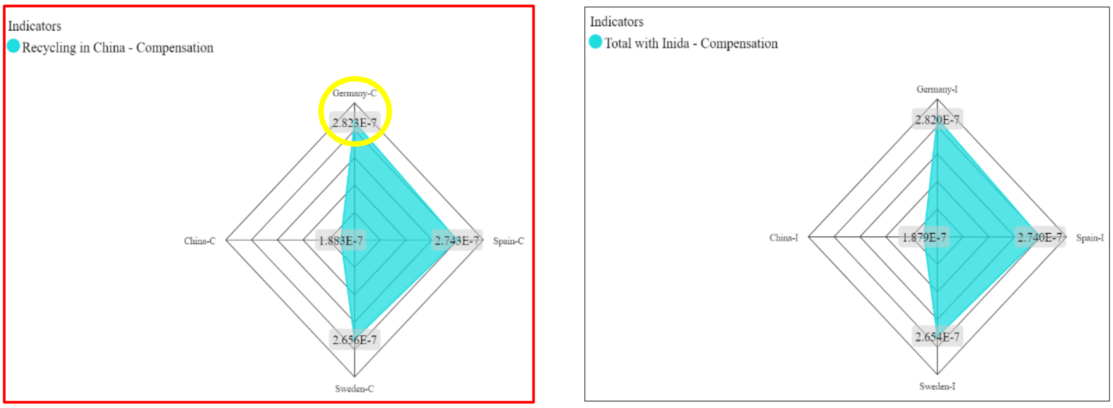


Figure 95 c) EB- compensation impacts in country (China and India scenario)

Figure 95 Compensation impacts in-country for EBs, CNG, and DBs

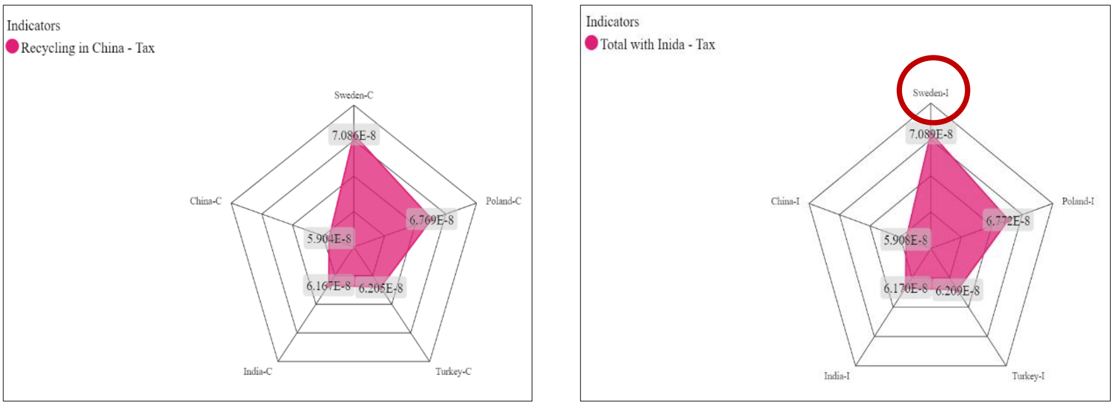


Figure 96 a) CNG bus- tax impacts in country (China and India scenario)

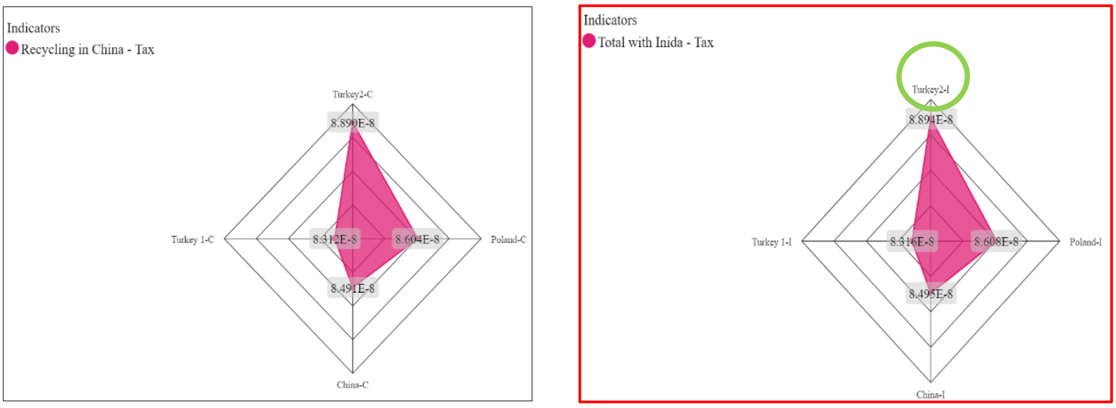


Figure 96 b) DB- tax impacts in country (China and India scenario)

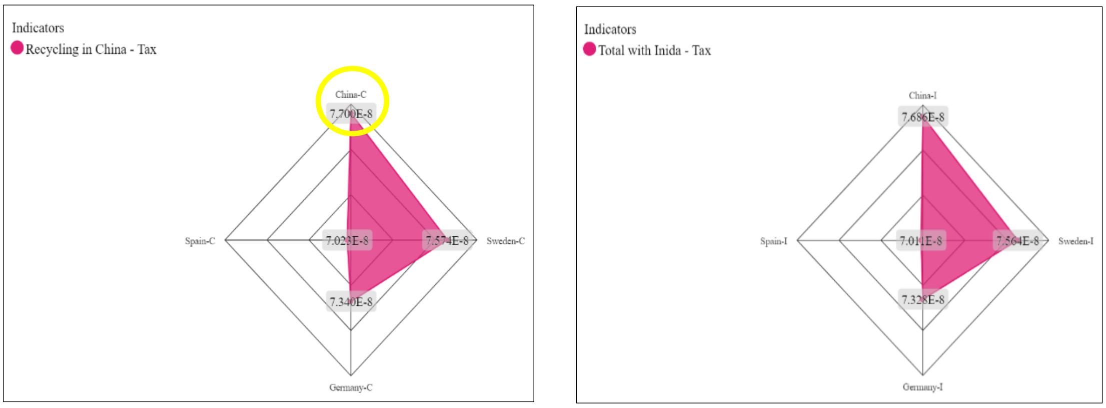


Figure 96 b) DB- tax impacts in country (China and India scenario)

Figure 96 Tax impacts in-country for EBs, CNG and DBs

4.5.3. Economic Impact

Fig. (97-98) illustrates the combined effects of the two indicators. According to the statistics, the Polish DBs buses outperformed all three major bus types in terms of operating surplus indicators. German EBs outperformed all other types for the GDP indicator. These findings corroborate our earlier discussions' analysis of the outcomes. Furthermore, India's recycling scenario outperformed China's recycling scenario in terms of the operating surplus indicator. However, China's recycling scenario is more beneficial to the GDP indicator.

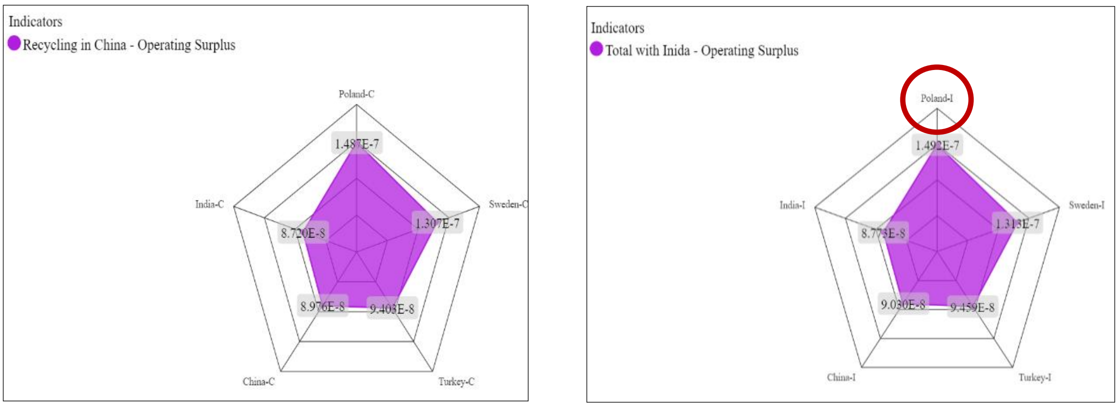


Figure 97 a) CNG bus- operating suplus impacts in country (China and India scenario)

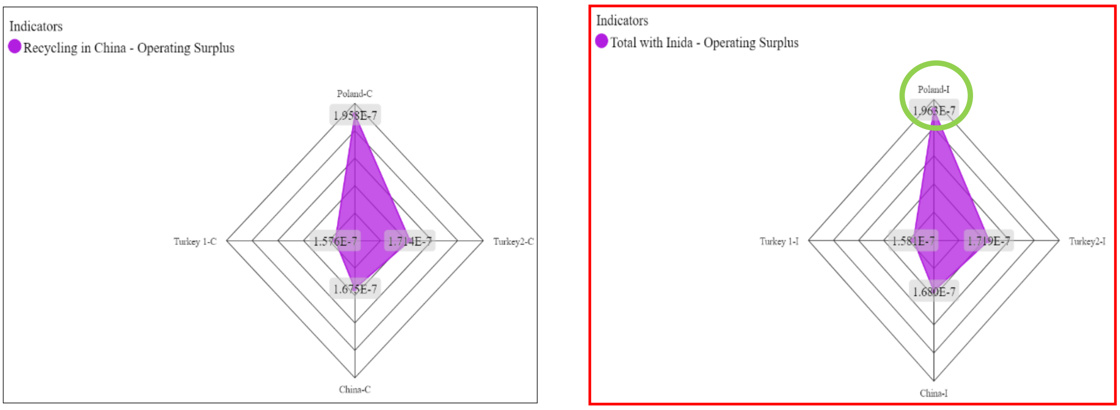


Figure 97 b) DB- operating suplus impacts in country (China and India scenario)

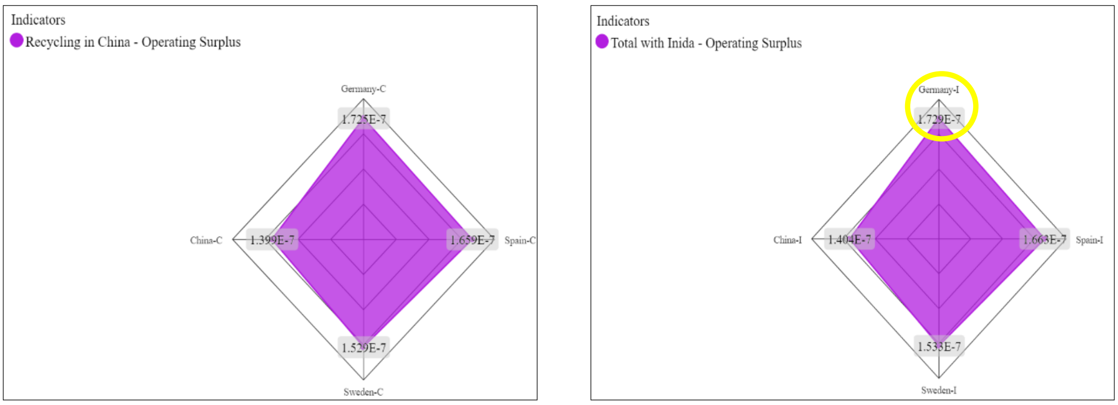


Figure 97 c) EB- operating suplus impacts in country (China and India scenario)

Figure 97 Operating impacts in-country for EBs, CNG, and DBs

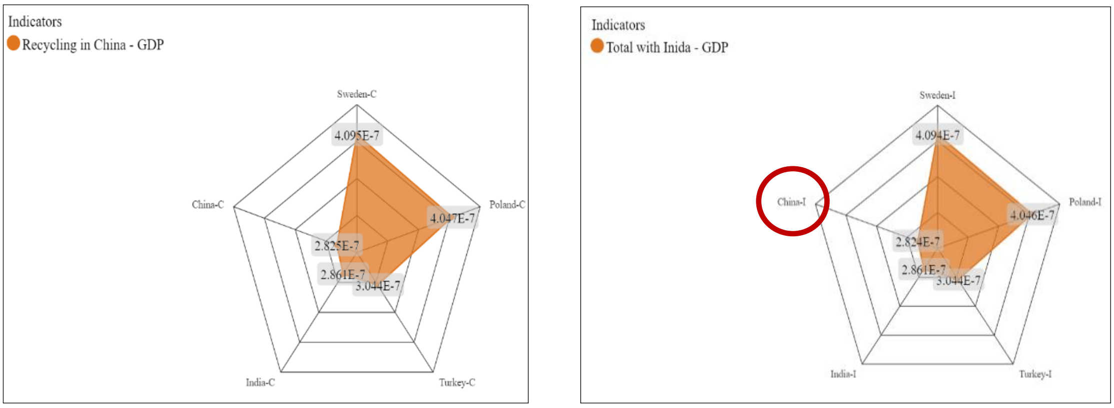


Figure 98 a) CNG bus- GDP impacts in country (China and India scenario)

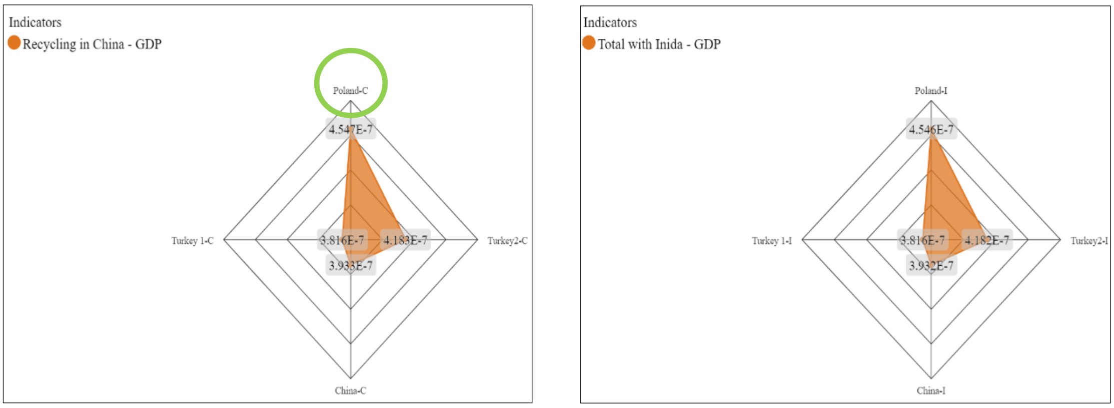


Figure 98 b) DB- GDP impacts in country (China and India scenario)

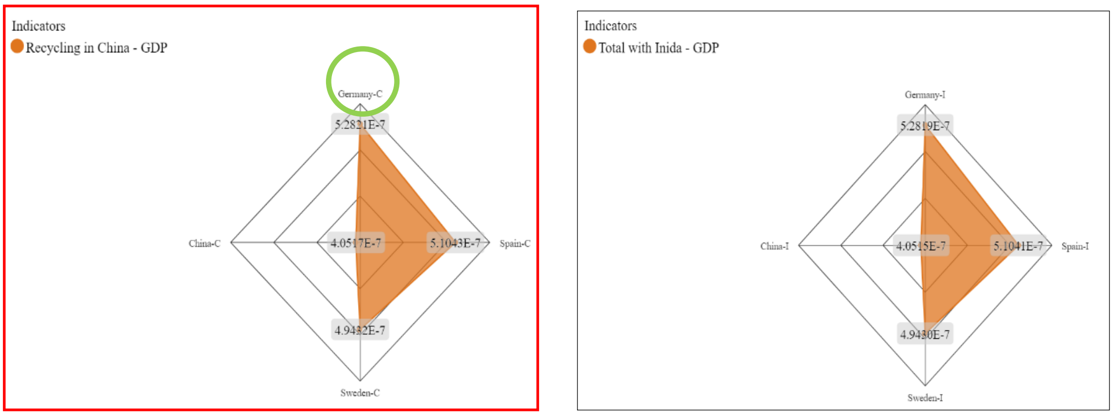


Figure 98 c) EB- GDP impacts in country (China and India scenario)

Figure 98 GDP impacts in-country for EBs, CNG, and DBs

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

Data visualization will provide a better insight into how to display the data professionally with simplicity and better eye recognition, which will be especially beneficial for stakeholders who are not experts or familiar with the outcomes of the LCSA study. It will be easier to understand data flow when visualizations are used. They will also reveal crucial trends and help us identify gaps and problems that need to be addressed. Additionally, they will aid in comparing the data and making more informed decisions based on the dashboards. The study relates the visualizations to a user-friendly design and interactive dashboards while also considering the common LCSA objectives.

Additionally, integrate the design processes and lay the groundwork for future development. Finally, by using the outcomes of the LCSA objectives, the study relates images to an intuitive layout and interactive dashboards. In addition, a framework for prospective evolution and improvement was constructed. This study concludes with a revolutionary platform for decision-making based on the product life cycle.

The following are the platforms and visualization analytic techniques that were employed in the study:

- Representing the three aspects of sustainability by evaluating and comparing thirteen sustainability indicators.
- Illustrating the LCSA system boundary as the visualizations will present which area or country can provide better outcomes through the Life Cycle process from the manufacturing phase to the End of Life phase (EOL).
- Presenting the two end-of-life scenarios were investigated as either by recycling the buses in China or India, the main focus will be on the following:
    - Recycling materials: including the bus body shell, the EB's battery,

and CNG's tank

- Showing the total energy required for recycling each material.
- Presenting and calculating the total cost for the energies using market prices for both China and India. Illustrating the total recycling materials impacts.

Limitations of the work:

- Limited access to fully publish the platform online.
- The need to integrate the platform to more applications, e.g. Power App, power Automate and power virtual agents, to improve the utilization quality.

Recommendations to increase the turnout on the usage of AFBs:

- Promote the usage of alternative-fuel bus choices among the public.
- Additional studies should be conducted to validate the long-term benefits of alternative fuel buses in order to demonstrate the critical nature of replacing conventional buses with new types. At the same time, awareness should be raised among community members, and they should be encouraged to implement the new transportation system gradually.

Future Work:

- Improvements to the existing dashboard would have to include additional features to evaluate the impacts.
- Specify the weights to deliver more advanced findings based on the important weights considered by the decision-makers so there will be more options when it comes to making decisions.
- Integrate more tools with the dashboard such as Machin learning, AI, etc.

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APPENDIX A: DATA COLLECTION

Table 8 GWP indicator data

Alternative vehicle	**Country**	**Bus Manufacturing**	**Battery Manufacturing**	**Tank Manufacturing**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China**	**EoL_India**	**Total with China**	**Total with Inida**
EB	China-EoL China	2.22E-01	5.48E-02	0.00000	6.43E-04	3.43E-02	8.04E-02	3.98E-01	0.00000	-1.87E-02	0.00000	7.72E-01	0.00000
EB	China-EoL India	2.22E-01	5.48E-02	0.00000	6.43E-04	3.43E-02	8.04E-02	3.98E-01	0.00000	0.00000	-1.35E-02	0.00000	7.77E-01
EB	Germany-EoL China	8.00E-02	1.65E-02	0.00000	1.17E-03	3.43E-02	8.04E-02	6.17E-01	0.00000	-1.83E-02	0.00000	8.11E-01	0.00000
EB	Germany-EoL India	8.00E-02	1.65E-02	0.00000	1.17E-03	3.43E-02	8.04E-02	6.17E-01	0.00000	0.00000	-1.32E-02	0.00000	8.16E-01
EB	Spain-EoL China	9.46E-02	2.06E-02	0.00000	4.28E-04	3.43E-02	8.04E-02	4.32E-01	0.00000	-1.72E-02	0.00000	6.45E-01	0.00000

Alternative vehicle	**Country**	**Bus Manufacturing**	**Battery Manufacturing**	**Tank Manufacturing**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China**	**EoL_India**	**Total with China**	**Total with Inida**
EB	Spain-EoL India	9.46E-02	2.06E-02	0.00000	4.28E-04	3.43E-02	8.04E-02	4.32E-01	0.00000	0.00000	-1.25E-02	0.00000	6.50E-01
EB	Sweden-EoL China	5.59E-02	8.87E-03	0.00000	4.91E-04	3.43E-02	8.04E-02	3.86E-01	0.00000	-1.36E-02	0.00000	5.52E-01	0.00000
EB	Sweden-EoL India	5.59E-02	8.87E-03	0.00000	4.91E-04	3.43E-02	8.04E-02	3.86E-01	0.00000	0.00000	-8.86E-03	0.00000	5.57E-01
CNG	China-EoL China	4.61E-02	0.00000	9.61E-03	5.87E-04	0.00000	1.06E-01	9.16E-02	8.05E-01	-3.07E-02	0.00000	1.03E+00	0.00000
CNG	China-EoL India	4.61E-02	0.00000	9.61E-03	5.87E-04	0.00000	1.06E-01	9.16E-02	8.05E-01	0.00000	-2.74E-02	0.00000	1.03E+00
CNG	Turkey-EoL China	1.97E-02	0.00000	3.59E-03	1.33E-04	0.00000	1.06E-01	1.02E-01	8.96E-01	-3.15E-02	0.00000	1.10E+00	0.00000
CNG	Turkey-EoL India	1.97E-02	0.00000	3.59E-03	1.33E-04	0.00000	1.06E-01	1.02E-01	8.96E-01	0.00000	-2.79E-02	0.00000	1.10E+00

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
CNG	Sweden-EoL China	3.39E-02	0.00000	3.16E-03	4.39E-04	0.00000	1.06E-01	1.04E-01	9.13E-01	-3.25E-02	0.00000	1.13E+00	0.00000
CNG	Sweden-EoL India	3.39E-02	0.00000	3.16E-03	4.39E-04	0.00000	1.06E-01	1.04E-01	9.13E-01	0.00000	-2.84E-02	0.00000	1.13E+00
CNG	Poland-EoL China	5.48E-02	0.00000	6.80E-03	9.35E-05	0.00000	1.06E-01	1.02E-01	8.96E-01	-3.16E-02	0.00000	1.13E+00	0.00000
CNG	Poland-EoL India	5.48E-02	0.00000	6.80E-03	9.35E-05	0.00000	1.06E-01	1.02E-01	8.96E-01	0.00000	-2.80E-02	0.00000	1.14E+00
CNG	India-EoL China	4.80E-02	0.00000	6.55E-03	2.69E-04	0.00000	1.06E-01	9.22E-02	8.10E-01	-3.07E-02	0.00000	1.03E+00	0.00000
CNG	India-EoL India	4.80E-02	0.00000	6.55E-03	2.69E-04	0.00000	1.06E-01	9.22E-02	8.10E-01	0.00000	-2.75E-02	0.00000	1.04E+00
DB	China-EoL China	6.88E-02	0.00000	0.00000	5.71E-04	0.00000	8.92E-02	4.50E-02	1.18E+00	-2.83E-02	0.00000	1.36E+00	0.00000

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_ China	EoL_ India	Total with China	Total with Inida
DB	China-EoL India	6.88E-02	0.00000	0.00000	5.71 E-04	0.00000	8.92 E-02	4.50 E-02	1.18 E+00	0.00000	-2.61E-02	0.00000	1.36E+00
DB	Turkey 1-EoL China	1.58E-02	0.00000	0.00000	1.33 E-04	0.00000	8.92 E-02	4.50 E-02	1.18 E+00	-2.83E-02	0.00000	1.30E+00	0.00000
DB	Turkey 1-EoL India	1.58E-02	0.00000	0.00000	1.33 E-04	0.00000	8.92 E-02	4.50 E-02	1.18 E+00	0.00000	-2.61E-02	0.00000	1.31E+00
DB	Turkey2-EoL China	2.77E-02	0.00000	0.00000	1.28 E-04	0.00000	8.92 E-02	4.70 E-02	1.24 E+00	-2.83E-02	0.00000	1.37E+00	0.00000
DB	Turkey2-EoL India	2.77E-02	0.00000	0.00000	1.28 E-04	0.00000	8.92 E-02	4.70 E-02	1.24 E+00	0.00000	-2.61E-02	0.00000	1.37E+00
DB	Poland-EoL China	4.77E-02	0.00000	0.00000	9.35 E-05	0.00000	8.92 E-02	4.30 E-02	1.13 E+00	-2.83E-02	0.00000	1.28E+00	0.00000
DB	Poland-EoL India	4.77E-02	0.00000	0.00000	9.35 E-05	0.00000	8.92 E-02	4.30 E-02	1.12964	0.00000	-2.61E-02	0.00000	1.28E+00

Table 9 PMF indicator data

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	China-EoL China	4.14E-04	1.02E-04	0.00000	5.13E-06	5.70E-05	1.05E-04	1.37E-04	0.00000	-4.00E-05	0.00000	7.80E-04	0.00000
EB	China-EoL India	4.14E-04	1.02E-04	0.00000	5.13E-06	5.70E-05	1.05E-04	1.37E-04	0.00000	0.00000	-3.33E-05	0.00000	7.87E-04
EB	Germany-EoL China	1.11E-04	2.20E-05	0.00000	1.02E-05	5.70E-05	1.05E-04	2.13E-04	0.00000	-3.89E-05	0.00000	4.80E-04	0.00000
EB	Germany-EoL India	1.11E-04	2.20E-05	0.00000	1.02E-05	5.70E-05	1.05E-04	2.13E-04	0.00000	0.00000	-3.23E-05	0.00000	4.86E-04
EB	Spain-EoL China	1.24E-04	2.61E-05	0.00000	0.00000	5.70E-05	1.05E-04	1.49E-04	0.00000	-3.66E-05	0.00000	4.29E-04	0.00000
EB	Spain-EoL India	1.24E-04	2.61E-05	0.00000	0.00000	5.70E-05	1.05E-04	1.49E-04	0.00000	0.00000	-3.06E-05	0.00000	4.35E-04

Alternative vehicle	**Country**	**Bus Manufacturing**	**Battery Manufacturing**	**Tank Manufacturing**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China**	**EoL_India**	**Total with China**	**Total with Inida**
EB	Sweden-EoL China	9.87E-05	1.60E-05	0.00000	0.00000	5.70E-05	1.05E-04	1.33E-04	0.00000	-3.00E-05	0.00000	3.84E-04	0.00000
EB	Sweden-EoL India	9.87E-05	1.60E-05	0.00000	0.00000	5.70E-05	1.05E-04	1.33E-04	0.00000	0.00000	-2.29E-05	0.00000	3.91E-04
CNG	China-EoL China	8.57E-05	0.00000	1.86E-05	0.00000	0.00000	1.39E-04	3.28E-05	9.52E-05	-5.49E-05	0.00000	3.21E-04	0.00000
CNG	China-EoL India	8.57E-05	0.00000	1.86E-05	0.00000	0.00000	1.39E-04	3.28E-05	9.52E-05	0.00000	-5.82E-05	0.00000	3.18E-04
CNG	Turkey-EoL China	2.96E-05	0.00000	6.06E-06	0.00000	0.00000	1.39E-04	3.66E-05	1.06E-04	-5.68E-05	0.00000	2.62E-04	0.00000
CNG	Turkey-EoL India	2.96E-05	0.00000	6.06E-06	0.00000	0.00000	1.39E-04	3.66E-05	1.06E-04	0.00000	-5.94E-05	0.00000	2.59E-04
CNG	Sweden-EoL China	5.98E-05	0.00000	6.34E-06	0.00000	0.00000	1.39E-04	3.73E-05	1.08E-04	-5.90E-05	0.00000	2.95E-04	0.00000
CNG	Sweden-EoL India	5.98E-05	0.00000	6.34E-06	0.00000	0.00000	1.39E-04	3.73E-05	1.08E-04	0.00000	-6.10E-05	0.00000	2.93E-04

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
CNG	Poland-EoL China	7.61E-05	0.00000	8.43E-06	0.00000	0.00000	1.39E-04	3.66E-05	1.06E-04	-5.71E-05	0.00000	3.09E-04	0.00000
CNG	Poland-EoL India	7.61E-05	0.00000	8.43E-06	0.00000	0.00000	1.39E-04	3.66E-05	1.06E-04	0.00000	-5.97E-05	0.00000	3.07E-04
CNG	India-EoL China	1.11E-04	0.00000	1.45E-05	0.00000	0.00000	1.39E-04	3.31E-05	9.59E-05	-5.51E-05	0.00000	3.41E-04	0.00000
CNG	India-EoL India	1.11E-04	0.00000	1.45E-05	0.00000	0.00000	1.39E-04	3.31E-05	9.59E-05	0.00000	-5.83E-05	0.00000	3.38E-04
DB	China-EoL China	1.28E-04	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.72E-05	2.43E-04	-4.95E-05	0.00000	5.00E-04	0.00000
DB	China-EoL India	1.28E-04	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.72E-05	2.43E-04	0.00000	-5.44E-05	0.00000	4.95E-04
DB	Turkey 1-EoL China	2.39E-05	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.72E-05	2.43E-04	-4.95E-05	0.00000	3.92E-04	0.00000
DB	Turkey 1-EoL India	2.39E-05	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.72E-05	2.43E-04	0.00000	-5.44E-05	0.00000	3.87E-04

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
DB	Turkey2-EoL China	4.17E-05	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.97E-05	2.54E-04	-4.95E-05	0.00000	4.23E-04	0.00000
DB	Turkey2-EoL India	4.17E-05	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.97E-05	2.54E-04	0.00000	-5.44E-05	0.00000	4.18E-04
DB	Poland-EoL China	6.62E-05	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.46E-05	2.32E-04	-4.95E-05	0.00000	4.20E-04	0.00000
DB	Poland-EoL India	6.62E-05	0.00000	0.00000	0.00000	0.00000	1.17E-04	5.46E-05	2.32E-04	0.00000	-5.44E-05	0.00000	4.15E-04

Table 10 POF indicator data

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	China-EoL China	4.83E-04	1.22E-04	0.00000	1.06E-05	9.63E-05	3.36E-04	5.69E-04	0.00000	-4.44E-05	0.00000	1.57E-03	0.00000

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	China-EoL India	4.83E-04	1.22E-04	0.00000	1.06E-05	9.63E-05	3.36E-04	5.69E-04	0.00000	0.00000	-3.56E-05	0.00000	1.58E-03
EB	Germany-EoL China	2.28E-04	4.46E-05	0.00000	2.14E-05	9.63E-05	3.36E-04	8.82E-04	0.00000	-4.31E-05	0.00000	1.56E-03	0.00000
EB	Germany-EoL India	2.28E-04	4.46E-05	0.00000	2.14E-05	9.63E-05	3.36E-04	8.82E-04	0.00000	0.00000	-3.47E-05	0.00000	1.57E-03
EB	Spain-EoL China	2.63E-04	5.67E-05	0.00000	7.30E-06	9.63E-05	3.36E-04	6.17E-04	0.00000	-4.06E-05	0.00000	1.34E-03	0.00000
EB	Spain-EoL India	2.63E-04	5.67E-05	0.00000	7.30E-06	9.63E-05	3.36E-04	6.17E-04	0.00000	0.00000	-3.27E-05	0.00000	1.34E-03
EB	Sweden-EoL China	2.02E-04	3.18E-05	0.00000	7.87E-06	9.63E-05	3.36E-04	5.51E-04	0.00000	-3.27E-05	0.00000	1.19E-03	0.00000
EB	Sweden-EoL India	2.02E-04	3.18E-05	0.00000	7.87E-06	9.63E-05	3.36E-04	5.51E-04	0.00000	0.00000	-2.42E-05	0.00000	1.20E-03

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
CNG	China-EoL China	1.00E-04	0.00000	1.96E-05	9.73E-06	0.00000	4.44E-04	1.25E-04	2.52E-04	-6.42E-05	0.00000	8.87E-04	0.00000
CNG	China-EoL India	1.00E-04	0.00000	1.96E-05	9.73E-06	0.00000	4.44E-04	1.25E-04	2.52E-04	0.00000	-6.45E-05	0.00000	8.87E-04
CNG	Turkey-EoL China	5.48E-05	0.00000	9.55E-06	0.00000	0.00000	4.44E-04	1.40E-04	2.81E-04	-6.61E-05	0.00000	8.66E-04	0.00000
CNG	Turkey-EoL India	5.48E-05	0.00000	9.55E-06	0.00000	0.00000	4.44E-04	1.40E-04	2.81E-04	0.00000	-6.58E-05	0.00000	8.66E-04
CNG	Sweden-EoL China	1.23E-04	0.00000	1.42E-05	7.49E-06	0.00000	4.44E-04	1.42E-04	2.86E-04	-6.84E-05	0.00000	9.49E-04	0.00000
CNG	Sweden-EoL India	1.23E-04	0.00000	1.42E-05	7.49E-06	0.00000	4.44E-04	1.42E-04	2.86E-04	0.00000	-6.73E-05	0.00000	9.50E-04
CNG	Poland-EoL China	1.55E-04	0.00000	1.84E-05	0.00000	0.00000	4.44E-04	1.40E-04	2.81E-04	-6.65E-05	0.00000	9.73E-04	0.00000

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
CNG	Poland-EoL India	1.55E-04	0.00000	1.84E-05	0.00000	0.00000	4.44E-04	1.40E-04	2.81E-04	0.00000	-6.60E-05	0.00000	9.73E-04
CNG	India-EoL China	1.31E-04	0.00000	1.63E-05	0.00000	0.00000	4.44E-04	1.26E-04	2.54E-04	-6.43E-05	0.00000	9.12E-04	0.00000
CNG	India-EoL India	1.31E-04	0.00000	1.63E-05	0.00000	0.00000	4.44E-04	1.26E-04	2.54E-04	0.00000	-6.46E-05	0.00000	9.12E-04
DB	China-EoL China	1.49E-04	0.00000	0.00000	9.46E-06	0.00000	3.72E-04	1.04E-04	1.01E-03	-5.87E-05	0.00000	1.59E-03	0.00000
DB	China-EoL India	1.49E-04	0.00000	0.00000	9.46E-06	0.00000	3.72E-04	1.04E-04	1.01E-03	0.00000	-6.07E-05	0.00000	1.59E-03
DB	Turkey 1-EoL China	4.42E-05	0.00000	0.00000	0.00000	0.00000	3.72E-04	1.04E-04	1.01E-03	-5.87E-05	0.00000	1.48E-03	0.00000
DB	Turkey 1-EoL India	4.42E-05	0.00000	0.00000	0.00000	0.00000	3.72E-04	1.04E-04	1.01E-03	0.00000	-6.07E-05	0.00000	1.47E-03

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
DB	Turkey2-EoL China	7.72E-05	0.00000	0.00000	0.00000	0.00000	3.72E-04	1.09E-04	1.06E-03	-5.87E-05	0.00000	1.56E-03	0.00000
DB	Turkey2-EoL India	7.72E-05	0.00000	0.00000	0.00000	0.00000	3.72E-04	1.09E-04	1.06E-03	0.00000	-6.07E-05	0.00000	1.56E-03
DB	Poland-EoL China	1.35E-04	0.00000	0.00000	0.00000	0.00000	3.72E-04	9.98E-05	9.66E-04	-5.87E-05	0.00000	1.51E-03	0.00000
DB	Poland-EoL India	1.35E-04	0.00000	0.00000	0.00000	0.00000	3.72E-04	9.98E-05	9.66E-04	0.00000	-6.07E-05	0.00000	1.51E-03

Table 11 Land Use indicator data

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	China-EoL China	9.54766E-08	2.34556E-08	0.00	2.67440E-10	1.47774E-08	4.44398E-08	7.84215E-09	0.00	-5.530	0.00000	1.81E-07	0.00000

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
										60E-09			
EB	China-EoL India	9.54766E-08	2.34556E-08	0.00	2.67440E-10	1.47774E-08	4.44398E-08	7.84215E-09	0.00	0.00000	-2.47450E-09	0.00000	1.84E-07
EB	Germany-EoL China	3.43223E-08	5.76349E-09	0.00	3.36269E-11	1.47774E-08	4.44398E-08	1.21584E-08	0.00	-5.52387E-09	0.00000	1.06E-07	0.00000
EB	Germany-EoL India	3.43223E-08	5.76349E-09	0.00	3.36269E-11	1.47774E-08	4.44398E-08	1.21584E-08	0.00	0.00000	-2.45979E-09	0.00000	1.09E-07
EB	Spain-EoL China	5.80355E-08	1.30287E-08	0.00	7.55423E-11	1.47774E-08	4.44398E-08	8.51086E-09	0.00	-4.99183E-09	0.00000	1.34E-07	0.00000
EB	Spain-EoL India	5.80355E-08	1.30287E-08	0.00	7.55423E-11	1.47774E-08	4.44398E-08	8.51086E-09	0.00	0.00000	-2.23123E-09	0.00000	1.37E-07

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	Sweden-EoL China	5.48804E-08	1.04946E-08	0.00	5.17284E-11	1.47774E-08	4.44398E-08	7.59898E-09	0.00	-4.15803E-09	0.00000	1.28E-07	0.00000
EB	Sweden-EoL India	5.48804E-08	1.04946E-08	0.00	5.17284E-11	1.47774E-08	4.44398E-08	7.59898E-09	0.00	0.00000	-1.90707E-09	0.00000	1.30E-07
CNG	China-EoL China	1.97745E-08	0.00	2.33406E-09	2.44362E-10	0.00	5.88295E-08	1.90452E-09	0.00	-6.58680E-09	0.00000	7.65E-08	0.00000
CNG	China-EoL India	1.97745E-08	0.00	2.33406E-09	2.44362E-10	0.00	5.88295E-08	1.90452E-09	0.00	0.00000	-2.66304E-09	0.00000	8.04E-08
CNG	Turkey-EoL China	1.24642E-08	0.00	2.40053E-09	3.55037E-12	0.00	5.88295E-08	2.12193E-09	0.00	-6.74709E-09	0.00000	6.91E-08	0.00000
CNG	Turkey-EoL India	1.24642E-08	0.00	2.40053E-09	3.55037E-12	0.00	5.88295E-08	2.12193E-09	0.00	0.00000	-2.745	0.00000	7.31E-08

Alternative vehicle	**Country**	**Bus Manufacturing**	**Battery Manufacturing**	**Tank Manufacturing**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China**	**EoL_India**	**Total with China**	**Total with Inida**
											90E-09		
CNG	Sweden-EoL China	3.32652E-08	0.00	3.58487E-09	7.75303E-11	0.00	5.88295E-08	2.16177E-09	0.00	-6.94344E-09	0.00000	9.10E-08	0.00000
CNG	Sweden-EoL India	3.32652E-08	0.00	3.58487E-09	7.75303E-11	0.00	5.88295E-08	2.16177E-09	0.00	0.00000	-2.84740E-09	0.00000	9.51E-08
CNG	Poland-EoL China	3.05688E-08	0.00	2.94408E-09	2.87627E-11	0.00	5.88295E-08	2.12193E-09	0.00	-6.77861E-09	0.00000	8.77E-08	0.00000
CNG	Poland-EoL India	3.05688E-08	0.00	2.94408E-09	2.87627E-11	0.00	5.88295E-08	2.12193E-09	0.00	0.00000	-2.76220E-09	0.00000	9.17E-08
CNG	India-EoL China	9.23589E-09	0.00	1.25619E-09	3.86239E-11	0.00	5.88295E-08	1.91770E-09	0.00	-6.59896E-09	0.00000	6.47E-08	0.00000

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
CNG	India-EoL India	9.23589E-09	0.00	1.25619E-09	3.86239E-11	0.00	5.88295E-08	1.91770E-09	0.00	0.00000	-2.66933E-09	0.00000	6.86E-08
DB	China-EoL China	2.95397E-08	0.00	0.00	2.37574E-10	0.00	4.92924E-08	1.74594E-08	0.00	-6.11931E-09	0.00000	9.04E-08	0.00000
DB	China-EoL India	2.95397E-08	0.00	0.00	2.37574E-10	0.00	4.92924E-08	1.74594E-08	0.00	0.00000	-2.42137E-09	0.00000	9.41E-08
DB	Turkey 1-EoL China	1.00406E-08	0.00	0.00	3.55037E-12	0.00	4.92924E-08	1.74594E-08	0.00	-6.11931E-09	0.00000	7.07E-08	0.00000
DB	Turkey 1-EoL India	1.00406E-08	0.00	0.00	3.55037E-12	0.00	4.92924E-08	1.74594E-08	0.00	0.00000	-2.42137E-09	0.00000	7.44E-08
DB	Turkey2-EoL China	1.75465E-08	0.00	0.00	3.41747E-12	0.00	4.92924E-08	1.82441E-08	0.00	-6.119	0.00000	7.90E-08	0.00000

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
										31E-09			
DB	Turkey2-EoL India	1.75465E-08	0.00	0.00	3.41747E-12	0.00	4.92924E-08	1.82441E-08	0.00	0.00000	-2.42137E-09	0.00000	8.27E-08
DB	Poland-EoL China	2.65895E-08	0.00	0.00	2.87627E-11	0.00	4.92924E-08	1.66747E-08	0.00	-6.11931E-09	0.00000	8.65E-08	0.00000
DB	Poland-EoL India	2.65895E-08	0.00	0.00	2.87627E-11	0.00	4.92924E-08	1.66747E-08	0.00	0.00000	-2.42137E-09	0.00000	9.02E-08

Table 12 Water Withdrawal indicator data

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	China-EoL China	5.69E-09	1.64E-09	0.00	1.73E-12	9.16E-10	1.57E-09	6.79E-08	0.00	-6.01E-10	0.00000	7.71E-08	0.00000
EB	China-EoL India	5.69E-09	1.64E-09	0.00	1.73E-12	9.16E-10	1.57E-09	6.79E-08	0.00	0.00000	-1.75E-09	0.00000	7.59E-08
EB	Germany-EoL China	2.89E-09	5.50E-10	0.00	4.39E-13	9.16E-10	1.57E-09	1.05E-07	0.00	-6.18E-10	0.00000	1.11E-07	0.00000
EB	Germany-EoL India	2.89E-09	5.50E-10	0.00	4.39E-13	9.16E-10	1.57E-09	1.05E-07	0.00	0.00000	-1.80E-09	0.00000	1.09E-07
EB	Spain-EoL China	3.69E-09	8.03E-10	0.00	9.10E-13	9.16E-10	1.57E-09	7.37E-08	0.00	-5.45E-10	0.00000	8.01E-08	0.00000
EB	Spain-EoL India	3.69E-09	8.03E-10	0.00	9.10E-13	9.16E-10	1.57E-09	7.37E-08	0.00	0.00000	-1.59E-09	0.00000	7.90E-08
EB	Sweden-EoL China	1.70E-09	3.49E-10	0.00	1.85E-12	9.16E-10	1.57E-09	6.58E-08	0.00	-4.37E-10	0.00000	6.99E-08	0.00000

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	Sweden-EoL India	1.70E-09	3.49E-10	0.00	1.85E-12	9.16E-10	1.57E-09	6.58E-08	0.00	0.00000	-1.24E-09	0.00000	6.91E-08
CNG	China-EoL China	1.18E-09	0.00	3.16E-10	1.58E-12	0.00	2.07E-09	8.51E-12	0.00	-8.36E-10	0.00000	2.74E-09	0.00000
CNG	China-EoL India	1.18E-09	0.00	3.16E-10	1.58E-12	0.00	2.07E-09	8.51E-12	0.00	0.00000	-2.73E-09	0.00000	8.47E-10
CNG	Turkey-EoL China	5.80E-10	0.00	1.40E-10	7.38E-14	0.00	2.07E-09	9.48E-12	0.00	-8.51E-10	0.00000	1.95E-09	0.00000
CNG	Turkey-EoL India	5.80E-10	0.00	1.40E-10	7.38E-14	0.00	2.07E-09	9.48E-12	0.00	0.00000	-2.77E-09	0.00000	3.56E-11
CNG	Sweden-EoL China	1.03E-09	0.00	1.94E-10	9.34E-13	0.00	2.07E-09	9.66E-12	0.00	-8.68E-10	0.00000	2.44E-09	0.00000
CNG	Sweden-EoL India	1.03E-09	0.00	1.94E-10	9.34E-13	0.00	2.07E-09	9.66E-12	0.00	0.00000	-2.81E-09	0.00000	4.99E-10

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
CNG	Poland-EoL China	1.43E-09	0.00	1.45E-10	2.19E-13	0.00	2.07E-09	9.48E-12	0.00	-8.53E-10	0.00000	2.80E-09	0.00000
CNG	Poland-EoL India	1.43E-09	0.00	1.45E-10	2.19E-13	0.00	2.07E-09	9.48E-12	0.00	0.00000	-2.77E-09	0.00000	8.79E-10
CNG	India-EoL China	2.50E-09	0.00	8.10E-10	1.14E-12	0.00	2.07E-09	8.57E-12	0.00	-8.37E-10	0.00000	4.55E-09	0.00000
CNG	India-EoL India	2.50E-09	0.00	8.10E-10	1.14E-12	0.00	2.07E-09	8.57E-12	0.00	0.00000	-2.73E-09	0.00000	2.66E-09
DB	China-EoL China	1.76E-09	0.00	0.00	1.54E-12	0.00	1.74E-09	2.81E-09	0.00	-7.95E-10	0.00000	5.52E-09	0.00000
DB	China-EoL India	1.76E-09	0.00	0.00	1.54E-12	0.00	1.74E-09	2.81E-09	0.00	0.00000	-2.63E-09	0.00000	3.69E-09
DB	Turkey 1-EoL China	4.68E-10	0.00	0.00	7.38E-14	0.00	1.74E-09	2.81E-09	0.00	-7.95E-10	0.00000	4.22E-09	0.00000

Alternative vehicle	**Country**	**Bus Manufacturing**	**Battery Manufacturing**	**Tank Manufacturing**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China**	**EoL_India**	**Total with China**	**Total with Inida**
DB	Turkey 1-EoL India	4.68E-10	0.00	0.00	7.38E-14	0.00	1.74E-09	2.81E-09	0.00	0.00000	-2.63E-09	0.00000	2.39E-09
DB	Turkey2-EoL China	8.17E-10	0.00	0.00	7.11E-14	0.00	1.74E-09	2.94E-09	0.00	-7.95E-10	0.00000	4.70E-09	0.00000
DB	Turkey2-EoL India	8.17E-10	0.00	0.00	7.11E-14	0.00	1.74E-09	2.94E-09	0.00	0.00000	-2.63E-09	0.00000	2.87E-09
DB	Poland-EoL China	1.24E-09	0.00	0.00	2.19E-13	0.00	1.74E-09	2.69E-09	0.00	-7.95E-10	0.00000	4.87E-09	0.00000
DB	Poland-EoL India	1.24E-09	0.00	0.00	2.19E-13	0.00	1.74E-09	2.69E-09	0.00	0.00000	-2.63E-09	0.00000	3.04E-09

Table 13 Water Consumption indicator data

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	China-EoL China	1.49E-08	4.18E-09	0.00	1.55E-11	2.45E-09	8.77E-09	2.58E-09	0.00	-1.52E-09	0.00000	3.1338E-08	0.0000E+00
EB	China-EoL India	1.49E-08	4.18E-09	0.00	1.55E-11	2.45E-09	8.77E-09	2.58E-09	0.00	0.00000	-1.02E-09	0.0000E+00	3.1844E-08
EB	Germany-EoL China	3.47E-09	6.75E-10	0.00	3.54E-12	2.45E-09	8.77E-09	4.00E-09	0.00	-1.53E-09	0.00000	1.7837E-08	0.0000E+00
EB	Germany-EoL India	3.47E-09	6.75E-10	0.00	3.54E-12	2.45E-09	8.77E-09	4.00E-09	0.00	0.00000	-1.03E-09	0.0000E+00	1.8338E-08
EB	Spain-EoL China	5.44E-09	1.23E-09	0.00	6.80E-12	2.45E-09	8.77E-09	2.80E-09	0.00	-1.37E-09	0.00000	1.9331E-08	0.0000E+00
EB	Spain-EoL India	5.44E-09	1.23E-09	0.00	6.80E-12	2.45E-09	8.77E-09	2.80E-09	0.00	0.00000	-9.20E-10	0.0000E+00	1.9780E-08
EB	Sweden-EoL China	4.57E-09	8.65E-10	0.00	6.39E-12	2.45E-09	8.77E-09	2.50E-09	0.00	-1.14E-09	0.00000	1.8022E-08	0.0000E+00

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
EB	Sweden-EoL India	4.57E-09	8.65E-10	0.00	6.39E-12	2.45E-09	8.77E-09	2.50E-09	0.00	0.00000	-7.72E-10	0.0000E+00	1.8389E-08
CNG	China-EoL China	3.08E-09	0.00	4.94E-10	1.42E-11	0.00	1.16E-08	5.87E-10	0.00	-1.73E-09	0.00000	1.4051E-08	0.0000E+00
CNG	China-EoL India	3.08E-09	0.00	4.94E-10	1.42E-11	0.00	1.16E-08	5.87E-10	0.00	0.00000	-1.19E-09	0.0000E+00	1.4591E-08
CNG	Turkey-EoL China	1.14E-09	0.00	1.95E-10	3.45E-13	0.00	1.16E-08	6.54E-10	0.00	-1.77E-09	0.00000	1.1831E-08	0.0000E+00
CNG	Turkey-EoL India	1.14E-09	0.00	1.95E-10	3.45E-13	0.00	1.16E-08	6.54E-10	0.00	0.00000	-1.22E-09	0.0000E+00	1.2380E-08
CNG	Sweden-EoL China	2.77E-09	0.00	2.18E-10	6.98E-12	0.00	1.16E-08	6.66E-10	0.00	-1.81E-09	0.00000	1.3452E-08	0.0000E+00
CNG	Sweden-EoL India	2.77E-09	0.00	2.18E-10	6.98E-12	0.00	1.16E-08	6.66E-10	0.00	0.00000	-1.25E-09	0.0000E+00	1.4013E-08

Alternative vehicle	**Country**	**Bus Manufacturing**	**Battery Manufacturing**	**Tank Manufacturing**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China**	**EoL_India**	**Total with China**	**Total with Inida**
CNG	Poland-EoL China	2.87E-09	0.00	2.46E-10	6.01E-12	0.00	1.16E-08	6.54E-10	0.00	-1.78E-09	0.00000	1.3609E-08	0.0000E+00
CNG	Poland-EoL India	2.87E-09	0.00	2.46E-10	6.01E-12	0.00	1.16E-08	6.54E-10	0.00	0.00000	-1.22E-09	0.0000E+00	1.4160E-08
CNG	India-EoL China	2.42E-09	0.00	5.18E-10	6.92E-12	0.00	1.16E-08	5.91E-10	0.00	-1.73E-09	0.00000	1.3406E-08	0.0000E+00
CNG	India-EoL India	2.42E-09	0.00	5.18E-10	6.92E-12	0.00	1.16E-08	5.91E-10	0.00	0.00000	-1.19E-09	0.0000E+00	1.3947E-08
DB	China-EoL China	4.60E-09	0.00	0.00	1.38E-11	0.00	9.73E-09	2.85E-09	0.00	-1.62E-09	0.00000	1.5569E-08	0.0000E+00
DB	China-EoL India	4.60E-09	0.00	0.00	1.38E-11	0.00	9.73E-09	2.85E-09	0.00	0.00000	-1.11E-09	0.0000E+00	1.6083E-08
DB	Turkey 1-EoL China	9.21E-10	0.00	0.00	3.45E-13	0.00	9.73E-09	2.85E-09	0.00	-1.62E-09	0.00000	1.1876E-08	0.0000E+00

Alternative vehicle	Country	Bus Manufacturing	Battery Manufacturing	Tank Manufacturing	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China	EoL_India	Total with China	Total with Inida
DB	Turkey 1-EoL India	9.21E-10	0.00	0.00	3.45E-13	0.00	9.73E-09	2.85E-09	0.00	0.00000	-1.11E-09	0.0000E+00	1.2389E-08
DB	Turkey2-EoL China	1.61E-09	0.00	0.00	3.32E-13	0.00	9.73E-09	2.98E-09	0.00	-1.62E-09	0.00000	1.2693E-08	0.0000E+00
DB	Turkey2-EoL India	1.61E-09	0.00	0.00	3.32E-13	0.00	9.73E-09	2.98E-09	0.00	0.00000	-1.11E-09	0.0000E+00	1.3206E-08
DB	Poland-EoL China	2.50E-09	0.00	0.00	6.01E-12	0.00	9.73E-09	2.72E-09	0.00	-1.62E-09	0.00000	1.3331E-08	0.0000E+00
DB	Poland-EoL India	2.50E-09	0.00	0.00	6.01E-12	0.00	9.73E-09	2.72E-09	0.00	0.00000	-1.11E-09	0.0000E+00	1.3844E-08

Table 14 Human Health indicaotr data

Alternative vehicle	**Country**	**Bus Manufacture**	**Battery Manufacture**	**Tank Manufacture**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China Scenario**	**EoL_India Scenario**	**Total with China**	**Total with Inida**
EB	China-EoL China	2.90E-10	7.15E-11	0.00	3.32E-12	4.05E-11	7.70E-11	1.40E-10	0.00	-2.77E-11	0.00	5.95E-10	0.00000
EB	China-EoL India	2.90E-10	7.15E-11	0.00	3.32E-12	4.05E-11	7.70E-11	1.40E-10	0.00	0.00	-2.28E-11	0.00000	5.99E-10
EB	Germany-EoL China	8.08E-11	1.61E-11	0.00	6.60E-12	4.05E-11	7.70E-11	2.16E-10	0.00	-2.69E-11	0.00	4.10E-10	0.00000
EB	Germany-EoL India	8.08E-11	1.61E-11	0.00	6.60E-12	4.05E-11	7.70E-11	2.16E-10	0.00	0.00	-2.21E-11	0.00000	4.15E-10
EB	Spain-EoL China	9.09E-11	1.92E-11	0.00	2.25E-12	4.05E-11	7.70E-11	1.52E-10	0.00	-2.53E-11	0.00	3.56E-10	0.00000
EB	Spain-EoL India	9.09E-11	1.92E-11	0.00	2.25E-12	4.05E-11	7.70E-11	1.52E-10	0.00	0.00	-2.09E-11	0.00000	3.60E-10
EB	Sweden-EoL China	6.96E-11	1.12E-11	0.00	2.41E-12	4.05E-11	7.70E-11	1.35E-10	0.00	-2.07E-11	0.00	3.15E-10	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	Sweden-EoL India	6.96E-11	1.12E-11	0.00	2.41E-12	4.05E-11	7.70E-11	1.35E-10	0.00	0.00	-1.56E-11	0.00000	3.20E-10
CNG	China-EoL China	6.01E-11	0.00	1.30E-11	3.03E-12	0.00	1.02E-10	3.29E-11	1.67E-10	-3.87E-11	0.00	3.39E-10	0.00000
CNG	China-EoL India	6.01E-11	0.00	1.30E-11	3.03E-12	0.00	1.02E-10	3.29E-11	1.67E-10	0.00	-4.03E-11	0.00000	3.38E-10
CNG	Turkey-EoL China	2.13E-11	0.00	4.29E-12	7.42E-13	0.00	1.02E-10	3.66E-11	1.86E-10	-4.00E-11	0.00	3.11E-10	0.00000
CNG	Turkey-EoL India	2.13E-11	0.00	4.29E-12	7.42E-13	0.00	1.02E-10	3.66E-11	1.86E-10	0.00	-4.12E-11	0.00000	3.10E-10
CNG	Sweden-EoL China	4.22E-11	0.00	4.42E-12	2.31E-12	0.00	1.02E-10	3.73E-11	1.90E-10	-4.15E-11	0.00	3.36E-10	0.00000
CNG	Sweden-EoL India	4.22E-11	0.00	4.42E-12	2.31E-12	0.00	1.02E-10	3.73E-11	1.90E-10	0.00	-4.22E-11	0.00000	3.35E-10

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
CNG	Poland-EoL China	5.52E-11	0.00	6.22E-12	1.02E-13	0.00	1.02E-10	3.66E-11	1.86E-10	-4.02E-11	0.00	3.46E-10	0.00000
CNG	Poland-EoL India	5.52E-11	0.00	6.22E-12	1.02E-13	0.00	1.02E-10	3.66E-11	1.86E-10	0.00	-4.13E-11	0.00000	3.45E-10
CNG	India-EoL China	7.66E-11	0.00	9.99E-12	1.32E-12	0.00	1.02E-10	3.31E-11	1.68E-10	-3.88E-11	0.00	3.52E-10	0.00000
CNG	India-EoL India	7.66E-11	0.00	9.99E-12	1.32E-12	0.00	1.02E-10	3.31E-11	1.68E-10	0.00	-4.04E-11	0.00000	3.51E-10
DB	China-EoL China	8.98E-11	0.00	0.00	2.95E-12	0.00	8.54E-11	4.20E-11	3.10E-10	-3.50E-11	0.00	4.96E-10	0.00000
DB	China-EoL India	8.98E-11	0.00	0.00	2.95E-12	0.00	8.54E-11	4.20E-11	3.10E-10	0.00	-3.77E-11	0.00000	4.93E-10
DB	Turkey 1-EoL China	1.71E-11	0.00	0.00	7.42E-13	0.00	8.54E-11	4.20E-11	3.10E-10	-3.50E-11	0.00	4.21E-10	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
DB	Turkey 1-EoL India	1.71E-11	0.00	0.00	7.42E-13	0.00	8.54E-11	4.20E-11	3.10E-10	0.00	-3.77E-11	0.00000	4.18E-10
DB	Turkey2-EoL China	3.00E-11	0.00	0.00	7.15E-13	0.00	8.54E-11	4.39E-11	3.24E-10	-3.50E-11	0.00	4.49E-10	0.00000
DB	Turkey2-EoL India	3.00E-11	0.00	0.00	7.15E-13	0.00	8.54E-11	4.39E-11	3.24E-10	0.00	-3.77E-11	0.00000	4.47E-10
DB	Poland-EoL China	4.80E-11	0.00	0.00	1.02E-13	0.00	8.54E-11	4.01E-11	2.96E-10	-3.50E-11	0.00	4.35E-10	0.00000
DB	Poland-EoL India	4.80E-11	0.00	0.00	1.02E-13	0.00	8.54E-11	4.01E-11	2.96E-10	0.00	-3.77E-11	0.00000	4.32E-10

Table 15 Employment indicator data

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	China-EoL China	1.03E-08	2.27E-09	0.00	3.61E-11	1.31E-09	4.16E-09	6.73E-10	0.00	-4.38E-10		1.83E-08	0.00000
EB	China-EoL India	1.03E-08	2.27E-09	0.00	3.61E-11	1.31E-09	4.16E-09	6.73E-10	0.00	0.00	-1.11E-09	0.00000	1.76E-08
EB	Germany-EoL China	4.97E-09	1.10E-09	0.00	4.82E-12	1.31E-09	4.16E-09	1.04E-09	0.00	-4.25E-10	0.00	1.22E-08	0.00000
EB	Germany-EoL India	4.97E-09	1.10E-09	0.00	4.82E-12	1.31E-09	4.16E-09	1.04E-09	0.00	0.00	-1.08E-09	0.00000	1.15E-08
EB	Spain-EoL China	6.19E-09	1.35E-09	0.00	7.47E-12	1.31E-09	4.16E-09	7.31E-10	0.00	-3.96E-10	0.00	1.33E-08	0.00000
EB	Spain-EoL India	6.19E-09	1.35E-09	0.00	7.47E-12	1.31E-09	4.16E-09	7.31E-10	0.00	0.00	-1.01E-09	0.00000	1.27E-08
EB	Sweden-EoL China	4.91E-09	9.32E-10	0.00	7.27E-12	1.31E-09	4.16E-09	6.52E-10	0.00	-3.18E-10	0.00	1.16E-08	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	Sweden-EoL India	4.91E-09	9.32E-10	0.00	7.27E-12	1.31E-09	4.16E-09	6.52E-10	0.00	0.00	-8.01E-10	0.00000	1.12E-08
CNG	China-EoL China	2.13E-09	0.00	2.36E-10	3.30E-11	0.00	5.50E-09	4.99E-10	0.00	-5.99E-10	0.00	7.80E-09	0.00000
CNG	China-EoL India	2.13E-09	0.00	2.36E-10	3.30E-11	0.00	5.50E-09	4.99E-10	0.00	0.00	-1.61E-09	0.00000	6.78E-09
CNG	Turkey-EoL China	1.97E-09	0.00	2.73E-10	5.35E-13	0.00	5.50E-09	5.56E-10	0.00	-6.13E-10	0.00	7.69E-09	0.00000
CNG	Turkey-EoL India	1.97E-09	0.00	2.73E-10	5.35E-13	0.00	5.50E-09	5.56E-10	0.00	0.00	-1.65E-09	0.00000	6.66E-09
CNG	Sweden-EoL China	2.98E-09	0.00	2.59E-10	7.67E-12	0.00	5.50E-09	5.66E-10	0.00	-6.30E-10	0.00	8.68E-09	0.00000
CNG	Sweden-EoL India	2.98E-09	0.00	2.59E-10	7.67E-12	0.00	5.50E-09	5.66E-10	0.00	0.00	-1.69E-09	0.00000	7.62E-09

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
CNG	Poland-EoL China	4.63E-09	0.00	5.81E-10	7.63E-12	0.00	5.50E-09	5.56E-10	0.00	-6.16E-10	0.00	1.07E-08	0.00000
CNG	Poland-EoL India	4.63E-09	0.00	5.81E-10	7.63E-12	0.00	5.50E-09	5.56E-10	0.00	0.00	-1.65E-09	0.00000	9.62E-09
CNG	India-EoL China	4.97E-09	0.00	6.80E-10	1.36E-11	0.00	5.50E-09	5.02E-10	0.00	-6.00E-10	0.00	1.11E-08	0.00000
CNG	India-EoL India	4.97E-09	0.00	6.80E-10	1.36E-11	0.00	5.50E-09	5.02E-10	0.00	0.00	-1.62E-09	0.00000	1.00E-08
DB	China-EoL China	3.18E-09	0.00	0.00	3.21E-11	0.00	4.61E-09	1.68E-09	0.00	-5.58E-10	0.00	8.94E-09	0.00000
DB	China-EoL India	3.18E-09	0.00	0.00	3.21E-11	0.00	4.61E-09	1.68E-09	0.00	0.00	-1.51E-09	0.00000	7.99E-09
DB	Turkey 1-EoL China	1.59E-09	0.00	0.00	5.35E-13	0.00	4.61E-09	1.68E-09	0.00	-5.58E-10	0.00	7.32E-09	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
DB	Turkey 1-EoL India	1.59E-09	0.00	0.00	5.35E-13	0.00	4.61E-09	1.68E-09	0.00	0.00	-1.51E-09	0.00000	6.37E-09
DB	Turkey2-EoL China	2.78E-09	0.00	0.00	5.15E-13	0.00	4.61E-09	1.76E-09	0.00	-5.58E-10	0.00	8.59E-09	0.00000
DB	Turkey2-EoL India	2.78E-09	0.00	0.00	5.15E-13	0.00	4.61E-09	1.76E-09	0.00	0.00	-1.51E-09	0.00000	7.63E-09
DB	Poland-EoL China	4.02E-09	0.00	0.00	7.63E-12	0.00	4.61E-09	1.61E-09	0.00	-5.58E-10	0.00	9.69E-09	0.00000
DB	Poland-EoL India	4.02E-09	0.00	0.00	7.63E-12	0.00	4.61E-09	1.61E-09	0.00	0.00	-1.51E-09	0.00000	8.73E-09

Table 16 Compensation indicator data

Alternative vehicle	**Country**	**Bus Manufacture**	**Battery Manufacture**	**Tank Manufacture**	**Shipping**	**Infrastructure**	**M&R**	**WTT**	**TTW**	**EoL_China Scenario**	**EoL_India Scenario**	**Total with China**	**Total with Inida**
EB	China-EoL China	6.75E-08	1.37E-08	0.00	1.21E-10	1.23E-08	8.24E-08	1.48E-08	0.00	-2.61E-09	0.00	1.88E-07	0.00000
EB	China-EoL India	6.75E-08	1.37E-08	0.00	1.21E-10	1.23E-08	8.24E-08	1.48E-08	0.00	0.00	-2.95E-09	0.00000	1.88E-07
EB	Germany-EoL China	1.36E-07	3.16E-08	0.00	6.75E-11	1.23E-08	8.24E-08	2.30E-08	0.00	-2.51E-09	0.00	2.82E-07	0.00000
EB	Germany-EoL India	1.36E-07	3.16E-08	0.00	6.75E-11	1.23E-08	8.24E-08	2.30E-08	0.00	0.00	-2.85E-09	0.00000	2.82E-07
EB	Spain-EoL China	1.37E-07	2.84E-08	0.00	1.79E-10	1.23E-08	8.24E-08	1.61E-08	0.00	-2.35E-09	0.00	2.74E-07	0.00000
EB	Spain-EoL India	1.37E-07	2.84E-08	0.00	1.79E-10	1.23E-08	8.24E-08	1.61E-08	0.00	0.00	-2.67E-09	0.00000	2.74E-07
EB	Sweden-EoL China	1.31E-07	2.72E-08	0.00	1.37E-10	1.23E-08	8.24E-08	1.44E-08	0.00	-1.88E-09	0.00	2.66E-07	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	Sweden-EoL India	1.31E-07	2.72E-08	0.00	1.37E-10	1.23E-08	8.24E-08	1.44E-08	0.00	0.00	-2.14E-09	0.00000	2.65E-07
CNG	China-EoL China	1.40E-08	0.00	1.36E-09	1.11E-10	0.00	1.09E-07	1.26E-08	0.00	-3.49E-09	0.00	1.34E-07	0.00000
CNG	China-EoL India	1.40E-08	0.00	1.36E-09	1.11E-10	0.00	1.09E-07	1.26E-08	0.00	0.00	-4.12E-09	0.00000	1.33E-07
CNG	Turkey-EoL China	2.60E-08	0.00	2.70E-09	5.70E-12	0.00	1.09E-07	1.40E-08	0.00	-3.57E-09	0.00	1.48E-07	0.00000
CNG	Turkey-EoL India	2.60E-08	0.00	2.70E-09	5.70E-12	0.00	1.09E-07	1.40E-08	0.00	0.00	-4.22E-09	0.00000	1.48E-07
CNG	Sweden-EoL China	7.95E-08	0.00	8.54E-09	1.84E-10	0.00	1.09E-07	1.43E-08	0.00	-3.67E-09	0.00	2.08E-07	0.00000
CNG	Sweden-EoL India	7.95E-08	0.00	8.54E-09	1.84E-10	0.00	1.09E-07	1.43E-08	0.00	0.00	-4.33E-09	0.00000	2.07E-07

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
CNG	Poland-EoL China	6.24E-08	0.00	6.31E-09	6.07E-11	0.00	1.09E-07	1.40E-08	0.00	-3.59E-09	0.00	1.88E-07	0.00000
CNG	Poland-EoL India	6.24E-08	0.00	6.31E-09	6.07E-11	0.00	1.09E-07	1.40E-08	0.00	0.00	-4.24E-09	0.00000	1.88E-07
CNG	India-EoL China	1.70E-08	0.00	1.86E-09	5.64E-11	0.00	1.09E-07	1.27E-08	0.00	-3.50E-09	0.00	1.37E-07	0.00000
CNG	India-EoL India	1.70E-08	0.00	1.86E-09	5.64E-11	0.00	1.09E-07	1.27E-08	0.00	0.00	-4.13E-09	0.00000	1.37E-07
DB	China-EoL China	2.09E-08	0.00	0.00	1.08E-10	0.00	9.14E-08	3.17E-08	0.00	-3.26E-09	0.00	1.41E-07	0.00000
DB	China-EoL India	2.09E-08	0.00	0.00	1.08E-10	0.00	9.14E-08	3.17E-08	0.00	0.00	-3.85E-09	0.00000	1.40E-07
DB	Turkey 1-EoL China	2.10E-08	0.00	0.00	5.70E-12	0.00	9.14E-08	3.17E-08	0.00	-3.26E-09	0.00	1.41E-07	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
DB	Turkey 1-EoL India	2.10E-08	0.00	0.00	5.70E-12	0.00	9.14E-08	3.17E-08	0.00	0.00	-3.85E-09	0.00000	1.40E-07
DB	Turkey2-EoL China	3.67E-08	0.00	0.00	5.49E-12	0.00	9.14E-08	3.31E-08	0.00	-3.26E-09	0.00	1.58E-07	0.00000
DB	Turkey2-EoL India	3.67E-08	0.00	0.00	5.49E-12	0.00	9.14E-08	3.31E-08	0.00	0.00	-3.85E-09	0.00000	1.57E-07
DB	Poland-EoL China	5.42E-08	0.00	0.00	6.07E-11	0.00	9.14E-08	3.03E-08	0.00	-3.26E-09	0.00	1.73E-07	0.00000
DB	Poland-EoL India	5.42E-08	0.00	0.00	6.07E-11	0.00	9.14E-08	3.03E-08	0.00	0.00	-3.85E-09	0.00000	1.72E-07

Table 17 Tax indicator data

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	China-EoL China	2.22E-08	6.01E-09	0.00	2.17E-11	5.21E-09	3.23E-08	1.26E-08	0.00	-1.30E-09	0.00	7.70E-08	0.00000
EB	China-EoL India	2.22E-08	6.01E-09	0.00	2.17E-11	5.21E-09	3.23E-08	1.26E-08	0.00	0.00	-1.43E-09	0.00000	7.69E-08
EB	Germany-EoL China	1.50E-08	2.65E-09	0.00	1.22E-11	5.21E-09	3.23E-08	1.95E-08	0.00	-1.25E-09	0.00	7.34E-08	0.00000
EB	Germany-EoL India	1.50E-08	2.65E-09	0.00	1.22E-11	5.21E-09	3.23E-08	1.95E-08	0.00	0.00	-1.38E-09	0.00000	7.33E-08
EB	Spain-EoL China	1.71E-08	3.14E-09	0.00	2.83E-11	5.21E-09	3.23E-08	1.36E-08	0.00	-1.17E-09	0.00	7.02E-08	0.00000
EB	Spain-EoL India	1.71E-08	3.14E-09	0.00	2.83E-11	5.21E-09	3.23E-08	1.36E-08	0.00	0.00	-1.29E-09	0.00000	7.01E-08
EB	Sweden-EoL China	2.36E-08	3.44E-09	0.00	2.40E-11	5.21E-09	3.23E-08	1.22E-08	0.00	-9.37E-10	0.00	7.57E-08	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	Sweden-EoL India	2.36E-08	3.44E-09	0.00	2.40E-11	5.21E-09	3.23E-08	1.22E-08	0.00	0.00	-1.04E-09	0.00000	7.56E-08
CNG	China-EoL China	4.60E-09	0.00	6.77E-10	1.98E-11	0.00	4.27E-08	1.29E-08	0.00	-1.86E-09	0.00	5.90E-08	0.00000
CNG	China-EoL India	4.60E-09	0.00	6.77E-10	1.98E-11	0.00	4.27E-08	1.29E-08	0.00	0.00	-1.82E-09	0.00000	5.91E-08
CNG	Turkey-EoL China	6.33E-09	0.00	5.49E-10	5.51E-12	0.00	4.27E-08	1.44E-08	0.00	-1.90E-09	0.00	6.21E-08	0.00000
CNG	Turkey-EoL India	6.33E-09	0.00	5.49E-10	5.51E-12	0.00	4.27E-08	1.44E-08	0.00	0.00	-1.87E-09	0.00000	6.21E-08
CNG	Sweden-EoL China	1.43E-08	0.00	1.16E-09	2.91E-11	0.00	4.27E-08	1.46E-08	0.00	-1.95E-09	0.00	7.09E-08	0.00000
CNG	Sweden-EoL India	1.43E-08	0.00	1.16E-09	2.91E-11	0.00	4.27E-08	1.46E-08	0.00	0.00	-1.92E-09	0.00000	7.09E-08

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
CNG	Poland-EoL China	1.15E-08	0.00	1.03E-09	1.31E-11	0.00	4.27E-08	1.44E-08	0.00	-1.91E-09	0.00	6.77E-08	0.00000
CNG	Poland-EoL India	1.15E-08	0.00	1.03E-09	1.31E-11	0.00	4.27E-08	1.44E-08	0.00	0.00	-1.88E-09	0.00000	6.77E-08
CNG	India-EoL China	7.13E-09	0.00	6.91E-10	1.17E-11	0.00	4.27E-08	1.30E-08	0.00	-1.86E-09	0.00	6.17E-08	0.00000
CNG	India-EoL India	7.13E-09	0.00	6.91E-10	1.17E-11	0.00	4.27E-08	1.30E-08	0.00	0.00	-1.83E-09	0.00000	6.17E-08
DB	China-EoL China	6.87E-09	0.00	0.00	1.93E-11	0.00	3.58E-08	4.40E-08	0.00	-1.74E-09	0.00	8.49E-08	0.00000
DB	China-EoL India	6.87E-09	0.00	0.00	1.93E-11	0.00	3.58E-08	4.40E-08	0.00	0.00	-1.70E-09	0.00000	8.50E-08
DB	Turkey 1-EoL China	5.10E-09	0.00	0.00	5.51E-12	0.00	3.58E-08	4.40E-08	0.00	-1.74E-09	0.00	8.31E-08	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
DB	Turkey 1-EoL India	5.10E-09	0.00	0.00	5.51E-12	0.00	3.58E-08	4.40E-08	0.00	0.00	-1.70E-09	0.00000	8.32E-08
DB	Turkey2-EoL China	8.90E-09	0.00	0.00	5.30E-12	0.00	3.58E-08	4.59E-08	0.00	-1.74E-09	0.00	8.89E-08	0.00000
DB	Turkey2-EoL India	8.90E-09	0.00	0.00	5.30E-12	0.00	3.58E-08	4.59E-08	0.00	0.00	-1.70E-09	0.00000	8.89E-08
DB	Poland-EoL China	9.99E-09	0.00	0.00	1.31E-11	0.00	3.58E-08	4.20E-08	0.00	-1.74E-09	0.00	8.60E-08	0.00000
DB	Poland-EoL India	9.99E-09	0.00	0.00	1.31E-11	0.00	3.58E-08	4.20E-08	0.00	0.00	-1.70E-09	0.00000	8.61E-08

Table 18 Operating Surplus indicator data

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	China-EoL China	6.94E-08	1.56E-08	0.00	1.08E-10	9.33E-09	3.29E-08	1.61E-08	0.00	-3.46E-09	0.00	1.40E-07	0.00000
EB	China-EoL India	6.94E-08	1.56E-08	0.00	1.08E-10	9.33E-09	3.29E-08	1.61E-08	0.00	0.00	-3.01E-09	0.00000	1.40E-07
EB	Germany-EoL China	8.95E-08	1.91E-08	0.00	1.46E-10	9.33E-09	3.29E-08	2.49E-08	0.00	-3.34E-09	0.00	1.72E-07	0.00000
EB	Germany-EoL India	8.95E-08	1.91E-08	0.00	1.46E-10	9.33E-09	3.29E-08	2.49E-08	0.00	0.00	-2.90E-09	0.00000	1.73E-07
EB	Spain-EoL China	8.71E-08	2.21E-08	0.00	1.24E-10	9.33E-09	3.29E-08	1.74E-08	0.00	-3.13E-09	0.00	1.66E-07	0.00000
EB	Spain-EoL India	8.71E-08	2.21E-08	0.00	1.24E-10	9.33E-09	3.29E-08	1.74E-08	0.00	0.00	-2.72E-09	0.00000	1.66E-07
EB	Sweden-EoL China	7.67E-08	2.08E-08	0.00	1.68E-10	9.33E-09	3.29E-08	1.56E-08	0.00	-2.48E-09	0.00	1.53E-07	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	Sweden-EoL India	7.67E-08	2.08E-08	0.00	1.68E-10	9.33E-09	3.29E-08	1.56E-08	0.00	0.00	-2.13E-09	0.00000	1.53E-07
CNG	China-EoL China	1.44E-08	0.00	1.62E-09	9.84E-11	0.00	4.35E-08	3.51E-08	0.00	-4.86E-09	0.00	8.98E-08	0.00000
CNG	China-EoL India	1.44E-08	0.00	1.62E-09	9.84E-11	0.00	4.35E-08	3.51E-08	0.00	0.00	-4.33E-09	0.00000	9.03E-08
CNG	Turkey-EoL China	1.44E-08	0.00	1.95E-09	9.09E-11	0.00	4.35E-08	3.91E-08	0.00	-4.97E-09	0.00	9.40E-08	0.00000
CNG	Turkey-EoL India	1.44E-08	0.00	1.95E-09	9.09E-11	0.00	4.35E-08	3.91E-08	0.00	0.00	-4.41E-09	0.00000	9.46E-08
CNG	Sweden-EoL China	4.65E-08	0.00	5.88E-09	1.27E-10	0.00	4.35E-08	3.98E-08	0.00	-5.09E-09	0.00	1.31E-07	0.00000
CNG	Sweden-EoL India	4.65E-08	0.00	5.88E-09	1.27E-10	0.00	4.35E-08	3.98E-08	0.00	0.00	-4.52E-09	0.00000	1.31E-07

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
CNG	Poland-EoL China	6.30E-08	0.00	7.86E-09	2.65E-10	0.00	4.35E-08	3.91E-08	0.00	-4.99E-09	0.00	1.49E-07	0.00000
CNG	Poland-EoL India	6.30E-08	0.00	7.86E-09	2.65E-10	0.00	4.35E-08	3.91E-08	0.00	0.00	-4.43E-09	0.00000	1.49E-07
CNG	India-EoL China	1.18E-08	0.00	1.44E-09	4.04E-11	0.00	4.35E-08	3.53E-08	0.00	-4.87E-09	0.00	8.72E-08	0.00000
CNG	India-EoL India	1.18E-08	0.00	1.44E-09	4.04E-11	0.00	4.35E-08	3.53E-08	0.00	0.00	-4.33E-09	0.00000	8.77E-08
DB	China-EoL China	2.15E-08	0.00	0.00	9.57E-11	0.00	3.64E-08	1.14E-07	0.00	-4.56E-09	0.00	1.67E-07	0.00000
DB	China-EoL India	2.15E-08	0.00	0.00	9.57E-11	0.00	3.64E-08	1.14E-07	0.00	0.00	-4.07E-09	0.00000	1.68E-07
DB	Turkey 1-EoL China	1.16E-08	0.00	0.00	9.09E-11	0.00	3.64E-08	1.14E-07	0.00	-4.56E-09	0.00	1.58E-07	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
DB	Turkey 1-EoL India	1.16E-08	0.00	0.00	9.09E-11	0.00	3.64E-08	1.14E-07	0.00	0.00	-4.07E-09	0.00000	1.58E-07
DB	Turkey2-EoL China	2.03E-08	0.00	0.00	8.74E-11	0.00	3.64E-08	1.19E-07	0.00	-4.56E-09	0.00	1.71E-07	0.00000
DB	Turkey2-EoL India	2.03E-08	0.00	0.00	8.74E-11	0.00	3.64E-08	1.19E-07	0.00	0.00	-4.07E-09	0.00000	1.72E-07
DB	Poland-EoL China	5.48E-08	0.00	0.00	2.65E-10	0.00	3.64E-08	1.09E-07	0.00	-4.56E-09	0.00	1.96E-07	0.00000
DB	Poland-EoL India	5.48E-08	0.00	0.00	2.65E-10	0.00	3.64E-08	1.09E-07	0.00	0.00	-4.07E-09	0.00000	1.96E-07

Table 19 GDP indicaotr data

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	China-EoL China	1.59E-07	3.54E-08	0.00	2.51E-10	2.68E-08	1.48E-07	4.35E-08	0.00	-7.36E-09	0.00	4.05E-07	0.00000
EB	China-EoL India	1.59E-07	3.54E-08	0.00	2.51E-10	2.68E-08	1.48E-07	4.35E-08	0.00	0.00	-7.38E-09	0.00000	4.05E-07
EB	Germany-EoL China	2.40E-07	5.33E-08	0.00	2.26E-10	2.68E-08	1.48E-07	6.74E-08	0.00	-7.11E-09	0.00	5.28E-07	0.00000
EB	Germany-EoL India	2.40E-07	5.33E-08	0.00	2.26E-10	2.68E-08	1.48E-07	6.74E-08	0.00	0.00	-7.13E-09	0.00000	5.28E-07
EB	Spain-EoL China	2.42E-07	5.37E-08	0.00	3.31E-10	2.68E-08	1.48E-07	4.72E-08	0.00	-6.65E-09	0.00	5.10E-07	0.00000
EB	Spain-EoL India	2.42E-07	5.37E-08	0.00	3.31E-10	2.68E-08	1.48E-07	4.72E-08	0.00	0.00	-6.67E-09	0.00000	5.10E-07
EB	Sweden-EoL China	2.31E-07	5.14E-08	0.00	3.30E-10	2.68E-08	1.48E-07	4.21E-08	0.00	-5.29E-09	0.00	4.94E-07	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
EB	Sweden-EoL India	2.31E-07	5.14E-08	0.00	3.30E-10	2.68E-08	1.48E-07	4.21E-08	0.00	0.00	-5.31E-09	0.00000	4.94E-07
CNG	China-EoL China	3.30E-08	0.00	3.66E-09	2.29E-10	0.00	1.95E-07	6.05E-08	0.00	-1.02E-08	0.00	2.82E-07	0.00000
CNG	China-EoL India	3.30E-08	0.00	3.66E-09	2.29E-10	0.00	1.95E-07	6.05E-08	0.00	0.00	-1.03E-08	0.00000	2.82E-07
CNG	Turkey-EoL China	4.68E-08	0.00	5.20E-09	1.02E-10	0.00	1.95E-07	6.74E-08	0.00	-1.04E-08	0.00	3.04E-07	0.00000
CNG	Turkey-EoL India	4.68E-08	0.00	5.20E-09	1.02E-10	0.00	1.95E-07	6.74E-08	0.00	0.00	-1.05E-08	0.00000	3.04E-07
CNG	Sweden-EoL China	1.40E-07	0.00	1.56E-08	3.40E-10	0.00	1.95E-07	6.87E-08	0.00	-1.07E-08	0.00	4.10E-07	0.00000
CNG	Sweden-EoL India	1.40E-07	0.00	1.56E-08	3.40E-10	0.00	1.95E-07	6.87E-08	0.00	0.00	-1.08E-08	0.00000	4.09E-07

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
CNG	Poland-EoL China	1.37E-07	0.00	1.52E-08	3.39E-10	0.00	1.95E-07	6.74E-08	0.00	-1.05E-08	0.00	4.05E-07	0.00000
CNG	Poland-EoL India	1.37E-07	0.00	1.52E-08	3.39E-10	0.00	1.95E-07	6.74E-08	0.00	0.00	-1.05E-08	0.00000	4.05E-07
CNG	India-EoL China	3.60E-08	0.00	4.00E-09	1.09E-10	0.00	1.95E-07	6.09E-08	0.00	-1.02E-08	0.00	2.86E-07	0.00000
CNG	India-EoL India	3.60E-08	0.00	4.00E-09	1.09E-10	0.00	1.95E-07	6.09E-08	0.00	0.00	-1.03E-08	0.00000	2.86E-07
DB	China-EoL China	4.92E-08	0.00	0.00	2.23E-10	0.00	1.64E-07	1.90E-07	0.00	-9.55E-09	0.00	3.93E-07	0.00000
DB	China-EoL India	4.92E-08	0.00	0.00	2.23E-10	0.00	1.64E-07	1.90E-07	0.00	0.00	-9.61E-09	0.00000	3.93E-07
DB	Turkey 1-EoL China	3.77E-08	0.00	0.00	1.02E-10	0.00	1.64E-07	1.90E-07	0.00	-9.55E-09	0.00	3.82E-07	0.00000

Alternative vehicle	Country	Bus Manufacture	Battery Manufacture	Tank Manufacture	Shipping	Infrastructure	M&R	WTT	TTW	EoL_China Scenario	EoL_India Scenario	Total with China	Total with Inida
DB	Turkey 1-EoL India	3.77E-08	0.00	0.00	1.02E-10	0.00	1.64E-07	1.90E-07	0.00	0.00	-9.61E-09	0.00000	3.82E-07
DB	Turkey2-EoL China	6.59E-08	0.00	0.00	9.82E-11	0.00	1.64E-07	1.98E-07	0.00	-9.55E-09	0.00	4.18E-07	0.00000
DB	Turkey2-EoL India	6.59E-08	0.00	0.00	9.82E-11	0.00	1.64E-07	1.98E-07	0.00	0.00	-9.61E-09	0.00000	4.18E-07
DB	Poland-EoL China	1.19E-07	0.00	0.00	3.39E-10	0.00	1.64E-07	1.81E-07	0.00	-9.55E-09	0.00	4.55E-07	0.00000
DB	Poland-EoL India	1.19E-07	0.00	0.00	3.39E-10	0.00	1.64E-07	1.81E-07	0.00	0.00	-9.61E-09	0.00000	4.55E-07

Table 20 LCC data

Alternative vehicle	Country	Initial Cost	Fuel Cost	Infastructions	Maintenance and Repair	Insurance Costs	Replacement	Salvage Value	Total Cost
EB	China	$395,000.00	$415,414.89	$150,000.00	$90,035.31	$167,999.09	$34,253.56	-$82,636.69	$1,170,066.18
EB	Germany	$724,800.00	$644,054.10	$150,000.00	$90,035.31	$167,999.09	$62,853.12	-$181,200.00	$1,658,541.62
EB	Spain	$604,050.00	$450,837.87	$150,000.00	$90,035.31	$167,999.09	$52,381.93	-$151,012.50	$1,364,291.71
EB	Sweden	$783,751.00	$402,533.81	$150,000.00	$90,035.31	$167,999.09	$67,965.22	-$195,937.75	$1,466,346.69
CNG	China	$90,000.00	$906,138.97		$117,723.16	$38,278.27		-$18,828.61	$1,133,311.79
CNG	Turkey	$200,000.00	$1,009,578.22		$117,723.16	$38,278.27		-$50,000.00	$1,315,579.65
CNG	Sweden	$360,000.00	$1,028,537.43		$117,723.16	$38,278.27		-$90,000.00	$1,454,538.86
CNG	Poland	$340,000.00	$1,009,578.22		$117,723.16	$38,278.27		-$85,000.00	$1,420,579.65
CNG	India	$109,535.90	$912,412.24		$117,723.16	$38,278.27		-$27,383.98	$1,150,565.59
DB	China	$121,000.00	$2,203,438.70		$98,604.52	$51,463.01		-$25,314.02	$2,449,192.21

Alternative vehicle	Country	Initial Cost	Fuel Cost	Infastructions	Maintenance and Repair	Insurance Costs	Replacement	Salvage Value	Total Cost
DB	Turkey 1	$145,000.00	$2,203,438.70		$98,604.52	$51,463.01		- $36,250.00	$2,462,256.23
DB	Turkey 2	$220,000.00	$2,302,469.65		$98,604.52	$51,463.01		- $55,000.00	$2,617,537.19
DB	Poland	$270,425.00	$2,104,407.75		$98,604.52	$51,463.01		- $67,606.25	$2,457,294.03

Table 21 GWP Inside/Outside Qatar Impacts

Alternative vehicle	Country	GWP-Outside Qatar	GWP-Inside Qatar	Total	%outside	%inside
EB	China	2.79E-01	5.11E-01	7.91E-01	35%	65%
EB	Germany	9.97E-02	7.30E-01	8.29E-01	12%	88%
EB	Spain	1.17E-01	5.45E-01	6.62E-01	18%	82%
EB	Sweden	6.65E-02	4.99E-01	5.66E-01	12%	88%
CNG	China	5.65E-02	1.00E+00	1.06E+00	5%	95%
CNG	Turkey	2.37E-02	1.10E+00	1.13E+00	2%	98%
CNG	Sweden	3.78E-02	1.12E+00	1.16E+00	3%	97%
CNG	Poland	6.20E-02	1.10E+00	1.17E+00	5%	95%
CNG	India	5.51E-02	1.01E+00	1.06E+00	5%	95%
DB	China	7.74E-02	1.31E+00	1.39E+00	6%	94%
DB	Turkey 1	6.02E-02	1.31E+00	1.37E+00	4%	96%

Alternative vehicle	Country	GWP-Outside Qatar	GWP-Inside Qatar	Total	%outside	%inside
DB	Turkey2	7.40E-02	1.36E+00	1.44E+00	5%	95%
DB	Poland	9.00E-02	1.25E+00	1.34E+00	7%	93%

Table 22 PMF Inside/Outside Qatar Impacts

Alternative vehicle	Country	PMF-Outside Qatar	PMF-Inside Qatar	Total	%outside	%inside
EB	China	5.23E-04	2.97E-04	8.21E-04	64%	36%
EB	Germany	1.47E-04	3.72E-04	5.19E-04	28%	72%
EB	Spain	1.56E-04	3.09E-04	4.65E-04	34%	66%
EB	Sweden	1.20E-04	2.93E-04	4.14E-04	29%	71%
CNG	China	1.10E-04	2.67E-04	3.76E-04	29%	71%
CNG	Turkey	3.74E-05	2.81E-04	3.19E-04	12%	88%
CNG	Sweden	7.03E-05	2.84E-04	3.54E-04	20%	80%
CNG	Poland	8.52E-05	2.81E-04	3.66E-04	23%	77%
CNG	India	1.28E-04	2.68E-04	3.96E-04	32%	68%
DB	China	1.45E-04	4.05E-04	5.49E-04	26%	74%
DB	Turkey 1	3.69E-05	4.05E-04	4.42E-04	8%	92%
DB	Turkey2	5.53E-05	4.18E-04	4.73E-04	12%	88%
DB	Poland	7.77E-05	3.92E-04	4.69E-04	17%	83%

Table 23 POF Inside/Outside Qatar Impacts

Alternative vehicle	Country	POF-Outside Qatar	POF-Inside Qatar	Total	%outside	%inside
EB	China	6.19E-04	9.97E-04	1.62E-03	38%	62%
EB	Germany	2.99E-04	1.31E-03	1.61E-03	19%	81%
EB	Spain	3.31E-04	1.05E-03	1.38E-03	24%	76%
EB	Sweden	2.45E-04	9.80E-04	1.23E-03	20%	80%
CNG	China	1.30E-04	8.21E-04	9.52E-04	14%	86%
CNG	Turkey	6.78E-05	8.64E-04	9.32E-04	7%	93%
CNG	Sweden	1.45E-04	8.72E-04	1.02E-03	14%	86%
CNG	Poland	1.75E-04	8.64E-04	1.04E-03	17%	83%
CNG	India	1.52E-04	8.24E-04	9.76E-04	16%	84%
DB	China	1.77E-04	1.47E-03	1.65E-03	11%	89%
DB	Turkey 1	6.50E-05	1.47E-03	1.53E-03	4%	96%
DB	Turkey2	9.88E-05	1.52E-03	1.62E-03	6%	94%
DB	Poland	1.53E-04	1.42E-03	1.57E-03	10%	90%

Table 24 Land Use Inside/Outside Qatar Impacts

Alternative vehicle	Country	Land Use-Outside Qatar	Land Use-Inside Qatar	Total	%outside	%inside
EB	China	1.27E-07	5.95E-08	1.86E-07	68%	32%
EB	Germany	5.19E-08	5.96E-08	1.11E-07	47%	53%
EB	Spain	7.94E-08	5.95E-08	1.39E-07	57%	43%

Alternative vehicle	Country	Land Use-Outside Qatar	Land Use-Inside Qatar	Total	%outside	%inside
EB	Sweden	7.28E-08	5.95E-08	1.32E-07	55%	45%
CNG	China	2.43E-08	5.88E-08	8.31E-08	29%	71%
CNG	Turkey	1.70E-08	5.88E-08	7.58E-08	22%	78%
CNG	Sweden	3.91E-08	5.88E-08	9.79E-08	40%	60%
CNG	Poland	3.57E-08	5.88E-08	9.45E-08	38%	62%
CNG	India	1.24E-08	5.88E-08	7.13E-08	17%	83%
DB	China	4.70E-08	4.95E-08	9.65E-08	49%	51%
DB	Turkey 1	2.73E-08	4.95E-08	7.68E-08	36%	64%
DB	Turkey2	3.56E-08	4.95E-08	8.51E-08	42%	58%
DB	Poland	4.31E-08	4.95E-08	9.26E-08	47%	53%

Table 25 Water Consumption Inside/Outside Qatar Impacts

Alternative vehicle	Country	W.C-Outside Qatar	W.C-Inside Qatar	Total	%outside	%inside
EB	China	2.09E-08	1.19E-08	3.29E-08	64%	36%
EB	Germany	7.06E-09	1.23E-08	1.94E-08	36%	64%
EB	Spain	8.72E-09	1.20E-08	2.07E-08	42%	58%
EB	Sweden	7.26E-09	1.19E-08	1.92E-08	38%	62%
CNG	China	4.17E-09	1.16E-08	1.58E-08	26%	74%
CNG	Turkey	1.99E-09	1.16E-08	1.36E-08	15%	85%
CNG	Sweden	3.66E-09	1.16E-08	1.53E-08	24%	76%
CNG	Poland	3.78E-09	1.16E-08	1.54E-08	25%	75%

Alternative vehicle	Country	W.C-Outside Qatar	W.C-Inside Qatar	Total	%outside	%inside
CNG	India	3.53E-09	1.16E-08	1.51E-08	23%	77%
DB	China	7.38E-09	9.80E-09	1.72E-08	43%	57%
DB	Turkey 1	3.69E-09	9.80E-09	1.35E-08	27%	73%
DB	Turkey2	4.50E-09	9.81E-09	1.43E-08	31%	69%
DB	Poland	5.15E-09	9.80E-09	1.50E-08	34%	66%

Table 26 Water Withdraw Inside/Outside Qatar Impacts

Alternative vehicle	Country	W.W-Outside Qatar	W.W-Inside Qatar	Total	%outside	%inside
EB	China	7.38E-09	7.03E-08	7.77E-08	9%	91%
EB	Germany	3.50E-09	1.08E-07	1.11E-07	3%	97%
EB	Spain	4.54E-09	7.61E-08	8.06E-08	6%	94%
EB	Sweden	2.09E-09	6.82E-08	7.03E-08	3%	97%
CNG	China	1.50E-09	2.07E-09	3.58E-09	42%	58%
CNG	Turkey	7.29E-10	2.08E-09	2.81E-09	26%	74%
CNG	Sweden	1.24E-09	2.08E-09	3.32E-09	37%	63%
CNG	Poland	1.58E-09	2.08E-09	3.66E-09	43%	57%
CNG	India	3.32E-09	2.08E-09	5.40E-09	61%	39%
DB	China	2.01E-09	4.31E-09	6.31E-09	32%	68%
DB	Turkey 1	7.13E-10	4.31E-09	5.02E-09	14%	86%
DB	Turkey2	1.07E-09	4.42E-09	5.49E-09	20%	80%
DB	Poland	1.47E-09	4.19E-09	5.67E-09	26%	74%

Table 27 Human Health Inside/Outside Qatar Impacts

Alternative vehicle	Country	H.H-Outside Qatar	H.H-Inside Qatar	Total	%outside	%inside
EB	China	3.67E-10	2.56E-10	6.22E-10	59%	41%
EB	Germany	1.06E-10	3.32E-10	4.37E-10	24%	76%
EB	Spain	1.14E-10	2.67E-10	3.81E-10	30%	70%
EB	Sweden	8.47E-11	2.51E-10	3.36E-10	25%	75%
CNG	China	7.65E-11	3.01E-10	3.78E-10	20%	80%
CNG	Turkey	2.67E-11	3.24E-10	3.51E-10	8%	92%
CNG	Sweden	4.93E-11	3.28E-10	3.78E-10	13%	87%
CNG	Poland	6.20E-11	3.24E-10	3.86E-10	16%	84%
CNG	India	8.83E-11	3.03E-10	3.91E-10	23%	77%
DB	China	1.01E-10	4.29E-10	5.31E-10	19%	81%
DB	Turkey 1	3.13E-11	4.29E-10	4.60E-10	7%	93%
DB	Turkey2	4.47E-11	4.45E-10	4.89E-10	9%	91%
DB	Poland	6.09E-11	4.14E-10	4.75E-10	13%	87%

Table 28 Employment Inside/Outside Qatar Impacts

Alternative vehicle	Country	Emp-Outside Qatar	Emp-Inside Qatar	Total	%outside	%inside
EB	China	1.27E-08	5.98E-09	1.87E-08	68%	32%
EB	Germany	6.31E-09	6.27E-09	1.26E-08	50%	50%

Alternative vehicle	Country	Emp-Outside Qatar	Emp-Inside Qatar	Total	%outside	%inside
EB	Spain	7.71E-09	6.03E-09	1.37E-08	56%	44%
EB	Sweden	6.00E-09	5.97E-09	1.20E-08	50%	50%
CNG	China	2.45E-09	5.95E-09	8.39E-09	29%	71%
CNG	Turkey	2.30E-09	6.00E-09	8.30E-09	28%	72%
CNG	Sweden	3.30E-09	6.01E-09	9.31E-09	35%	65%
CNG	Poland	5.27E-09	6.00E-09	1.13E-08	47%	53%
CNG	India	5.71E-09	5.95E-09	1.17E-08	49%	51%
DB	China	3.86E-09	5.64E-09	9.50E-09	41%	59%
DB	Turkey 1	2.24E-09	5.64E-09	7.88E-09	28%	72%
DB	Turkey2	3.46E-09	5.69E-09	9.14E-09	38%	62%
DB	Poland	4.65E-09	5.59E-09	1.02E-08	45%	55%

Table 29 Compensation Inside/Outside Qatar Impacts

Alternative vehicle	Country	Compensation-Outside Qatar	Compensation-Inside Qatar	Total	%outside	%inside
EB	China	8.21E-08	1.09E-07	1.91E-07	43%	57%
EB	Germany	1.68E-07	1.17E-07	2.85E-07	59%	41%
EB	Spain	1.67E-07	1.10E-07	2.77E-07	60%	40%
EB	Sweden	1.59E-07	1.08E-07	2.68E-07	59%	41%
CNG	China	1.58E-08	1.21E-07	1.37E-07	11%	89%
CNG	Turkey	2.91E-08	1.23E-07	1.52E-07	19%	81%
CNG	Sweden	8.85E-08	1.23E-07	2.12E-07	42%	58%

CNG	Poland	6.91E-08	1.23E-07	1.92E-07	36%	64%
CNG	India	1.93E-08	1.21E-07	1.41E-07	14%	86%
DB	China	2.47E-08	1.19E-07	1.44E-07	17%	83%
DB	Turkey 1	2.47E-08	1.19E-07	1.44E-07	17%	83%
DB	Turkey2	4.05E-08	1.21E-07	1.61E-07	25%	75%
DB	Poland	5.78E-08	1.18E-07	1.76E-07	33%	67%

Table 30 Tax Inside/Outside Qatar Impacts

Alternative vehicle	**Country**	**Tax-Outside Qatar**	**Tax-Inside Qatar**	**Total**	**%outside**	**%inside**
EB	China	2.84E-08	4.99E-08	7.83E-08	36%	64%
EB	Germany	1.80E-08	5.67E-08	7.47E-08	24%	76%
EB	Spain	2.05E-08	5.09E-08	7.14E-08	29%	71%
EB	Sweden	2.72E-08	4.95E-08	7.67E-08	35%	65%
CNG	China	5.35E-09	5.56E-08	6.09E-08	9%	91%
CNG	Turkey	6.94E-09	5.70E-08	6.40E-08	11%	89%
CNG	Sweden	1.55E-08	5.73E-08	7.28E-08	21%	79%
CNG	Poland	1.26E-08	5.70E-08	6.96E-08	18%	82%
CNG	India	7.89E-09	5.56E-08	6.35E-08	12%	88%
DB	China	7.74E-09	7.89E-08	8.66E-08	9%	91%
DB	Turkey 1	5.95E-09	7.89E-08	8.49E-08	7%	93%
DB	Turkey2	9.80E-09	8.08E-08	9.06E-08	11%	89%
DB	Poland	1.08E-08	7.70E-08	8.78E-08	12%	88%

Table 31 Operating Surplus Inside/Outside Qatar Impacts

Alternative vehicle	Country	Operating Surplus-Outside Qatar	Operating Surplus-Inside Qatar	Total	%outside	%inside
EB	China	8.58E-08	5.76E-08	1.43E-07	60%	40%
EB	Germany	1.10E-07	6.61E-08	1.76E-07	77%	38%
EB	Spain	1.10E-07	5.89E-08	1.69E-07	77%	35%
EB	Sweden	9.83E-08	5.71E-08	1.55E-07	69%	37%
CNG	China	1.63E-08	7.83E-08	9.46E-08	11%	83%
CNG	Turkey	1.67E-08	8.23E-08	9.90E-08	12%	83%
CNG	Sweden	5.28E-08	8.30E-08	1.36E-07	37%	61%
CNG	Poland	7.14E-08	8.23E-08	1.54E-07	50%	54%
CNG	India	1.35E-08	7.86E-08	9.21E-08	9%	85%
DB	China	2.47E-08	1.47E-07	1.72E-07	17%	86%
DB	Turkey 1	1.48E-08	1.47E-07	1.62E-07	10%	91%
DB	Turkey2	2.37E-08	1.52E-07	1.76E-07	17%	87%
DB	Poland	5.81E-08	1.42E-07	2.00E-07	40%	71%

Table 32 GDP Inside/Outside Qatar Impacts

Alternative vehicle	Country	GDP-Outside Qatar	GDP-Inside Qatar	Total	%outside	%inside
EB	China	1.96E-07	2.16E-07	4.13E-07	48%	52%

EB	Germany	2.96E-07	2.39E-07	5.35E-07	55%	45%
EB	Spain	2.97E-07	2.20E-07	5.17E-07	57%	43%
EB	Sweden	2.85E-07	2.15E-07	5.00E-07	57%	43%
CNG	China	3.74E-08	2.55E-07	2.93E-07	13%	87%
CNG	Turkey	5.27E-08	2.62E-07	3.15E-07	17%	83%
CNG	Sweden	1.57E-07	2.63E-07	4.20E-07	37%	63%
CNG	Poland	1.53E-07	2.62E-07	4.15E-07	37%	63%
CNG	India	4.07E-08	2.56E-07	2.96E-07	14%	86%
DB	China	5.71E-08	3.46E-07	4.03E-07	14%	86%
DB	Turkey 1	4.55E-08	3.46E-07	3.91E-07	12%	88%
DB	Turkey2	7.40E-08	3.54E-07	4.28E-07	17%	83%
DB	Poland	1.27E-07	3.38E-07	4.64E-07	27%	73%

Table 33 LCSA data matrix

			Environmental Aspects				**Social Aspects**			**Economic Aspects**					
			GWP	PMF	POF	Land use	W.C.	W.W.	H.H.	Employment	Tax	Compensation	Operating Surplus	GDP	LCC
			kg CO2-eqv	kg PMF -eqv	kg P0F-eqv	Km^2	mm^3	mm^3	DALY	1000 person	M Euro	M Euro	M Euro	M Euro	M Euro
EoL	EC	China	7.72 E-01	7.80 E-04	1.57 E-03	1.81 E-07	3.13 E-08	7.71 E-08	5.95 E-10	1.83E-08	7.70 E-08	1.88E-07	1.24E-07	3.89 E-07	1.27E+00

		Environmental Aspects				Social Aspects				Economic Aspects				
	Germany	8.11E-01	4.80E-04	1.56E-03	1.06E-07	1.78E-08	1.11E-07	4.10E-10	1.22E-08	7.34E-08	2.82E-07	1.48E-07	5.03E-07	1.48E+00
	Spain	6.45E-01	4.29E-04	1.34E-03	1.34E-07	1.93E-08	8.01E-08	3.56E-10	1.33E-08	7.02E-08	2.74E-07	1.48E-07	4.93E-07	1.40E+00
	Sweden	5.52E-01	3.84E-04	1.19E-03	1.28E-07	1.80E-08	6.99E-08	3.15E-10	1.16E-08	7.57E-08	2.66E-07	1.37E-07	4.79E-07	1.52E+00
CNG	China	1.03E+00	3.21E-04	8.87E-04	7.65E-08	1.41E-08	2.74E-09	3.39E-10	7.80E-09	5.90E-08	1.34E-07	8.98E-08	2.82E-07	8.36E-01
	Turkey	1.10E+00	2.62E-04	8.66E-04	6.91E-08	1.18E-08	1.95E-09	3.11E-10	7.69E-09	6.21E-08	1.48E-07	9.40E-08	3.04E-07	9.01E-01
	Sweden	1.13E+00	2.95E-04	9.49E-04	9.10E-08	1.35E-08	2.44E-09	3.36E-10	8.68E-09	7.09E-08	2.08E-07	1.31E-07	4.10E-07	9.99E-01
	Poland	1.13E+00	3.09E-04	9.73E-04	8.77E-08	1.36E-08	2.80E-09	3.46E-10	1.07E-08	6.77E-08	1.88E-07	1.49E-07	4.05E-07	9.87E-01
	India	1.03E+00	3.41E-04	9.12E-04	6.47E-08	1.34E-08	4.55E-09	3.52E-10	1.11E-08	6.17E-08	1.37E-07	8.72E-08	2.86E-07	8.45E-01
Diesel	China	1.36E+00	5.00E-04	1.59E-03	9.04E-08	1.56E-08	5.52E-09	4.96E-10	8.94E-09	8.49E-08	1.41E-07	1.67E-07	3.93E-07	8.51E-01
	Turkey (ISUZU)	1.30E+00	3.92E-04	1.48E-03	7.07E-08	1.19E-08	4.22E-09	4.21E-10	7.32E-09	8.31E-08	1.41E-07	1.58E-07	3.82E-07	8.62E-01
	Turkey	1.37E+00	4.23E-04	1.56E-03	7.90E-08	1.27E-08	4.70E-09	4.49E-10	8.59E-09	8.89E-08	1.58E-07	1.71E-07	4.18E-07	9.08E-01
	Poland	1.28E+00	4.20E-04	1.51E-03	8.65E-08	1.33E-08	4.87E-09	4.35E-10	9.69E-09	8.60E-08	1.73E-07	1.96E-07	4.55E-07	9.39E-01

			Environmental Aspects				Social Aspects				Economic Aspects				
EoL in India	EC	China	7.77E-01	7.87E-04	1.58E-03	1.84E-07	3.18E-08	7.59E-08	5.99E-10	1.76E-08	7.69E-08	1.88E-07	1.24E-07	3.89E-07	1.27E+00
		Germany	8.16E-01	4.86E-04	1.57E-03	1.09E-07	1.83E-08	1.09E-07	4.15E-10	1.15E-08	7.33E-08	2.82E-07	1.48E-07	5.03E-07	1.48E+00
		Spain	6.50E-01	4.35E-04	1.34E-03	1.37E-07	1.98E-08	7.90E-08	3.60E-10	1.27E-08	7.01E-08	2.74E-07	1.49E-07	4.93E-07	1.40E+00
		Sweden	5.57E-01	3.91E-04	1.20E-03	1.30E-07	1.84E-08	6.91E-08	3.20E-10	1.12E-08	7.56E-08	2.65E-07	1.38E-07	4.79E-07	1.52E+00
	CNG	China	1.03E+00	3.18E-04	8.87E-04	8.04E-08	1.46E-08	8.47E-10	3.38E-10	6.78E-09	5.91E-08	1.33E-07	9.03E-08	2.82E-07	8.36E-01
		Turkey	1.10E+00	2.59E-04	8.66E-04	7.31E-08	1.24E-08	3.56E-11	3.10E-10	6.66E-09	6.21E-08	1.48E-07	9.46E-08	3.04E-07	9.01E-01
		Sweden	1.13E+00	2.93E-04	9.50E-04	9.51E-08	1.40E-08	4.99E-10	3.35E-10	7.62E-09	7.09E-08	2.07E-07	1.31E-07	4.09E-07	9.99E-01
		Poland	1.14E+00	3.07E-04	9.73E-04	9.17E-08	1.42E-08	8.79E-10	3.45E-10	9.62E-09	6.77E-08	1.88E-07	1.49E-07	4.05E-07	9.87E-01
		India	1.04E+00	3.38E-04	9.12E-04	6.86E-08	1.39E-08	2.66E-09	3.51E-10	1.00E-08	6.17E-08	1.37E-07	8.77E-08	2.86E-07	8.45E-01
	Diesel	China	1.36E+00	4.95E-04	1.59E-03	9.41E-08	1.61E-08	3.69E-09	4.93E-10	7.99E-09	8.50E-08	1.40E-07	1.68E-07	3.93E-07	8.51E-01
		Turkey (ISUZU)	1.31E+00	3.87E-04	1.47E-03	7.44E-08	1.24E-08	2.39E-09	4.18E-10	6.37E-09	8.32E-08	1.40E-07	1.58E-07	3.82E-07	8.62E-01
		Turkey	1.37E+00	4.18E-04	1.56E-03	8.27E-08	1.32E-08	2.87E-09	4.47E-10	7.63E-09	8.89E-08	1.57E-07	1.72E-07	4.18E-07	9.08E-01

	Environmental Aspects				Social Aspects				Economic Aspects				
Poland	1.28E+00	4.15E-04	1.51E-03	9.02E-08	1.38E-08	3.04E-09	4.32E-10	8.73E-09	8.61E-08	1.72E-07	1.96E-07	4.55E-07	9.39E-01

Appendix B: Definitions of Indicators

Abbreviations	**Explanation**
EV	Electric Vehicle
BEV	Battery Electric Vehicles
HEV	Hybrid Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
AFB	Alternative Fuel Bus
M&R	Maintenance and repair
WTT	Wheel to tank
TTW	Tank to wheel
EoL	End of life for recycling
GWP	Global warming potential
PMF	Particulate Matter Formation
POF	Photochemical Ozone Formation
W.C.	Water consumption
W.W.	Water withdraw

Abbreviations	Explanation
H.H.	Human Health
Emp.	Employment
GDP	Gross Domestic Product
LCSA	Life Cycle Sustainability Assessment
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
SLCA	Social Life Cycle Assessment
ICE	Internal Combustion Engines
LDV	Light-duty vehicle applications
PT	Public Transportation
FFV	Flexible-Fuel Vehicle