FACULTY OF SCIENCE AND TECHNOLOGY

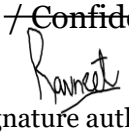
MASTER THESIS

Study programme / specialisation: City and Regional Planning

The spring semester, 2022

Open / ~~Confidential~~

Author: Ravneet Kaur



(Signature author)

Course coordinator: Daniela Müller-Eie

Supervisor(s): Daniela Müller-Eie

Thesis title: Electrification of public transport in India – A feasibility study of electrifying the bus system in Amritsar.

Credits (ECTS): 30

Keywords: Electric buses, carbon emissions, coal based power plants, cost and infrastructure of buses.

Pages: 61

+ appendix: 9

Stavanger, 14/2022

TABLE OF CONTENTS

CHAPTER 1- INTRODUCTION 1
1.1. Introduction to topic 1
1.2. Relevance of the topic 2
1.3. Research question 3
1.4. Research design 5
1.5. Methodology 6
CHAPTER 2 10
TRANSPORT CHARACTERISICTIS IN INDIA 10
2.1. Emissions from road transport sector in india (country) and amritsar (city). 10
2.2. Electric vehicle policies and incentives 10
2.3. Status of public transport e-buses in India, Punjab, and Amritsar. 13
CHAPTER 3 16
EXISTING SCENARIO OF AMRITSAR CITY 16
3.1. City profile 16
3.2. Existing public transport in amritsar city (e-rickshaws and buses) 17
3.3 Bus rapid transit system (brts) 17
3.4. Environment impact on the city. 18
CHPATER 4 20
PUBLIC TRANSPORT CHARACTERISTICS OF AMRITSAR CITY 20
4.1. Existing route details 20
4.2. Daily ridership 21
CHAPTER - 5 23
INFRASTRUCTURE, COST AND CARBON EMISSIONS OF THE BUS SYSTEM IN AMRITSAR CITY. 23
5.1. DIESEL BUS 23
5.1.1. Calculation of Carbon Emissions from Diesel buses in the city. 23
5.1.2. Cost and Infrastructure for Diesel Buses. 24
5.1.3. Infrastructure of the Diesel buses 25
5.2. ELECTRIC BUSES 27
5.2.1 Carbon Emissions from Electric buses running on electricity which is provided From Coal Based Power Plants 27
5.2.3 Cost for electric buses running on electricity sourced from coal. 29

5.2.4 Infrastructure Requirement for Electric Bus Running on Coal.....31

5.3.Calculation of Carbon emissions electric buses from electricity sourced from solar…….... 32

5.3.1.Cost for electric buses running on electricity sourced from solar.....33

5.3.2.Infrastructure Requirement for Electric Bus Running on Solar.....34

CHAPTER 6 - SCENARIO FOR THE FUTURE OF PUBLIC TRANSPORT IN AMRITSAR.....35

6.1. Scenario created on the basis of infrastructure and emissions.....35

6.2. Comparison of tco of diesel bus and electric bus.....37

CHAPTER 7.....41

ANALYSIS.....41

7.1. Impact of electrification on coal.....41

7.2 Impact of electrification on environment.....41

7.3 Impact of electrification on infrastructure –.....42

7.4 Economic impact of electrification on public fleet in amritsar city.....43

CHAPTER 8.....45

DISCUSSION.....45

CHAPTER 9.....49

CONCLUSION.....49

APPENDIX A.....62

APPENDIX B.....64

APPENDIX C.....67

APPENDIX D.....70

LIST OF FIGURES

Figure 1: Emission reduction by 2030. 2
Figure 2: Electric Vehicle Policies in India 12
Figure 3: Showing the allocation of buses in India under the FAME 2 scheme. 12
Figure 4: Deployment of e-bus in different cities of India under the scheme of Fame I & II. 15
Figure 5: The Golden Temple in Amritsar city. 16
Figure 6: The BRTS bus stops in the city. 17
Figure 7: Average Daily ridership of the BRTS buses 22
Figure 8: Level Boarding Alighting 26
Figure 9: Space for wheelchair in the bus 27
Figure 10: An overview of the electricity supply from exsiting pwer grid of the city. 32
Figure 11: Emissions calculated on the basis of scenarios created. 36
Figure 12: Comparison of TCO of 12m AC diesel and electric bus 38
Figure 13: Comparison of operation and maintenance cost of diesel and electric bus 38
Figure 14: Vehicle and Battery cost of diesel and electric bus 39
Figure 15: Cost of diesel fuel, coal and solar 43

LIST OF TABLES

Table 1: Total Emissions saved as of June 2021 with e-buses deployed under the FAME scheme.....13

Table 2: The existing route details of BRTS buses.....20

Table 3: Route details of BRTS and distance of the routes 23

Table 4: Cost parameters for 12m AC Bus.....25

Table 5: Funding done for the infrastructure of diesel buses under the policy and state government. 26

Table 6: Cost already spent on infrastructure constructed for the BRTS in the city. 26

Table 7: Cost parameters for 12m AC Electric Bus with source of electricity from coal 29

Table 8: Detail breakdown of charging infrastructure cost in India. 31

Table 9: Route wise emissions from solar panels with the required electricity.....33

Table 10: Cost paramters for electric bus with source of electricity from solar panels.....33

Table 11: Detail breakdown of the charging infrastructure cost in India. 34

Table 12: Cost and infrastructure requirement based on the different scenarios created. 37

Table 13: Comparison of Technical feasibility of the buses and three wheelers in Amritsar city.....46

Table 14: The distance travelled by the buses on the 3 routes.....62

Table 15: Route wise emissions from solar based electricity. 66

Table 16: Detail calculation of the scenarios of future public transport in Amritsar city. 67

Table 17: Infrastructure requirement based on the scenarios. 67

Table 18: Operation and maintenance cost of diesel and electric bus. 69

Table 19: Vehicle and Battery cost of electric and diesel vehicle. 69

ACKNOWLEDGEMENT

I avail this opportunity to express my thanks to my respected teacher/supervisor Daniela Müller-Eie for her constant supervision, for laying out the guidelines for thesis and working under her guidance has been a great learning experience. The academic and professional experience that I have gained during my post-graduation in the school has been a value addition to my knowledge.

My respected parents who always have been a source of inspiration for me, always guided me in my way to achieve success and supported in every phase of life.

On a personal note, I would like to express thanks to all my friends who helped and supported me during this journey of my post-graduation as an international student.

ABSTRACT

Human activities are the major factor of current global greenhouse Emission, resulting in extreme climate change, Transportation is one of the major causes of the carbon emissions ranking on the third highest emitter in India. To overcome this the public transport in the city is promoted, but with this there is a need to change the use of conventional fuel in public transport. To replace all the traditional diesel fuel urban buses with alternative energy buses.

In the country like India where there is limited source of renewable energy to power the buses, the conventional diesel fuel is the major source of energy. This study will analyse the current scenario of diesel buses, by calculating the carbon emissions, cost, and infrastructure. In case of Indian city to study the feasibility of the electric buses with electricity sourced from coal and solar, different scenarios was created for the future of public transport based on carbon emissions, cost and infrastructure. Based on the scenario assessment, phase wise implementation is recommended to distribute the financial burden of high upfront cost of electric buses.

CHAPTER 1- INTRODUCTION

1.1. INTRODUCTION TO TOPIC

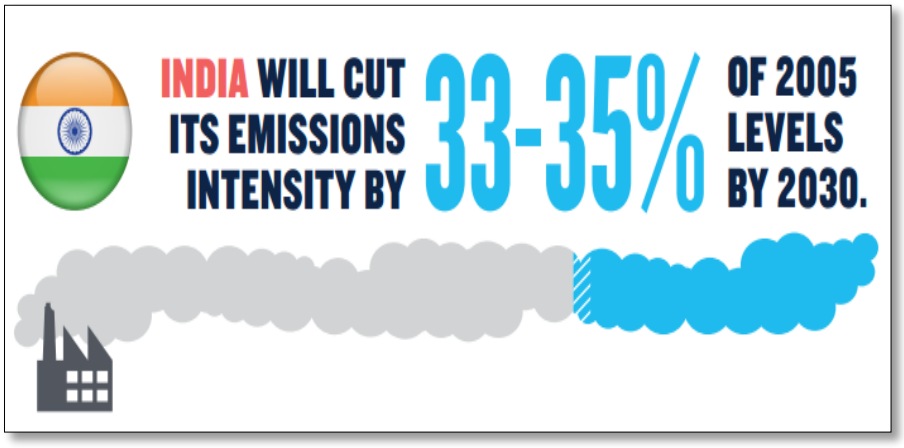
In India the transport sector ranks on the third as the highest emitter of carbon dioxide emissions. In case of transport sector, the road transport emits 90% of carbon dioxide emissions(Singh et al., 2021). All the vehicles in India either public transport or private runs on diesel and petrol. These fuels are dominant because of its easy availability. The fueling stations for diesel and petrol are located in rural and urban areas, therefore accessible by everyone at any time. The number of vehicles is increasing because of growing population and increase in the economic development of the country. As a result, these vehicles use billions of Liters of fuel and pollutes the air quality index of the cities. Therefore, to protect the environment and air quality of the Indian cities, the Indian Government took initiatives through various policies and incentives to promote the electric vehicle adoption in India.

The urban city in India is currently facing the challenge of more usage of private vehicles, increase in travel demand leading to the travel congestion with the increase in level of local air pollution. With the rapid increase in diesel based private vehicles and less usage of public transport the country is facing energy shortage with the constant pressure to reduce the greenhouse gas emission levels in the transport sector. As many cities around the world is taking a step towards the green and clean mobility by opting for electric vehicles as one of the potentials to address the emerging issues. The source of electricity in India still largely depends on the coal. Every state in India has number of thermal power plants which are operating to meet the requirements of electricity of different cities in India. The Climate change National Action Plan of India recommended to increase the use of public transport in the country with renewable energy sources to reduce the emissions from the transport sector.

The study focuses on the feasibility of replacing diesel buses with electric buses in the public transport fleet of 93AC buses. The analysis will be done by calculating emissions from diesel bus and emissions from source of electricity to charge e-bus by estimating the cost, infrastructure requirement, and financial burden it would entail, to have a transition from diesel to electric buses. However, it is important to analyze how the increasing cost of electric buses should be distributed across the population and state government to avoid the financial

burden on one section. The electric buses cannot be operated independently it requires all the systems to be interconnected such as power supply, charging infrastructure, batteries, and innovative technology. The location of study area is Amritsar city in the state of Punjab. The city is chosen for the study, firstly because the air quality index of city is increasing day by day affecting the health of the citizens,("Current Air Quality," 2022) secondly according to the WHO report Amritsar city is one of the most polluted cities of Punjab. (N/A, n.d.)

Figure 1: Emission reduction by 2030.



Source - (Jaiswal, 2017)

1.2. RELEVANCE OF THE TOPIC

During the COP21 summit, government of India made commitments to reduce the emission level by 33-35% by 2030 as compared to 2005 levels of emission (Government of India & Minister of Power, n.d.). Therefore, Indian government is taking initiatives to shift the public transport buses and other vehicles from diesel to electric. In India the mostly preferred mode of public transport are the buses, therefore it is important to prioritize the transition of diesel buses to electric buses. The modal share of public transport in India for the year 2007 was 27% (Ministry of Urban Development, n.d.). In the case of Amritsar city the present modal share of public transport is 1.5% and the city officials are making plans to increase the modal share to 20% (council, 2019). The 90% of public transport demand is met by the buses because it is considered as cheap, convenient and accessible mode of transport in urban and rural areas (Roychowdhury & Sayan, 2021). Electric vehicles come with zero tailpipe carbon dioxide emissions depending on the source of electricity used to charge the vehicle, as a result, if the source of electricity is from renewable energy sources it could help in reducing the emission levels, hence promoting healthy lifestyle. Adoption of electric buses will also help in reducing the local air pollution. Keeping in view the benefits of having electric buses

on the roads such as clean air, less environment degradation, less amount of depletion of fossil fuels, and much lower noise from the buses, there will be still pollution from other particulate particles but a lot less than the diesel buses. Electric buses also comes with several challenges such as charging infrastructure and high upfront cost of the buses. The study focuses on calculating the emissions from diesel bus and calculating emissions from e-bus on the basis of source of electricity such as coal and solar. The draft electric policy of the state government focuses on electrifying the 25% of total state's fleet therefore, this study will help in analyzing the difference between carbon dioxide emissions from different sources of electricity along with focus on cost and infrastructure of diesel and e-bus.(Government of Punjab, 2019)

1.3. RESEARCH QUESTION

What are the environmental, physical and economic consequences of electrifying the public transport in case of Amritsar city?

Recognising the need to have clean air and environment friendly modes of transport, the research question of the study first focuses on how much electricity will be required to charge the total fleet of the buses running in the city. Secondly, what will be the source of electricity and impact on emission reduction after the public transport electrification.

The energy generation for the state of Punjab largely depends on coal-based power plants which generates 7025MW of electricity, 1531MW is generated from hydro and 1605 MW electricity is generated through renewables sources such as solar (Environment & Forest, n.d.). Therefore, it is important to calculate the emission from the source of electricity to charge electric bus.

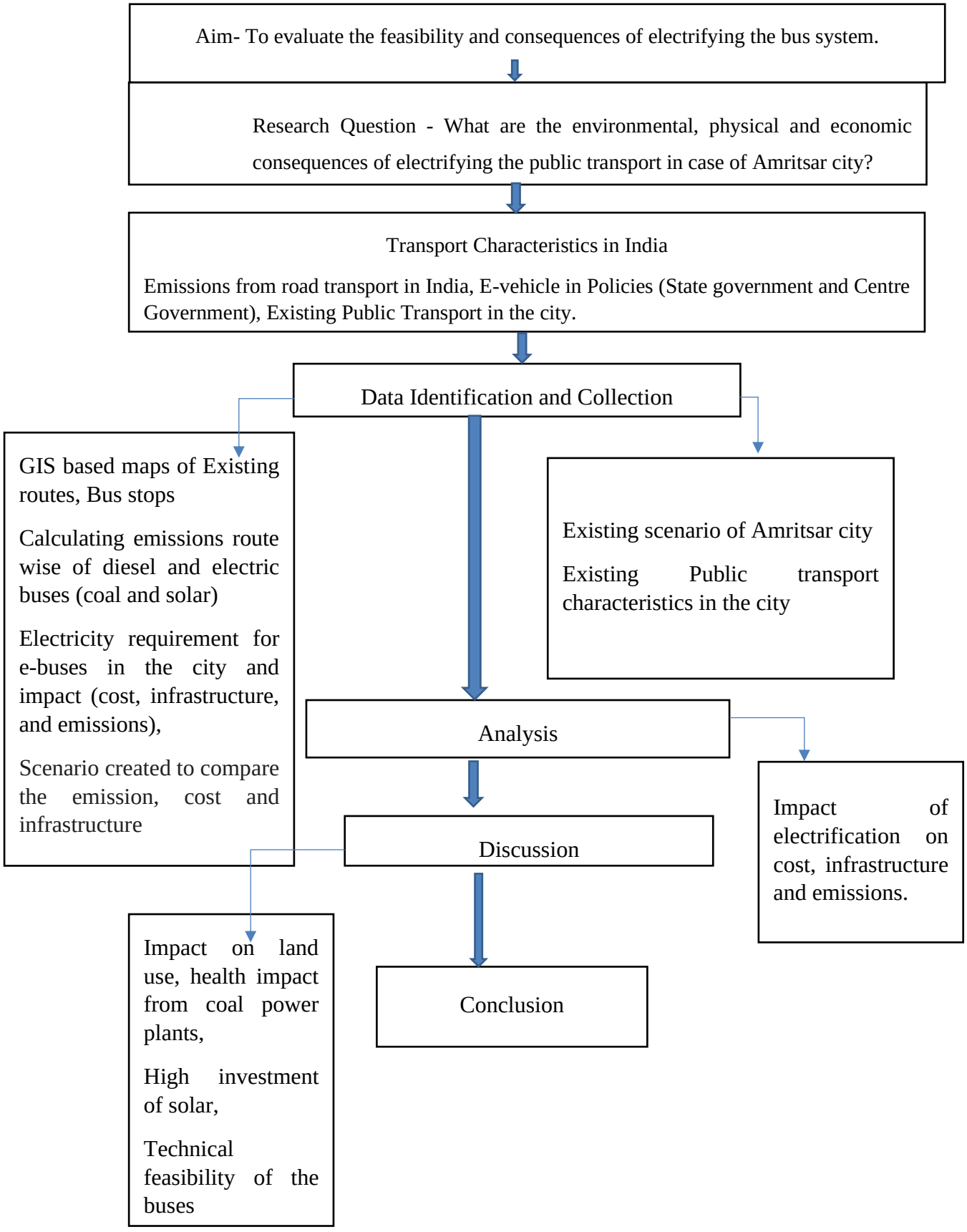
In India transport sector ranks on the third in case of highest emitter of CO_2 emissions and electrifying the public transport can help in reducing the dependency on fossil fuel. The CO_2 emissions has tripled as compared to 1990 levels and it is expected to increase because of growing population in India and increase in number of registered private vehicles (Sinha & Sharma, 2022). Diesel buses are expensive to operate and maintain. The price of fuel is increasing every day which is making it difficult to drive diesel and petrol fuel-based vehicles. Electrifying public buses can help in reducing the operational and maintenance cost of the government. Emission from diesel and petrol vehicles increases the risk of health issues such as lung and heart diseases, making it more vulnerable for the senior citizen people.

Electrification of public transport in the city can also benefit in the economic development. It will create jobs for different occupations hence contributing to increasing the GDP (Gross Domestic Product) at the same time benefiting the environment and clean air in the city. As a result, transport electrification can help in reducing the worst impacts of climate change on the cities and health of people. Providing adequate infrastructure is one of the prerequisites of electric buses in order to charge the electric buses on time and efficiently. Hence, infrastructure requirement and total cost of ownership of diesel bus and electric bus will be calculated in the further study.

This study will analyze the impact in terms of cost, infrastructure and carbon dioxide emissions by introducing electric buses in the fleet of Amritsar city, with the focus on answering the following sub research questions

i. What is the impact of electrification with coal or solar electricity supply on carbon dioxide emissions?
ii. What is the impact of electrification on infrastructure to power the buses?
iii. What is the impact of electrification on the cost?

1.4. RESEARCH DESIGN



1.5. METHODOLOGY

The main aim of the study is to evaluate the feasibility and consequences of electrifying the bus system along with electricity sources used to charge e-buses. This study was conducted through different literature, case studies, graphical representations and by studying the existing transport facilities of the city. To analyse the research question and to fulfil the objectives of the study, secondary survey has been conducted. The data collected through secondary survey has been useful in calculating emissions, infrastructure and cost comparison of the diesel and electric buses. To study the feasibility of the electric buses in Amritsar city, the following methodology has been used:

- ***Transport characteristics in India***

In this section documents and reports issued by the Indian government on the electric vehicle policies has been studied to know the current status of policies and the procurement of the e-buses, and to know more in depth regarding the adoption rate under the various schemes and incentives. Electric vehicle policies in case of Amritsar city were also discussed to study the gap between the adoption and incentives of the policies. Further, due to the rapid increase of vehicles in India, the emissions from diesel-based vehicles are also increasing, therefore carbon dioxide emissions from road transport in India and carbon dioxide emissions in the case of study area that is Amritsar city has been studied in the paper. At the end of this section the number of electric buses that is currently deployed in India, Punjab and Amritsar was also elaborated, this will help in studying the results of the policy goals.

- ***Existing scenario of Amritsar city.***

Amritsar is world famous tourist attraction, therefore there are number of factors which needs to be considered before calculating the emissions. In this section all the existing details of the city has discussed to understand the city profile. Secondly, the status of existing public transport system which is 93 diesel buses (BRTS) and with the large number of auto-rickshaws (3-wheelers) on the roads, has been analyzed to know the environment impact of diesel vehicles in the city.

- ***Public transport characteristics***

The secondary data is collected to compare the carbon dioxide emissions between diesel buses and electric buses, the existing BRTS (Bus Rapid Transit System) which is currently running with the fleet of 93 AC diesel buses has been collected through the secondary survey. In this section all the details of BRTS have been studied such as -

- Route Length
- Headway Gap
- One side running time
- Terminal Halt or turn around
- Fleet size
- Daily ridership
- Vehicle km traveled
- Accessibility of the BRTS has been calculated to know how much area is served by the public transport system.

Spatial analysis has been done by making GIS based map to mark the existing route details, route length and the type of land use around the route areas. This will help to know what type of passenger are using the buses most, and where it lacks. Land use analysis along the bus routes has done using the GIS software.

- ***Calculating carbon emissions from diesel bus.***

In this section carbon emissions from the existing fleet of 93 AC diesel buses was calculated. The emissions are obtained by using the formula of vehicle kilometre travelled and the emission factor of diesel buses based on Indian standards.

Emissions from diesel bus = Vehicle km traveled X carbon dioxide emission factor of diesel bus.

Emission factor is the pollutant that diesel buses release into the atmosphere.

In the next part the analysis of cost and infrastructure diesel buses was analyzed. The 93 fleet of AC buses are owned and funded by state government. The analysis has been done using the secondary data from different government documents and reports.

The operation and maintenance cost has been analysed using the cost parameters such as vehicle cost, fuel cost, fuel economy, diesel engine and maintenance cost.

- ***To Calculate the emissions from electric buses with source of electricity as a coal.***

In this part the electricity required to charge the fleet of 93 buses is calculated which is used to calculate the emissions by the usage of coal in thermal power plants.

The cost to deployed electric buses in Amritsar city has been obtained by using the cost parameters such as Battery capacity, battery cost, import duties, vehicle cost, fuel economy, and annual cost of charger which shows the electric buses have high upfront cost.

The infrastructure requirement for the procurement of electric buses is calculated by using the detail breakdown of charging infrastructure cost in India. The parameters included converter, electrical installation, safety and security, inspection, monitoring and control and wiring.

- ***To Calculate the emissions from electric buses with source of electricity from solar panels.***

Electric buses come with zero tailpipe emissions, but the source of electricity in this section is from solar panels. By using the required electricity calculated in the previous section, the emission from the solar panels is calculated. The solar power plants generate 40g per kwh of CO_2 emissions.

The cost and infrastructure cost of the electricity supply from solar panels is obtained by using the following parameters such as – Vehicle cost, fuel cost, fuel economy, maintenance cost, charging infrastructure cost, import on battery system components, annualized cost per charger and total capital cost of the charger.

For the infrastructure of solar panels – Grid connection (including transformer), cabling/wiring, converter, electrical installation, safety and security.

- **Scenario created based on emissions cost and infrastructure**

Six scenarios were created to compare the emission levels, cost and infrastructure.

Scenario 1 is the current situation of public transport in Amritsar city which is 100% diesel buses. Scenario 2 is 50%diesel buses and 50% of electric buses are deployed with the source of electricity from coal. Scenario 3 is based on 50% diesel and 50% electricity from renewable sources of energy such as solar. Scenario 4 calculated the carbon emission cost and infrastructure for 100%electric buses with the electric supply from coal plants. Scenario 5 is if 50% of electric buses gets supply from coal plant and the rest 50% from solar plant. Scenario 6 is the emissions cost and infrastructure for electric buses with source of electricity from solar.

Further, the comparison between the emission, cost and infrastructure has been done using the six mentioned scenarios.

- ***Analysis***

In the next section of analysis, the impact of electrification on emissions, infrastructure, environment, and economic has been done. This section answers the research questions of the study.

Limitation of the study is that only the carbon dioxide emissions has been calculated and the study is based on only 3 parameters that is emission, coal and infrastructure. There are so many other particles that are generated by coal-based power plants such as Pm2.5, sulfur dioxide which are as harmful as the carbon emissions.

CHAPTER 2
TRANSPORT CHARACTERISICTIS IN INDIA

2.1. EMISSIONS FROM ROAD TRANSPORT SECTOR IN INDIA (COUNTRY) AND AMRITSAR (CITY).

In India the registration of private vehicles is increasing every day. High number of private vehicles run on diesel and petrol, which contributes highly to the emissions from transport sector. In the year 2020, the Carbon dioxide emissions from the road transport was 274 Tg. The highest contribution was from the Heavy Duty vehicles (HDV) and Light Duty vehicles (LDV) running on diesel accounts for 38% (104Tg), whereas private vehicles emit only 2% less than HDV and LDV that is 36% (97,5Tg) and public transport contributes 15%(41,3Tg) (Singh et al., 2021) As a result, the total diesel vehicles which emits CO_2 emissions are 61%, gasoline vehicles are 37% and 2% is from CNG vehicles(Singh et al., 2021).

In Amritsar due to tourism and educational trips, people use various public transport to cover their short trips. Mostly trips are done by using Auto-Rickshaws (three wheeler) which runs on petrol and diesel. According to WHO, Amritsar city is considered in the 20 most polluted cities(N/A, n.d.). Total carbon emissions emitted by the auto- rickshaws in the year 2014 were 155,505g/km (*Bus Rapid Transit System (BRTS) Amritsar, Punjab. Asia BRT Conference*, 2014).

2.2. ELECTRIC VEHICLE POLICIES AND INCENTIVES

RAAHI – Amritsar was selected for implementing Smart City Project in Punjab. In the transport and mobility sector the project includes the road development, provision of pedestrian roads, cycle sharing system and no vehicle zone. But there is hardly any development seen in the city. Later, the Smart city initiated the program of RAAHI (Rejuvenation of Auto Rickshaws in Amritsar through Holistic Intervention). This project was formed under the CITIIS program. The CITIIS program is handled by NIUA (National Institute of Urban Affairs). The Funding for RAAHI project is from French Development Agency, Smart City Amritsar, and European Union.

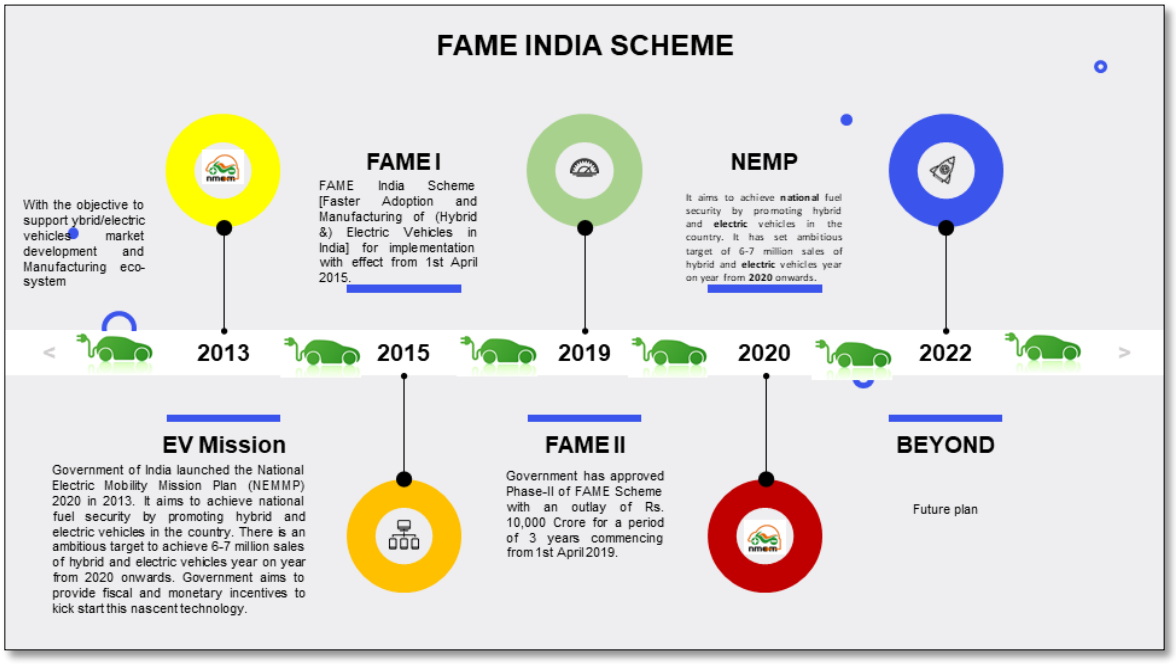
Amritsar was selected among 12 projects across the country for special funding of RAAHI Project (Amritsar Smart City, n.d.). No work has been done under the Center level policies in case of Amritsar City.

National Urban Transportation Policy (NUTP) – National Urban Transportation Policy formed in 2006 to change and improve the current transport in the urban areas. Later, the Policy was revised in 2014, which included the use of clean fuel and technology. Under this Policy, the use of CNG was maximized in the buses in Delhi. The policy mainly focuses on road safety, congestion, non-motorised transport and maximum utilization of the existing transport infrastructure (Ministry of Urban Development & Government of India, 2014).

FAME I - The scheme was formed on 1st April 2015 and extended until 31st March 2019. Department of Heavy Industries introduced another scheme for electric vehicles known as FAME 1(Faster adoption of Manufacturing of Hybrid and Electric vehicles). The scheme mainly focuses on providing charging infrastructure, demand creation, pilot projects and technology development (Ministry of Heavy Industries & Public Enterprises, 2019). In case of Punjab, only three cities are covered under this scheme that is, Amritsar, Mohali and Ludhiana (Government of India, 2015). Various incentives for the buyers and manufacturers were given under this scheme to attract more people towards electric vehicles, which also included buses. As a result, 465 buses were deployed under this initiative in different cities of India (Ministry of Heavy Industries & Public Enterprises, 2019).

The figure 2 explains the various policies implemented by the government of India to increase the electric vehicles on the roads. FAME scheme was launched in 2015 in which Indian government provided the subsidies to electric and hybrid vehicles, the total incentive of the scheme was Rs. 3430 million (Desai, 2020). In April 2019, government of India launched FAME II with specific focus on charging infrastructure, demand, innovative technology and market creation.

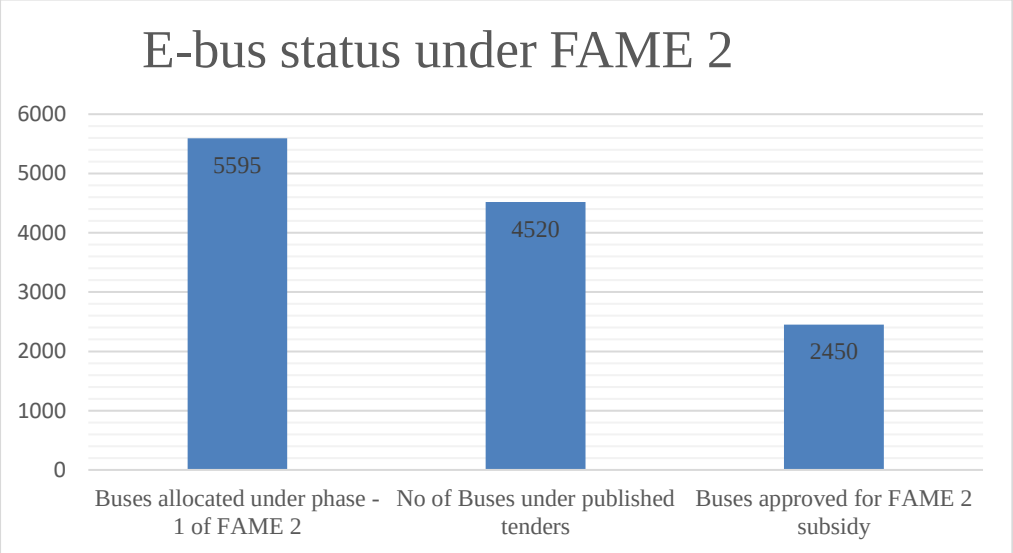
Figure 2: Electric Vehicle Policies in India



Source - (Desai, 2020)

FAME II – This scheme started on 1st April 2019 for three years, later the scheme is extended for two more years and will be completed in 2024 (The New Indian Express, 2021). In the second phase government has sanctioned 670 buses in different states with 241 charging stations. Under the FAME II scheme, the charging stations are proposed on highways at 25km each ("FAME India Scheme Phase II," n.d.).

Figure 3: Showing the allocation of buses in India under the FAME 2 scheme.



Source - (Gulia & Thayillam, 2020)

To support clean and advanced technology the electric vehicle incentives will be given to those who will meet the battery technology criteria and other requirements for pollution free vehicles. In this Scheme the expected outcome by electrification of vehicles is saving fuel by 1944403 liters whereas there will be reduction of CO_2 by 44251802kg (Chhabra, 2022). Under the FAME I and FAME II, no work has been done in the state.

2.3. STATUS OF PUBLIC TRANSPORT E-BUSES IN INDIA, PUNJAB, AND AMRITSAR.

In the past years, the state government are also taking initiatives in deploying the electric vehicles in the cities. Out of the 6265 e-buses, sanctioned under the scheme of FAME II, only 958 buses are running on the road. These buses resulted in saving 20,4 million liters of fuel and avoided the 0,3 million tonnes of carbon dioxide emissions from coming out into the air. As a result, when all the sanctioned buses will be running on the road, it is estimated to reduce carbon dioxide emissions by 2,6 million tonnes (Vijaykumar et al., 2021).

Table 1: Total Emissions saved as of June 2021 with e-buses deployed under the FAME scheme.

Fame – I, II and State Funds	Total number
E-buses sanctioned	958
Cities with e-buses in operation	20
OEMs supplying public transport buses	5
Total Kms Covered	51 million
Total emissions reduced (CO2)	0,3 million tonnes
Fossil fuel saved (litres)	20,4 million

Source - (Vijaykumar et al., 2021)

In Indian states, Maharashtra is the only state with highest share of 49% of electric buses running on the road. The states like West Bengal and Gujarat have only 7,14% and 7,6% of electric buses on road. The Gujarat state also got support from private bus agencies such as

TATA, PMI Electric Mobility Services. As of June 2021, Gujarat has 74 buses running on the road which saved 73 kilotons of carbon dioxide emissions (Vijaykumar et al., 2021).

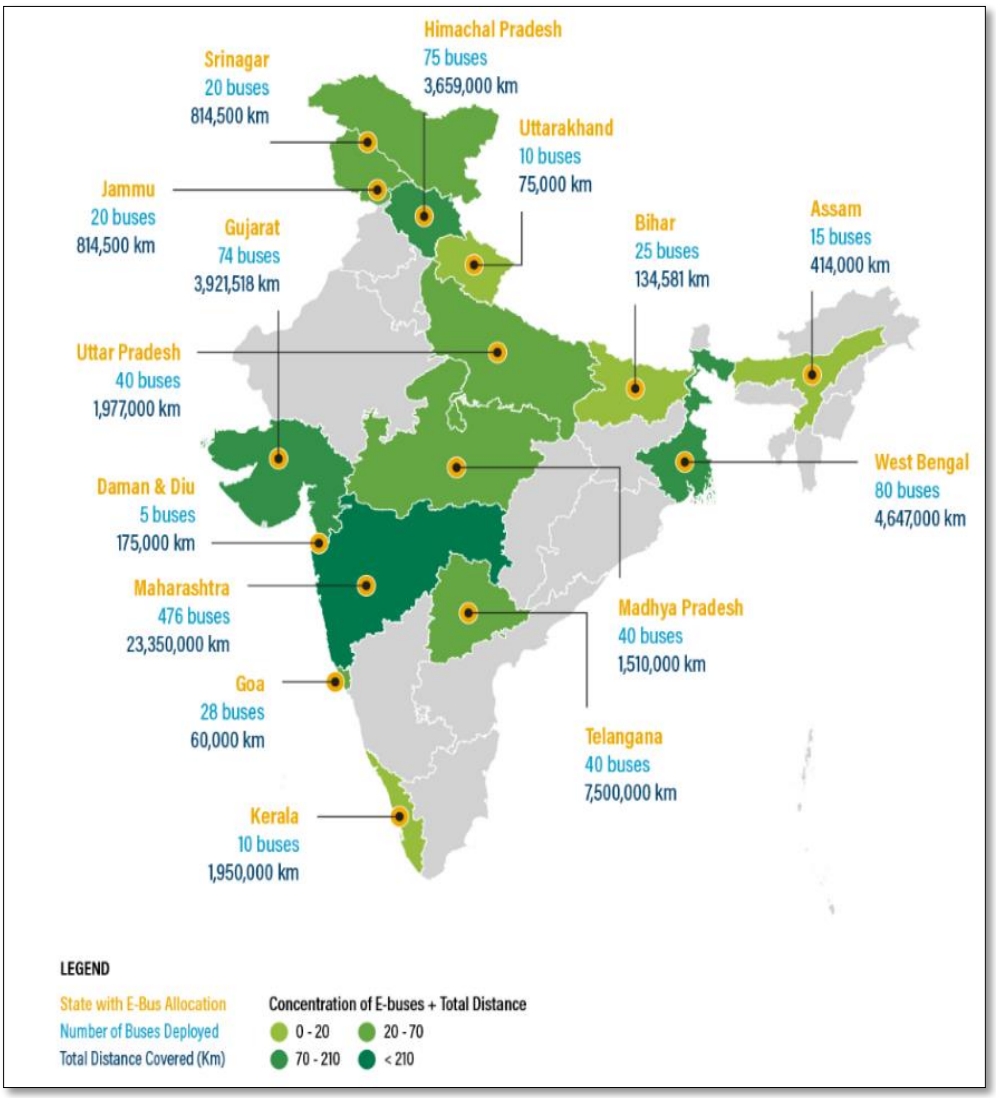
In 2015, when the FAME scheme was introduced, they supported the state government by providing subsidies for the electric buses. Later, the scheme failed to reach its goals and objectives because the cost of the electric buses are 1,5 times higher than the diesel (Vijaykumar et al., 2021). Secondly, there was a lack of skilled workers which failed to operate and maintain the electric vehicle industry.

In the second phase of FAME, which is named as FAME II. The bus agencies agreed on paying the cost by per km cost of electric bus for operation and its maintenance. As a result, 5095 buses were sanctioned with the increase in subsidy of Rs 20000/kwh. With the increase in benefits 2450 buses have been deployed in November 2020 (P. Kumar & Vijaykumar, 2021). The high upfront cost of electric buses was compensated by FAME II scheme because of which state governments provided additional support and funding in transition to e-buses.

In Punjab(state), the e-buses have been only deployed in Chandigarh city. The first lot of 40 buses was sanctioned under the FAME II scheme (Nagarkoti, 2021). The private bus contractors won the bid and signed to run the environment friendly buses on the road of Chandigarh. The buses were deployed on the basis of km scheme, therefore all the expenditure, charging infrastructure, major or minor issues of the buses is the responsibility of the contractor during the contract period of 10 years from October 2021 (Nagarkoti, 2021).

The transport department will pay the cost of Rs 60per km to the company as per the contract signed under the scheme condition.(Nagarkoti, 2021). The bus is estimated to cover the distance of 200-300km after the fully charge. The full charging of the bus will take two to three hours.

Figure 4: Deployment of e-bus in different cities of India under the scheme of Fame I & II



Source - (Vijaykumar et al., 2021)

CHAPTER 3
EXISTING SCENARIO OF AMRITSAR CITY

3.1. CITY PROFILE

Amritsar is the largest city in the state of Punjab. According to 2011 Census, the population of the city is 1,184 million (*Bus Rapid Transit System (BRTS) Amritsar, Punjab. Asia BRT Conference*, 2014). It lies in the proximity of Pakistan and shares one of its borders with Pakistan which is world famous for border closing ceremony. The city is also famous tourist place for Golden Temple, the place of worship for Sikh religion. Figure 5 shows the Golden temple in Amritsar, the temple situated in the middle of the water is built with gold. Due to its highly rich culture and history, the tourist footfall of the city is 0,1million every day (*Bus Rapid Transit System (BRTS) Amritsar, Punjab. Asia BRT Conference*, 2014). According to Master plan of Amritsar, the tourist and visitor footfall of the city were 36 million per annum (*Master Plan Amritsar*, n.d.). There are three state highways and two national highways in the city, which shows strong connectivity to other cities of the country. The city has International Airport which makes it easy for international visitors arriving to the city. As a result, visitors arriving in the city by air were 0,11 million in the year 2007, which contributed 2,2% to country's GDP (Gross domestic product) (*Master Plan Amritsar*, n.d.).

Figure 5: The Golden Temple in Amritsar city.

Source- (Sri Harmandir Sahib (Golden Temple), n.d.)

3.2. EXISTING PUBLIC TRANSPORT IN AMRITSAR CITY (E-RICKSHAWS AND BUSES)

The road pattern in the city is radial cum circumferential with all the roads connected to the walled city (core city). The rail network is well connected to the other cities of the country. The rail is also connected with Wagha border and Pakistan.

The city has international airport which also serves the state of Punjab. It has highly rich culture and world famous tourist destinations, because of which people from different countries visit the city. But there is no public transport connectivity from the airport to the city. There are only Taxis which are operated by OLA and Uber.

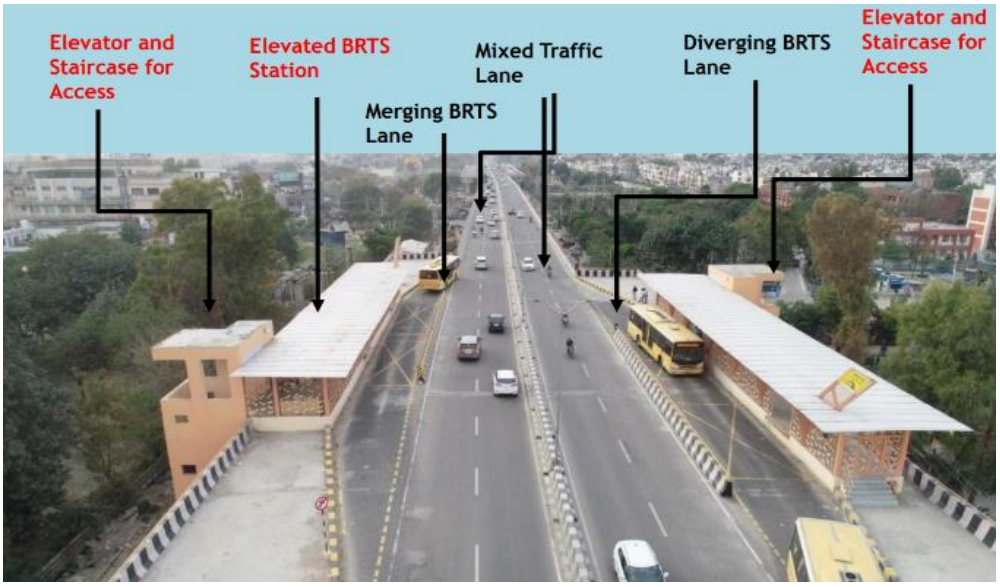
There are 50,000 unregistered auto rickshaws(3-wheelers) which runs on diesel and are privately owned (N/A, n.d.). These autorickshaws helps in providing services to the people where public transport is not accessible. The main problem with the countless number of auto rickshaws is their uncontrollable movement on major roads which causes traffic congestion and road accidents. It also led to environment degradation because the fuel used is diesel. Due to increase in air pollution the local government initiated e- auto scheme under the CITIIS program. This will replace the diesel autos in the city and the subsidy will be provided to each owner with the provision of loans from the Banks to buy the e-autos.

3.3 BUS RAPID TRANSIT SYSTEM (BRTS)

BRTS is span of 31km with median side double docking stations. Currently it has fleet of 93 buses running on the road, which connects major parts of the city (Dhamija et al., n.d.). The 93 BRTS buses have been sanctioned under the JNNURM (Jawahar Lal Nehru National Urban Renewal Mission) scheme.

Government of Punjab Bus Metro Society has implemented the BRTS in the city of Amritsar. As, Amritsar is the world famous city with footfall of 0,1 million international/national visitors every day. Therefore, 31km of BRT corridor was proposed in the city covering all the major parts of the city. The Total Fleet of the BRTS buses are 93 Diesel AC buses in 12 meters of length. It covered the 40% of the city's road network (*Technical Session 3 – Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS*, n.d.).

Figure 6: The BRTS bus stops in the city.



Source - (Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS, n.d.)

The buses run on following 3 routes.

1. India gate to MCA gate
2. India gate to Verka Canal
3. Verka canal to MCA gate

For the last mile connectivity, where the BRTS buses are not accessible there are many 3 – wheelers and rickshaws standing at the bus stop to provide the connectivity. BRTS buses are also easily accessible by the disabled person. The infrastructure and Bus stop designs are barrier free for the use of disabled people incorporated with the norms and standards which makes it easier for everyone to have easy access to the public buses. Earlier the BRTS was for free to use, to make people adapt to the use of Public Bus system. Now, the fare is low for students, senior citizens and physically challenged people with the discount on ticket, to make it more attractive and easily adaptable by the people.

3.4. ENVIRONMENT IMPACT ON THE CITY.

Amritsar is the hub of education Centers; tourist places and different types of industries are also located here. As a result, many people from villages and other neighboring towns migrate to Amritsar city for better employment, education and facilities. Overcrowded areas and transport have led to degradation of environment and infrastructure of the city. Amritsar is also one of the cities which comes under non-attainment category because it does not meet the air quality standards continuously for five years. At present there are 3 state highways and 2 national highways passes through the city. Therefore, the number of heavy vehicles,

passenger cars are increasing day by day. The number of vehicles on the road are 809705 which contributes highly to vehicular emissions in the air (Directorate of Environment and Climate Change & Department of Science, Technology and Environment, 2019). The unhealthy levels of Air Quality Index are affecting the people living in the city, which creates the awareness among the environmentalist to take measures to prevent the increasing pollution in the city.

CHPATER 4
PUBLIC TRANSPORT CHARACTERISTICS OF AMRITSAR CITY

4.1. EXISTING ROUTE DETAILS

In case of BRTS there are main routes in the city on which the buses are running with the fleet of 93 AC buses. These routes were implemented in Phase I of the BRTS implementation. With the implementation of the BRTS project in the city, it has decreased the number of Auto rickshaws (3-wheelers) on the roads by the number 840. As a result, the amount of carbon emissions has also been reduced, as auto rickshaws run on diesel with less capacity of carrying passengers hence contributing more to environmental degradation. The Route 1 of the BRTS has 1 university (Guru Nanak Dev University) and 1 college (Khalsa College), therefore the buses can be seen more occupied. The Route 2 land use mainly is mixed land use but connects to the main tourist places of the city such as Golden Temple. The Route 3 in the map goes to the outskirts of the city, where mostly industries are located, therefore making it easier for workers to have the easy accessibility of the BRTS buses.

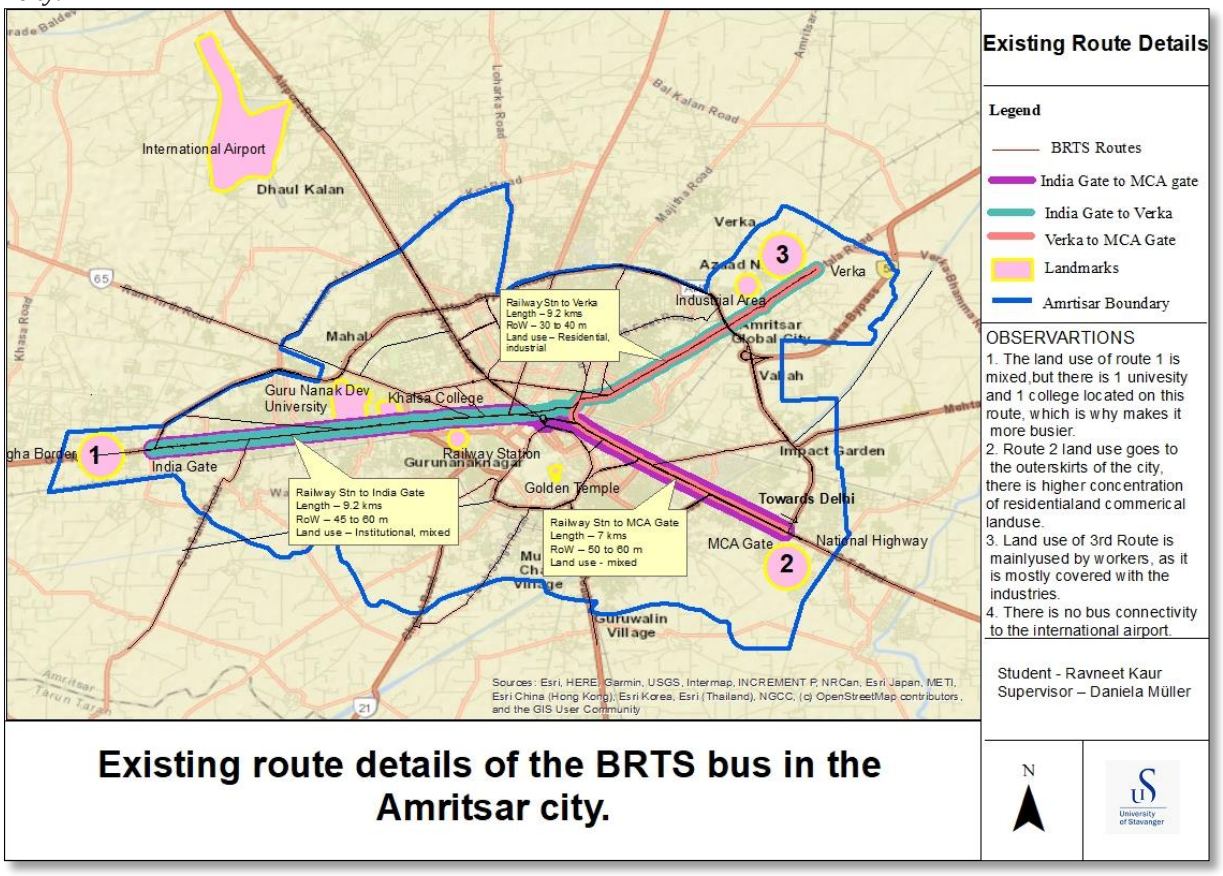
Table 2: The existing route details of BRTS buses

Route Details	Route Length (one way) in kms	Headway gap(minutes)	One side running time	Terminal halt or turn around	Fleet size
India Gate to MCA gate	16,2	4	48	10	30
India gate to Verka Canal	18,4	4	54	6	32
Verka Canal to MCA gate	13,0	4	39	10	24

Source - (Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS, n.d.)

In the first phase of BRTS implementation only 3 routes have been proposed. The one way route length from India gate to MCA gate is 16,2km, India gate to Verka Canal is 18,4km and from Verka Canal to MCA gate is 13km. The headway gap between the buses are 4 minutes.

Map 1: The GIS based map shows the exisiting route details of the BRTS bus routes in Amritsar city.

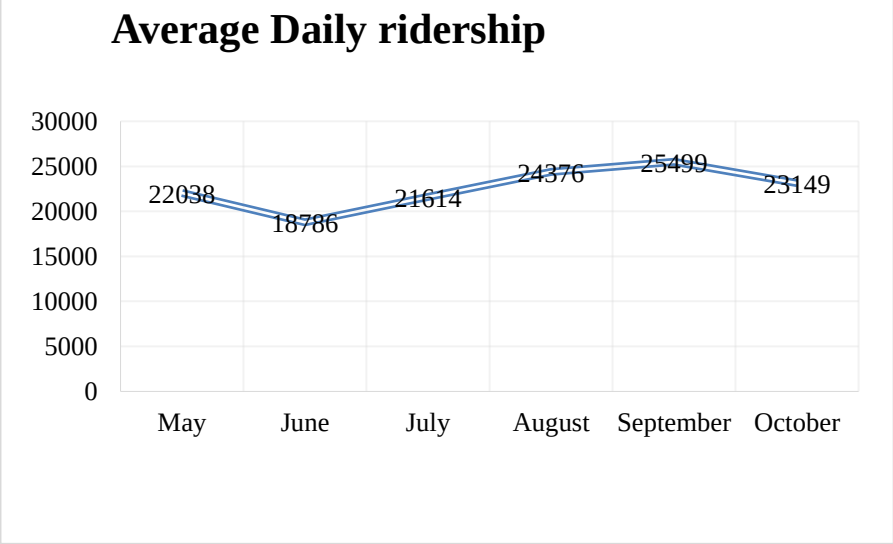


4.2. DAILY RIDERSHIP

The number of passengers using the BRTS buses are lowest in the month of June and October because of vacation time in schools and colleges. In last three months, BRTS ridership observed an increase in the number of passengers using the buses. Earlier the ridership was around 25000 now it has increased to 40000 per day (Teja, 2021) The increase in ridership is because of reopening of schools and universities after Covid-19. The tickets for the students from High school are free. Also, the price of tickets for the university students are

much lower which makes it more affordable to use the air conditioned buses. The ridership is expected to increase more in the festive time of the year.

Figure 7: Average Daily ridership of the BRTS buses



Source - (Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS, n.d.)

CHAPTER - 5
INFRASTRUCTURE, COST AND CARBON EMISSIONS OF THE BUS SYSTEM IN AMRITSAR CITY.

5.1. DIESEL BUS

5.1.1. Calculation of Carbon Emissions from the existing fleet of Diesel bus.

Government of Punjab realize the need for electrifying the vehicles when the level of emissions from the vehicles in major cities like Ludhiana and Amritsar contribute more than 50%(Government of Punjab, 2019). In these cities buses are the highest emitter of carbon dioxide emissions. Therefore, by adopting electric buses it would reduce the carbon dioxide emissions. The study is to calculate the carbon dioxide emissions from the public buses in case of Amritsar city. In the city, there is BRTS diesel buses running on the three major routes and to calculate the emissions from these routes, formula for carbon emissions is used. The formula used for calculating Carbon emissions from 1 bus stop to 2nd bus stop = Vehicle km travelled * emission factor. (Roychowdhury & Dubey, n.d.)

Amritsar BRTS (Bus Rapid Transit System) has large network, which covers all the main areas of the city. The existing route details of the bus routes are –

Table 3: Route details of BRTS and distance of the routes

Existing Route Details	Distance traveled round trip(km)
India gate to MCA gate	32.4
India gate to Verka Canal	36.8
Verka Canal to MCA gate	26

Source - (Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS, n.d.)

The basis and guidelines followed for calculations of emissions in Amritsar:

Carbon Emissions are calculated using vehicle km travelled which is mentioned in the Table 4, and emission factors for the buses are taken from the Indian Air quality Standards for diesel buses.

The calculated emissions for the Route 1 (India Gate to MCA gate) are 1170307,44g/km, for the Route 2 (India Gate to Verka Canal) are 1329238,08g/km and for the Route 3 (Verka Canal to MCA gate) are 939135,6g/km.

Therefore, total emissions from all the bus routes are = 3438681,12 g/km or 3438,6 kg/km. (Refer to Appendix A for the detail Route wise calculations of emissions from diesel buses in the city).

93 AC buses are running only on the three routes of the city yet emitting higher amount of carbon dioxide emissions. The surroundings of the bus routes are mix land use affecting the health of the people.

5.1.2. Cost for Diesel Buses.

Diesel is most common fuel used in vehicles in India, because of its great mileage and efficiency in the cars, buses, trucks and trains. The diesel prices in India fluctuates every month or even revised every day in the morning. The price of diesel is rising making it expensive for the diesel vehicle owners to use the diesel based vehicles. When the increase in rate of international crude oil increases, it increases the prices of diesel in India. The diesel prices in July 2018 were Rs 75/Liter which increased by 11% in three months which increases every month due to import of 76% of crude oil from other countries (Diesel Price In India Today., n.d.). Despite the various policies and incentives in electric buses, the diesel bus sales continue to grow in the year 2016-2017. It grew by 7,6% from the fiscal year 2015-2016(Khandekar et al., 2018). Despite the various policies and incentives in electric buses, the diesel bus sales continue to grow. The price of diesel is still lower than the price of petrol. Transport sector is considered as the primary consumer of Diesel oil. As a result, it makes more expensive to operate and maintain diesel buses because the supply of diesel is less as compared to the increasing demand. The exported crude oil also has Centre Tax and State tax, this is also the reason of higher prices of Diesel in India.

The operation, maintenance and fuel cost of the diesel buses are higher than that of electric buses. Also, there is increase in diesel prices every month. The total cost of operation and

maintenance for the diesel bus is 23 Rs/km. The average of the diesel bus is 2,5 per km/Litre which is 1,7 km/litre more than of electric bus (Khandekar et al., 2018). The increase in operation and maintenance cost of the bus will lead to higher ownership cost in the future. The vehicle cost for the diesel bus is low which makes it more attractive for the buyers neglecting the high operation and maintenance cost and environment impact of the diesel buses on the health and climate. With the increase and fluctuation of fossil fuels in India, the cost of diesel fuel will increase in the coming years leading to more increase in operation and maintenance cost.

Table 4: Cost parameters for 12m AC Bus

Cost Parameters	Diesel Bus
Vehicle production cost (INR)	6000000
Diesel Engine/ Battery cost	2296269
Fuel cost	Rs95/Litre
Fuel economy	2.5km/L
Maintenance cost	Rs.8/km
Discount rate	10%
Vehicle life	12 years

Source - (Khandekar et al., 2018)

5.1.3. Infrastructure of the Diesel buses

The total 93 BRTS buses has been already deployed under the JNNURM bus funding scheme which costs around 4,96 billion in which 1,28 billion is spent in in the infrastructure of the BRTS corridor.

Table 5: Funding done for the infrastructure of diesel buses under the policy and state government.

Bus Type	JNNURM (scheme by government of India)	State of Punjab	Amritsar Municipality	Total
93 AC diesel buses(12mm)	50%	20%	30%	100%
Cost (in billion)	0,418	0,167	0,251	0,837

Source : (BRTS, 2014)

Public Transport plays an important role in urban areas of India which helps in improving the mobility of people from rural areas to urban areas. The infrastructure in Amritsar BRTS was implemented under the JNNURM scheme, in which different bus lanes were constructed, bus depot was made at the periphery of the city. The retrofitting of elevated roads was done to construct the BRTS lanes in the city along with the provision of storm and water drainage system. BRTS of the Amritsar city covers the 40% of city's total road network.(*Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS*, n.d.)

Table 6: Cost already spent on infrastructure constructed for the BRTS in the city.

Sr.no	Item	Cost in crores
	Development including roads, drainage, street lighting and street furniture	210,37
	Foot over bridge	3,91
	Bicycle sharing stand	0,16
	Bus shelter	17,17
	Cost of Depot	7,55
	Cost of ITS infrastructure	28,07
	Cost of provision for pedestrian's crossings along BRTS corridors	1,23

Source - (BRTS, 2014)

There is also provision for the disabled people such as entrance ramps to stations, buses with uniform floor level, space for wheelchair in the buses, automated doors and level boarding and alighting.

Figure 8 Level Boarding Alighting

Source - (Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS, n.d.)

Figure 9: Space for wheelchair in the bus

Source - (Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS, n.d.)

5.2. ELECTRIC BUSES

5.2.1 Carbon Emissions from Electric buses running on electricity which is provided From Coal Based Power Plants

Challenges faced in adopting the electric vehicles in India.

Electrifying the public transport in India comes with various challenges. Before making people to adopt the electric vehicles, government needs to focus on the source of electricity to charge the electric vehicles. The majority of electricity comes from coal thermal power plants which makes difficult to electrify all the vehicles.

There are 3 coal power plants, currently operating around the city to meet the energy requirement in different cities of the Punjab (Goenka & Guttikunda, n.d.).

The air pollution from coal based plants contains higher level of pollutants which severely impact the health of people living around the plants or the employees working in the plants for its operation and maintenance. The operation of thermal power plants requires high quantity of water.

For example – 500MW of power plant will consume 14 million m^3 of water per year. As a result, it impacts the rivers and depletion of ground water. The power plants are also highest emitter of mercury, it emits 10% of the mercury on land and rest of the 90% into the air. In India 65 tonnes of mercury is released into the air by Indian power plants affecting the lives of people (S. Kumar et al., 2013). However, in India 75% of electricity production is generated from coal thermal power plants (Ministry of Coal & Government of India, 2022). Therefore, finding renewable source of energy or minimizing the impact of coal based power plants requires lot of measures and collective efforts from Centre and state government. The setting up of coal based power plants acquire large chunks of agriculture land which government buys from the farmers on the market price under the land acquisition act, leading to protest against the state government for acquiring fertile land at a cheap price. The residents near the thermal power plants in Punjab has filed case against the coal based plants to shut down the operation because of increase in the air pollution, fly ash can be seen in the air and the plant is not following the proper pollution guidelines to minimize the emissions emitting into the air.

Based on the data of existing deployed of electricity buses in different cities of India, they require 1,06km/kwh of electricity for 1km (Basu et al., n.d.). Therefore, by calculating the total vehicle km travelled of the buses in the Amritsar city, it will give the total requirement of the electricity route wise.

5.2.2 Calculation of Carbon emissions of electric buses from electricity sourced from coal.

To calculate the carbon emissions from the source of electricity from coal, First the vehicle km traveled was calculated, secondly electricity requirement to charge the fleet of existing 93 buses was calculated. The required electricity for Route 1 = 195,7608kg/kwh, for Route 2 = 222,345kg/kwh and for the Route 3 the required electricity = 157,092kg/kwh

Therefore, total required electricity required to charge the fleet of 93 AC buses = 575,19kg/kwh (Refer to Appendix B for the Route wise calculations of emissions from electric bus in which source of electricity is from coal).

The emissions from coal based power plant for generating 1kwh electricity is =

0,95kg/kwh (Mittal, n.d.).Therefore, the amount of emissions released from total

required electricity to charge the electric bus would be:

575,19 X 0,95 = 546,43kg/kwh

5.2.3 Cost for electric buses running on electricity sourced from coal.

A shift towards clean and environment friendly public transport has been increasing in India. In many metropolitan cities of India, the government has deployed electric buses. The electricity price from the coal based power plant is Rs 5,76 per unit (Rambani, 2022). The Table number 8 explains the cost parameters of the electric bus with its price per Kwh based on the source of electricity from coal.

Table 7: Cost parameters for 12m AC Electric Bus with source of electricity from coal

Cost Parameters	EV Bus (Coal)
Vehicle production cost (INR)	100031094
Diesel Engine/ Battery cost	15304,66

Import of tariff of battery system components	30%
Fuel cost	Rs5,7/Kwh (Rambani, 2022)
Fuel economy	0,8km/kWh
Maintenance cost	Rs 4/km
Charging infrastructure cost	2,5Rs/km
Battery Capacity	320kWh
Battery range	200km
Total Capital cost of the charger (Rs)	7076160
Charging infrastructure life	20 years
Number of buses sharing a charger	2
Annualized Cost per charger (Rs/yr)	831163

Source - (Khandekar et al., 2018)

It has been observed that operation and maintenance cost of the electric bus is low as compared to diesel bus, but the electric buses have high upfront cost. Efficiency of electric buses are 5 to 6 times higher than that of diesel buses (P. Kumar & Vijaykumar, 2022). The energy consumption or fuel cost highly depends on vehicle utilization, road conditions, driver behavior and age of the vehicle. This also affects the battery health and maintenance cost of the buses. The cost of operational decrease in electric buses with the increase in vehicle utilization.

The high upfront cost of electric buses is decreasing with the more advanced technologies introduced in India. Secondly the government is allocating subsidies in different sector of electric vehicles making it more affordable to purchase. The electrification of public buses allows to bear any kind of risks comes after the electrification. The high upfront cost of electric buses can be decreased by opting different options for battery technology, planning for charging infrastructure and location efficiently.

5.2.4 Infrastructure Requirement for Electric Bus Running on Coal

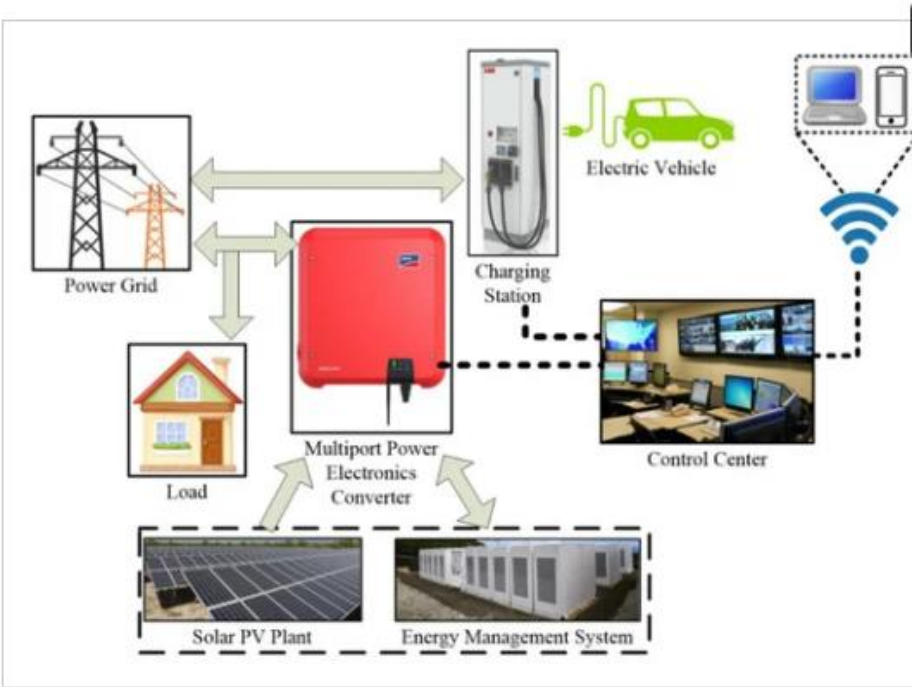
There are only 93 public buses in Amritsar city, therefore, to charge the existing fleet with source of electricity from coal overnight depot charging strategy should be considered because the depot has enough space to park more than 100 buses at the same time. The city gets its electricity from coal stations therefore the existing city power grid will help in power supply to the depot. Assuming 12m AC buses with battery storage of 320 kwh. The calculations for infrastructure requirement to charge the electric bus is given in the Table.

Table 8: Detail breakdown of charging infrastructure cost in India.

Cabling / Wiring	$81
Converter	$46
Electrical installation	$38
Safety and security	$66
Inspection	$9
Monitoring and Control	$3
Total capital cost ($/kW)	$243

Source - (Khandekar et al., 2018)

Figure 10: An overview of the electricity supply from exsiting pwer grid of the city.



Source - (Jha et al., 2019)

To charge the electric buses with the source of electricity from the coal based power plants, there is already existing power grid in the city, therefore the first investment for the infrastructure would be cabling and wiring from the main power grid to the bus depot. The total capital cost for setting up of the electricity infrastructure is 243$/kw. There is no requirement for the storage bank of electricity because the electricity supply from coal based is 24 hours.

Figure 11 explains the electricity supply from the power grid to the electric chargers to charge the buses. From one charger two buses can be charged at one time.

5.3. Calculation of Carbon emissions of electric buses from electricity sourced from solar.

It would be incorrect to say electricity from solar panels comes with zero emissions. There are some parts of solar panel and components that are made up by mining and processing. However, even considering all the factors the lifetime emissions of solar panel are still much lesser than the fossil fuels.

To calculate the carbon emissions from the source of electricity from solar, First the vehicle km traveled was calculated, secondly electricity requirement to charge the fleet of existing 93

buses was calculated. The required electricity for Route 1 = 195,7608kg/kwh, for Route 2 = 222,345kg/kwh and for the Route 3 the required electricity = 157,092kg/kwh

Therefore, total required electricity required to charge the fleet of 93 AC buses = 575,19kg/kw (Refer to Appendix B for the Route wise calculations of emissions from electric bus in which source of electricity is from solar).

The solar plant emits 0,4kg/kwh of emissions therefore, emissions from the routes are - ("How Much Emissions Does a Solar Power System Prevent?," 2020)

Table 9: Route wise emissions from solar panels with the required electricity.

Routes	Emissions
Route 1	78,30432
Route 2	88,93824
Route 3	62,8368
	230,07936kg/kwh

Source – Computed values.

5.3.1 Cost for electric buses running on electricity sourced from solar.

The cost of electric bus with the supply of electricity from solar would be the same as that of coal. The only difference is between the Fuel cost, whereas the solar electricity has fixed prices. In addition to low prices, the state governments in India are providing the subsidies and incentives for electric buses and projects based on renewable energy sources which will cut down the solar prices even lower in the future. Solar prices in India are very constant, unlike the increase of diesel prices every week, that's why electric buses with source of electricity from solar considered to be a good economic choice even without the government subsidy and environment benefits

Table 10: Cost paramters for electric bus with source of electricity from solar panels.

Cost Parameters	**EV Bus (Solar)**

Vehicle production cost (INR)	100031094
Diesel Engine/ Battery cost	15304,66
Import of tariff of battery system components	30%
Fuel cost	Rs 6/Kw
Fuel economy	0,8km/kWh
Maintenance cost	Rs 4/km
Charging infrastructure cost	2,5Rs/km
Battery Capacity	320kWh
Battery range	200km
Total Capital cost of the charger (Rs)	7076160
Charging infrastructure life	20 years
Number of buses sharing a charger	3
Annualized Cost per charger (Rs/yr)	831163

Source - (Khandekar et al., 2018)

5.3.2. Infrastructure Requirement for Electric Bus Running on Solar.

The infrastructure cost of charging the buses with source of electricity from solar is calculated in the Table. The cost estimation includes setting up of new grid connection, wiring, converter which will convert the current and storage bank to charge the buses overnight. As per the number of public bus fleet only two storage banks are required. The cost of solar electricity will be higher at the initial stage but the advantages having of cleaner mobility is more in number.

By providing fast charging stations, electric buses can also charge during daytime because with the fast chargers it takes one hour to charge to cover the distance of 200km.(Khandekar et al., 2018)

Table 11: Detail breakdown of the charging infrastructure cost in India.

Grid Connection (including Transformer)	$74

Cabling / Wiring	$81
Converter	$46
Electrical installation	$38
Safety and security	$66
Inspection	$9
Monitoring and Control	$3
Total capital cost ($/kW)	316

Source - (Khandekar et al., 2018)

The table 12 explains the breakdown of providing charging infrastructure. In case of electricity from solar based power plants, there will be setup of new grid connection and new transformer along with the solar panels. For placing the new solar panels, new area is required to set up the panels. For 1MW of solar panels, 5 acres of land is required, therefore, to charge the buses with solar electricity, 7MW of solar panels are needed, which will be placed in 35 acres of land.(“5 MW Solar Power Energy Plant in India: Profit, Cost & Land Requirement,” 2021)

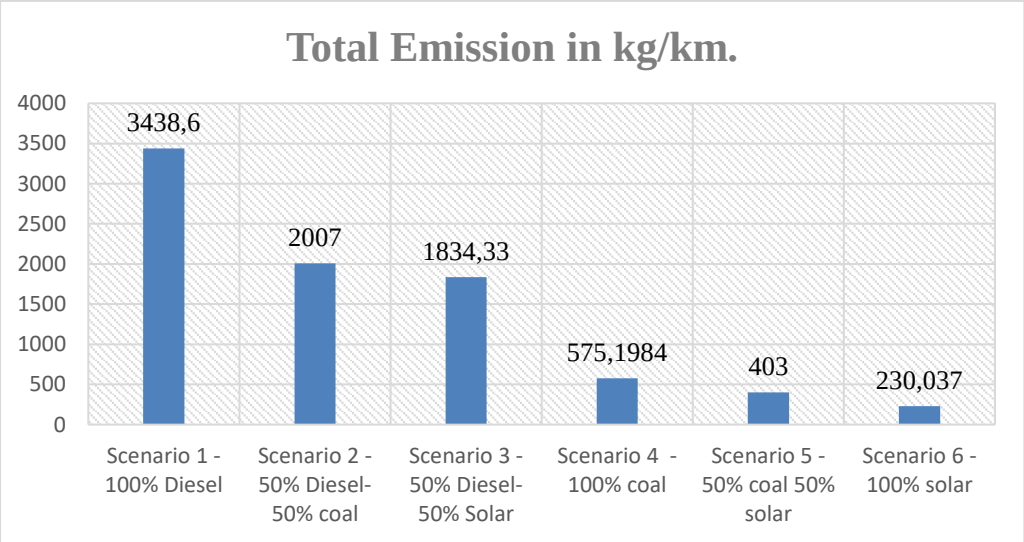
CHAPTER 6 - SCENARIO FOR THE FUTURE OF PUBLIC TRANSPORT IN AMRITSAR

6.1. SCENARIO CREATED ON THE BASIS OF INFRASTRUCTURE AND EMISSIONS

Scenario 1 explains about the current situation that is 100% diesel buses. Scenario 2 shows if the buses are 50% diesel and 50%electric running on coal. Scenario 3 explains about if there will be 50% diesel and 50% solar. Scenario 4 is 100% electric buses with a source of electricity from coal power plants. Scenario 5 explains if the source of electricity for charging in electric bus is 50% from coal and 50% from solar in the last scenario 6 explains if the source of electricity to charge a bus is from solar (Refer to appendix C for the details of calculations).

It has been observed that difference between in the emissions from scenario 2 and scenario 3 is minimum that is only 172,67 kilogram per kilometre. Because the carbon emissions are calculated only for the three routes in the city, other particulate matter such as PM2.5, sulphur dioxide, nitrogen dioxide are not considered in the calculations, secondly in the case of coal power plants only carbon dioxide emissions are taken into consideration for the calculation. But in case of scenario 4 and scenario 6 which is 100% Coal and 100% solar respectively, the difference between the emissions is 345,1194kg/km. Overall based on the scenario assessment emissions scenario 6 that is 100% solar will help in promoting towards the shift of clean and environment friendly mobility in the case of public transport buses

Figure 11: Emissions calculated on the basis of scenarios created.



Source – Calculated values

In case of infrastructure there is no infrastructure required for diesel buses there is one existing depot at the periphery of the city with the space available for 93 buses The infrastructure cost for the scenario 2 that is 50% diesel and 50% electric buses with a source of electricity from coal is 7, 89 million Whereas in case of scenario 3 which is 50% diesel and 50% electric buses with a source of electricity from solar the cost of infrastructure is 14, 2 million which is double the cost of scenario 2. Because in case electricity supply from coal, the existing grid of the city can be used, whereas for the solar, new grid and transformer needs to be constructed. Also, in case of solar the storage bank is required to charge the buses overnight. Based on the calculations for the infrastructure course of scenario 4 that is 100% source of electricity from coal the cost is still less than scenario 3 that is 50% diesel and 50% solar.

Table 12: Cost and infrastructure requirement based on the different scenarios created.

Scenario	Cost (Infrastructure)	Infrastructure Required.
Scenario 1- 100% Diesel		Nil
Scenario 2 - 50 Diesel-50 coal	7,89 million	Inverter EV Charging Station
Scenario 3 – 50 Diesel-50 Solar	14,2 million	Solar Panel Charge Controller Hybrid Storage Bank Inverter EV Charging Station
Scenario 4- 100 Coal	13,2million	Inverter EV Charging Station
Scenario 5 - 50 coal 50 solar	14,2million	Solar Panel Charge Controller Hybrid Storage Bank Inverter EV Charging Station
Scenario6 – 100 Solar	28 million	Solar Panel Charge Controller Hybrid Storage Bank Inverter EV Charging Station

Source- Calculated values

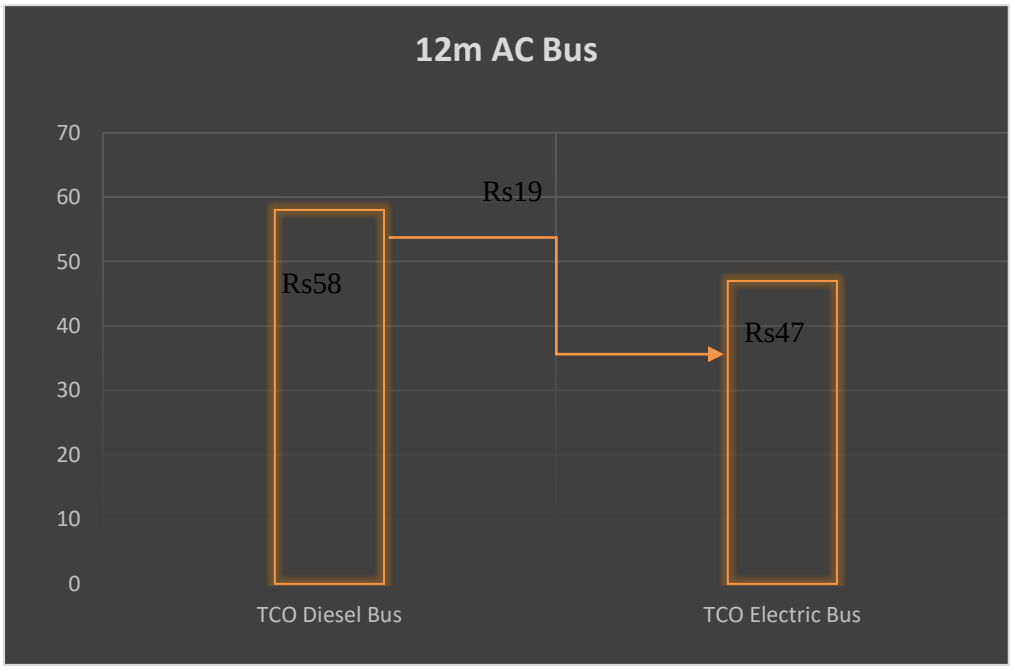
On the basis of infrastructure scenario there will be a high upfront cost in shifting from source of electricity coal to the renewable sources of energy such as solar power plant. The cost of setting up of solar power plant to meet the need of required electricity recharge the fleet of 93 buses is 28 million. Therefore, if the shift to cleaner mobility done in phase wise implementation it will help in reducing the cost secondly in the coming years with the

advancement of technology the cost of electric bus and solar power plant solar will also reduce.

6.2. COMPARISON OF TCO OF DIESEL BUS AND ELECTRIC BUS

In India the total cost of ownership of electric buses is lower even without the government subsidies as compared to the total cost of ownership of diesel buses. With the advancement of technology, the cost of lithium-ion battery used in electric buses had fallen more than 80% in the year 2017 as compared to the cost of battery in 2010 (Khandekar et al., 2018). Like the diesel costs which are unstable, EV buses are ready to exploit low and 20-year. Nominally fixed solar power cost which are considerably below the present normal expense of fuel. Nonetheless, a correlation of the Total Cost of Ownership (TCO) among diesel and electric buses shows that the electric buses are more economically effective. As shows in the figure 13, expecting the typical driving of buses 200 km each day for AC buses, the assessed TCO for 12m AC diesel bus are Rs 58 for every km whereas in case of AC electric buses with a battery cost for every unit limit expected as $200 per kWh (excluding import tax), buses for 12m transport, it is about Rs. 47 for each km (Khandekar et al., 2018).

Figure 12: Comparison of TCO of 12m AC diesel and electric bus

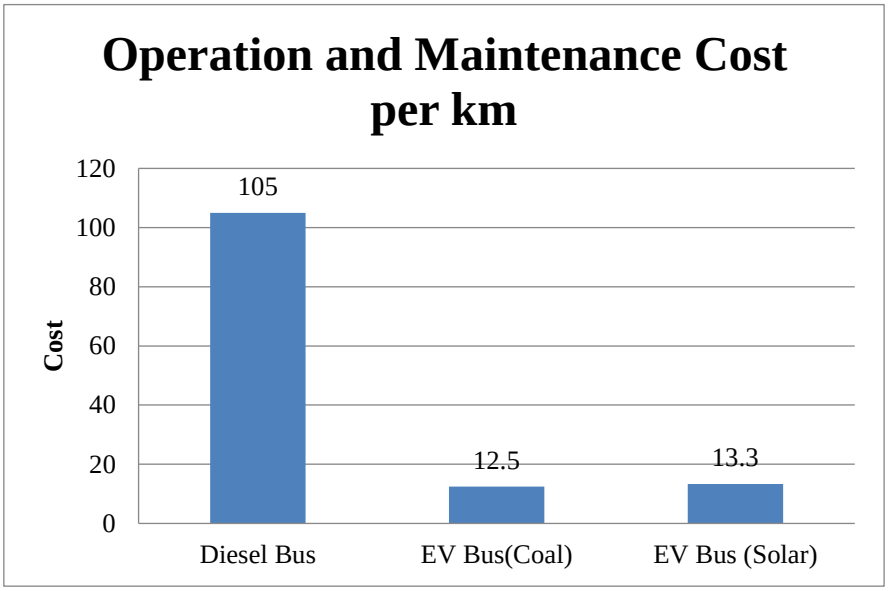


Source - (Khandekar et al., 2018)

As the calculations done in the findings and scenario part it has been concluded that the operation and maintenance cost of electric buses is lower than that of diesel buses as a result electric bus is

an attractive option, feasible, environment friendly hence helps in achieving the climate change targets of India.

Figure 13: Comparison of operation and maintenance cost of diesel and electric bus

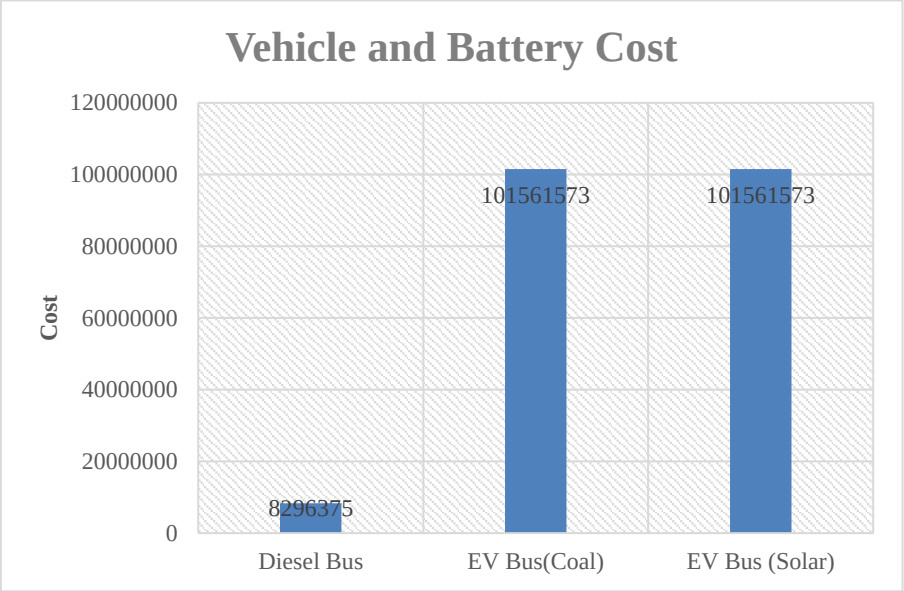


Source – Calculated Values

Therefore, electric buses market has a higher potential growth in Indian market, with the government subsidies for electric buses in public transport has also attracted lot of buyers. The operational maintenance cost of an electric bus is more stable and lower as compared to diesel bus because electric buses have few moving parts in the bus therefore much more predictable and lower operating cost. The fluctuation in the maintenance cost by 50% shows that the TCO per kilometre of electric bus increase or decrease only by 3 or 4% whereas it fluctuates by 8 to 11% for the diesel buses (Vijaykumar et al., n.d.).

The vehicle and battery cost reduction of the electric buses has been seen in last few years and is expected to decrease with the advancement of technology in India but at the same time the fuel consumption of diesel buses which drives the same distance per day is much higher than electric buses. The adoption of electric vehicles in India has been slow due to the high upfront cost of the electric buses. The policies by Indian government for electric buses such as FAME provides the subsidies which helps in reducing the TCO of 12-meter electric bus to less than that of diesel bus. However, changes in technology of infrastructure and batteries for electric buses reduces their price as a result helping introduce the capital cost.

Figure 14: Vehicle and Battery cost of diesel and electric bus



Source – calculated values

CHAPTER 7
ANALYSIS

7.1. IMPACT OF ELECTRIFICATION ON COAL

The production of coal in India has increased in recent years and imports have been decreased. Despite the increase in coal production due to more demand, the country is facing coal shortage. Therefore, electrification of public buses with renewable energy sources can reduce the dependency on fossil fuels. This shows the negative impact on the electric vehicles if the source of electricity is from coal. In case of renewable energy, India has already achieved high rate of success in generating electricity from solar. The country was generating 2,6GW of electricity in 2014 from solar energy whereas in the year 2021, according to the ministry of renewable energy the electricity production from the solar has increased to 44,1GW which shows that in coming years the production will increase further (H. K. Kumar, 2021).

But as the cost of renewable energy sources is declining and the cost of coal-based electricity is increasing, government is shifting towards the renewable sources which will also support the decrease the emission in the cities.

7.2 IMPACT OF ELECTRIFICATION ON ENVIRONMENT

The environment impact of running electric buses by replacing diesel buses depends on the source of electricity and footprints of the electricity generated which depends on the how much electricity is required to meet the total fleet and how much share of coal is there in the generation of electricity. The public transport buses could ensure to have less emissions if the buses are on the source of renewable energy.

Electric buses come with zero tail -pipe emissions as compared to diesel buses which is considered as the highest emitter of air pollution in the cities. The air quality will improve by introducing the electric buses hence contributing to a reduction in local pollution as compared to the diesel buses running in the cities. Electric buses will become more favourable in the cities where the electricity source is majorly from renewable energy such as solar panels. Therefore, when the electric buses are charged using electricity from solar the advantages are far past then the air quality. As a result, the electric buses combined with renewable source of

electricity will guarantee the future dependency on fossil fuels and a way forward for cleaner innovations and fuels.

The total cost of environment degradation estimated by the world bank is about INR 3,75 trillion which is equal to India's 5,7% of the GDP (Gross Domestic Product) and the outdoor air pollution is responsible for around 30% of the environment degradation cost. Noise pollution which is also generated by the diesel buses is linked to number of health problems such as hypertension, coronary heart disease and dementia. It also affects the sleep at night and creates the issue of annoyance. Electric buses are much quieter as compared to diesel buses by 17 decibels (dB). Electric buses produce about 60dB whereas Diesel bus produces noise as loud as 70dB (Pavaska et al., 2016).

7.3 IMPACT OF ELECTRIFICATION ON INFRASTRUCTURE

In order to convert the total fleet of 160000 buses in India which is owned and operated by government transport will increase the total electricity consumption of the country by 0,7% for 150km/day to 1,2% for 250km/day (Khandekar et al., 2018). Therefore, by providing the fast-charging stations is the prerequisite to electrify the bus fleet and emission reduction. To install a fast charger for 12m AC bus which will charge the battery of 320kW in one hour would require initial investment of INR 7 million per charger including all the electricity components required for the grid and transformer (Khandekar et al., 2018). However, the cost of the fast-charging infrastructure and providing the new transmission/ distribution system for solar are considered as the key bottlenecks in the fast adoption of electric buses. The infrastructure cost of electric buses with source of electricity from solar has a life of 15-20 years and the cost of solar electricity is constant that would be only Rs 2 to Rs 5 per km (Khandekar et al., 2018). If the government allows to share the charging facilities with the private bus owners, the cost of infrastructure per km will drop further.

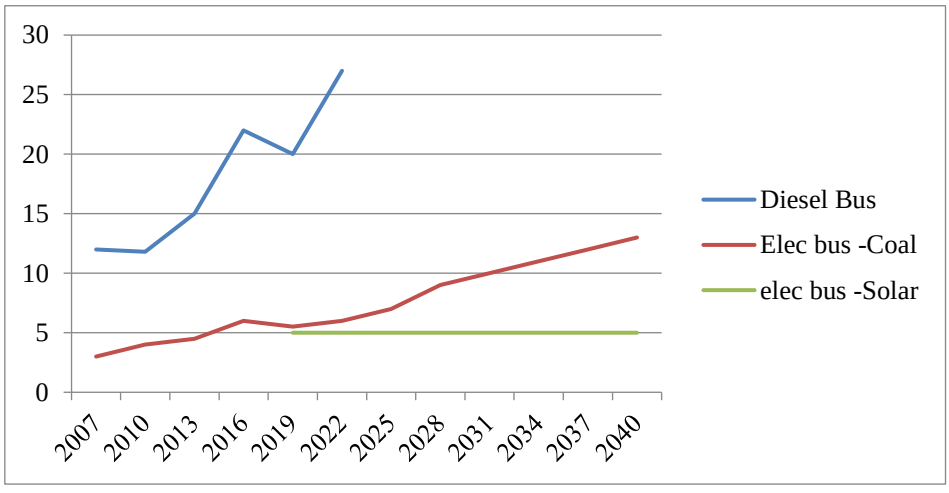
If by electrifying the entire fleet of the country would increase the electricity consumption by 1,2% then at the state level power system, no major upgradation of distribution is required (Khandekar et al., 2018). However, it requires more analysis and assessment at the city level. The total required electricity for the public fleet is very small fraction and if the supply of the electricity is made through the renewable energy sources such as solar it will increase the economic impact and environment benefits.

The difference between the calculated carbon dioxide emissions from the diesel buses and electric buses are low, but in the calculations only carbon emissions are considered. Coal based power plants emits other harmful particulate matter which as adverse effect on human health and environment. Other emissions such as PM2.5 emitted from the fuel combustion is considered as the main cause of cardiovascular diseases which is leading to premature death in India. The outdoor air pollution was responsible for 0,627 million deaths in India. The PM2.5 is much higher in the North Indian region than the prescribed standards of the air quality. Therefore, if the PM2.5 emissions will remain under the prescribed value then the life expectancy will increase by 3,2 per person per year (Pavaska et al., 2016).

7.4 ECONOMIC IMPACT OF ELECTRIFICATION ON PUBLIC FLEET IN AMRITSAR CITY

The payback cost of upfront electric buses can be achieved in three years, which is quick as comparative to 12 years of total life spam of bus. India is largely dependent on crude oil to meet the need of transport fuel. The price of crude oil has fluctuated broadly from 400% increase in the years 2001 – 2012 to 25% decline from 2011-2012 to 2013-2014. Therefore, electrifying the public transport buses will help in saving the energy because the transport sector of India consumes 74% of crude oil (Pavaska et al., 2016).

Figure 15: cost of diesel fuel, coal and solar



Source - (Khandekar et al., 2018)

The electric buses growth in the city will provide jobs in different sector such as bus manufacturing department, charging infrastructure, EV related accessory and batteries. The automobile industry of India has been rising in volume and exports in the past 10 years making it one of the fastest globally. The policy of NEEMP has an aim to make and promote the Electric vehicles by making India a global manufacturer.

According to the Electric vehicle policy in the state of Punjab, the draft has been prepared which states that the total fleet of buses will be replaced by 25% of electric buses within the five years of the policy notification after the final stage has been approved (B. Kumar, 2021).

CHAPTER 8
DISCUSSION

There are many resources available in India, but the major resource is the fertile land. The demand for food, shelter, energy and various other needs depends on the optimum utilization of resources. The land in India is declining every year. In the year 2001 the land was 0,26ha which declined to 0,17ha in the year 2015 (Mukhopadhyay, 2011). The availability of fertile land for farming and other crops is worse. Along with number of different natural causes for land degradation, mining has also contributed to depleting the soil, fertile land, forest and agriculture land because of increase in the usage of diesel based vehicles, dependency on fossil fuel increased in the past four decades. The local effects of mining on the nearby areas such as ground water depletion, no availability of agriculture land and forests have been cut down, these issues cannot be neglected.

The coal only occurs under the fertile agriculture land and the loss of mined area is very essential part of the natural resources which forces to compromise on the future needs. Presently, because of the coal based power plants around 1500 ha of the land is transformed to unproductive every year in addition to the land destroyed due to the past activities(Mukhopadhyay, 2011). Land degradation is mainly responsible due to increase in the dependency on surface mining, as a result due to large excavation it produces very noticeable and dramatic changes in the landscape of the area.

In India around 115000 people die every year because of the release harmful pollutants from coal-based power plant (Friedman, 2013). As coal is the major fuel used in all part of the country and the demands of energy are skyrocketing, but the fine particle pollution released from coal plants are directly linked to health problems and premature deaths in India. There were 100000 premature deaths with millions of patients suffering from asthma and respiratory problems due to coal exposure. There were 10000 number of children who are under the age of five and were fatal victims of the coal power plants (Friedman, 2013). The health damage which coal-based power plants are causing can be avoided by replacing it with renewable sources of energy, which will also help in reducing the emissions and maintaining local air pollution. Although the initial investment of renewable energy sources such as solar is high, but in the long term it will play a pivotal role in achieving the climate change targets of India and emission reduction. Electric buses are more efficient as they produce no tailpipe

emissions as compared to the diesel buses, which helps in reducing the pollution levels of the cities by only emitting warm air and water vapour.

India's commitment at the COP26 to achieve net-zero emissions by the year 2070 and reducing the emission levels by 45% from 2005 levels by the year 2030 can be achieved by first electrifying the public transport in India, with source of electricity from renewable sources (khan, 2021)**.**

Amritsar city is considered among the highest emitter of carbon dioxide emissions in the state of Punjab. Therefore, to reduce the emissions from the transport sector Punjab introduced the policy for electric vehicles. The policy is known as Punjab Electric Vehicle Policy 2019 which at the same time works on sustainable development goals (SDGs) (Government of Punjab, 2019). Further the policy also focused in helping the cities with adoption of Electric buses with provision for charging infrastructure. For the private owners of the e-buses, there will be no motor vehicle tax for 5 years, for the companies who will manufacture the buses in Punjab there will be no motor vehicle tax for 10 years. Also, there will be 100% fee waiver on the route permits. As for now, only draft has been made of the policy in which the government targeted to electrify the 25% of the buses in Punjab state in coming 5 years (Government of Punjab, 2019).

In case of Technical Feasibility, BRTS buses takes less time as compared to the Auto-rickshaws in the city. First, it saves time and helps in reduction of emissions. The auto rickshaws in the city runs on diesel and emits two times more carbon dioxide emissions as compared to BRTS buses. Secondly, the passenger capacity of one auto rickshaw is four whereas capacity of the bus is around 80-100 seats.

Table 13:Comparison of Technical feasibility of the buses and three wheelers in Amritsar city

Route Name	Distance Travelled (in Kms)	BRTS Bus	Auto	Difference
Amritsar Railway station to India gate	8,5	00:24:53	00:51:10	00:26:17

India Gate to Amritsar Railway Station	8,5	00:24:41	00:37:10	00:12:29
Amritsar Railway station to Verka	9,5	00:21:57	00:36:15	00:14:18
Verka to Amritsar Railway Station	9,5	00:30:30	00:37:45	00:07:15
Verka to Amritsar MCA Gate	13	00:34:18	00:40:35	00:05:53
Amritsar MCA Gate to Verka	13	00:34:05	00:39:55	00:05:55

Source - (*Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS*, n.d.)

While there are many e-buses benefits such as environment and air quality, at the same time there are many challenges in adopting the e-bus. The cost of purchasing e-buses and setting up of infrastructure is much higher as compared to diesel buses. This makes it difficult for private and public bus owners to purchase and operate an e-bus even with the subsidies. Electric vehicles considered to emit no pollution hence promote the cleaner mobility in the city but in case of India, it largely depends on the source of electricity for charging. In India the source of electricity is still largely depends on the coal and thermal power plants. In the analysis done of cost between coal and solar, the electricity from solar is Rs0,3 expensive than that of coal. Although the environment benefits of solar electricity are more as compared to coal.

In case of BRTS buses in Amritsar when the government has decreased the ticket price with student discounts and less price for senior citizens. The daily ridership has increased to 40000(Teja, 2021). Also, with the development of technology passengers who uses the bus

service on daily basis does not have to stand in the long queues to buy the tickets. Smart cards have been issued to daily users to avoid the overcrowding in the lines.

The impact of electrification on public transport will be in various way to the city. First, with the electrification and coming of charging infrastructure people from different department will be employed to have expertise in electric vehicle technology. Secondly, in the first phase of replacing the diesel buses with 5 % of electric buses can reduce the emissions by 3094 tons per year(*India: Electrifying Public Transportation in Kolkata.*, 2021). With the electrification it will improve the air quality index of the city hence improving the health of the people living in the city.

CHAPTER 9
CONCLUSION

The comparison of carbon dioxide emissions between diesel buses and electric buses with the source of electricity from solar and coal has done. The study of cost and infrastructure comparison was also carried out in the study. The analysis shows that on the basis of emission calculated and scenario created, the difference between the emissions from the scenario 2 that is 50% diesel,50% coal and scenario 3 which is 50% diesel, 50% solar is less. It shows that electrifying the buses from coal-based supply may help in reducing the emissions in the city but as the grid-based electricity is coming from coal based thermal plants therefore the emissions in the coal area and the negative impact because of coal plants will remain the same.

Even if the cost of the batteries will decrease annually with the development in technology it will take few years to come at the price of diesel buses. However, to avoid the high upfront cost in today's date, replacing the diesel buses with electric buses a phase wise implementation is suggested. For example, If the scenario 2 will be implemented in the first phase that is 50% diesel, 50% coal, in this case the only investment would be for electric buses as the electricity supply will be from the existing power grid. Therefore, while doing the second phase of implementation, there will be already electric buses and charging infrastructure for half of the fleet hence, the second phase could be the scenario 5 which is 50% coal, 50% solar. As a result, the financial burden will only be on the 50% solar, because of the existing 50% coal in phase 1.

While the Indian government has electric vehicle policies and incentives for faster adoption of electric transport, at the same time it lacks long term goals and objectives against which the policies result could be estimated and improved with time. However, the centre government of India lacks control over the city and state-owned bus transport organizations, Centre policies could make a strategy to focus on a select set of cities to check the feasibility of such objectives. This type of strategy could have more effect over the long run rather than a policy which allocated incentives/subsidies in a diffused way across each city. A centre coordinated strategy would have been more beneficial utilization of economies in bus procurement and establishment of charging infrastructure. Educating the decision makers in electric transport organizations regarding the new economies of e-bus might address the

failures emerging from lack of information it would help in the increase of efficiency of the FAME scheme.

The high upfront cost of the buses could be tended by providing low-cost or interest free loans to subsidize the high cost in investing the electric bus and infrastructure. This method can help in electrifying the greater number of buses with the total policy budget.
For example – A 12m Ac electric bus cost Rs. 7,5 million gets the subsidy of Rs 4,5 million under the Level 2 incentive. However, the price is still higher as compared to diesel buses, but it is three times less than the original cost. If the subsidy funds will be allocated in this manner with the total budget of Rs 35000 million it will electrify around 4% of India's public buses and 1% of public and privately owned buses. In case of Amritsar city, if the existing fleet of 93 AC buses would be electrified, it will require only 0,008% of the city's total electricity (Refer to Appendix D for detail calculation).
Another important need is to ensure to have the clean and cheap electricity. As only the small part of electricity is required cross country to electrify the whole fleet of public buses, therefore if that small fraction could be supply through the renewable energy sources it will increase the economic and environment benefits. There should also be policies on the charging heavy vehicles by renewable source of electricity.

To conclude, the findings done in the study shows that the high up-front cost of electric buses and charging infrastructure is the main barrier in transition to electric buses in case of India. While there are many government policies which are helping in adopting the electric buses at a faster rate with lower cost it will also help in improving the local air pollution with the better quality of service and growth in ridership.

BIBLIOGRAPHY

5 MW Solar Power Energy Plant in India: Profit, Cost & Land Requirement. (2021). *Waaree*. https://www.waaree.com/blog/5-mw-solar-power-plant-in-india

Amritsar Smart City. (n.d.). *RAAHI Project*. https://www.smartcityamritsar.com/project/raahi-project-citiis

Amritsar State of Punjab,India,South Asia. (2013). *GLOBAL COVENANT of MAYORS for CLIMATE & ENERGY*. https://dataportalforcities.org/south-asia/india/state-punjab/amritsar

Basu, R., Moura, Dr. S., Gill, P., Osserian, L., & Sengupta, Dr. R. (n.d.). *Electric Bus Operation in Kolkata City*. https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-Kolkata-Clarifications.pdf

BRTS, A. (2014). *Amritsar BRTS (A Project sanctioned under JnNURM on January 21, 2014)*. http://www.asiabrts.org/images/Amritsar%20BRTSnote.pdf

Bus Rapid Transit System (BRTS) Amritsar, Punjab. Asia BRT Conference. (2014). https://www.unescap.org/sites/default/files/2b.2_BRT%20Amritsar_LaghuParashar.pdf

Chhabra, K. (2022, March 28). *FAME India Scheme Phase 2*. https://sarkariyojana.com/fame-india-scheme/

council, smart cities. (2019). *Amritsar takes bold steps to tackle air pollution & reduce carbon footprint.* https://www.smartcitiescouncil.com/article/amritsar-takes-bold-steps-tackle-air-pollution-reduce-carbon-footprint#:~:text=The%20present%20modal%20share%20for%20public%20transport%20is%201.5%20per%20cent.

Current Air Quality. (2022). *Accuweather*. https://www.accuweather.com/en/in/amritsar/205593/air-quality-index/205593

Desai, Y. (2020). The Growing Lithium-ion Battery Market of India. *Contempo Clean Energy Research*. https://electrochemicalenergy.wordpress.com/2020/08/01/the-growing-lithium-ion-battery-market-of-india/

Dhamija, A., Saxena, S., & Acharya, T. (n.d.). *PROJECT PREPAREDNESS FRAMEWORK. SUSTAINABLE MOBILITY*. City Investments To Innovate, Integrate and Sustain. https://www.niua.org/citiis/sites/default/files/Sustainable%20Mobility%20.pdf

Diesel Price In India Today. (n.d.). Diesel Price In India Today. *Bank Bazzar*. https://www.bankbazaar.com/fuel/diesel-price-india.html

Directorate of Environment and Climate Change, & Department of Science, Technology and Environment. (2019). *Action Plan for Clean Air, Amritsar*. Government of Punjab. https://cpcb.nic.in/Actionplan/Amritsar.pdf

Environment, M. of, & Forest, M. of. (n.d.). Energy Scenario in Punjab. *Environmental Information System*. http://www.punenvis.nic.in/index2.aspx?slid=5822&mid=1&langid=1&sublinkid=1004#:~:text=The%20total%20installed%20capacity%20of,central%20share%20of%204215%20MW.

EV Charging Station. (n.d.). https://www.indiamart.com/proddetail/ev-charging-station-25383517597.html?pos=9&kwd=ev%20charging%20station&tags=A||||7613.566|Price|product|

FAME India Scheme Phase II. (n.d.). *Drishti*. https://www.drishtiias.com/pdf/1605085497-fame-india-scheme-phase-ii.pdf

Friedman, L. (2013). Coal-Fired Power in India May Cause More Than 100,000 Premature Deaths Annually. *Scientific American*. https://www.scientificamerican.com/article/coal-fired-power-in-india-

may-cause-more-than-100000-premature-deaths-annually/#:~:text=Environment-,Coal%2DFired%20Power%20in%20India%20May%20Cause,Than%20100%2C000%20Premature%20Deaths%20Annually&text=As%20many%20as%20115%2C000%20people,groundbreaking%20new%20study%20released%20today.

Goenka, D., & Guttikunda, S. (n.d.). *Coal Kills -An Assessment of Death and Disease caused by India's Dirtiest Energy Source*. Urban emissions and Green pace. https://www.banktrack.org/download/coal_kills

Government of India. (2015). *Ministry of Heavy Industries and Public Enterprises.* https://heavyindustries.gov.in/writereaddata/UploadFile/30%20june%2015.PDF

Government of India, & Minister of Power. (n.d.). *Bureau of Energy Efficiency.* https://beeindia.gov.in/content/e-mobility

Government of Punjab. (2019). *DRAFT PUNJAB ELECTRIC VEHICLE POLICY (PEVP)*. https://www.transportpolicy.net/wp-content/uploads/2019/12/Punjab_Draft_EV_Policy_20191115.pdf

Gulia, J., & Thayillam, A. K. (2020). *Electric buses India Market Analysis*. jmk research & analytics. https://jmkresearch.com/electric-vehicles-published-reports/electric-buses-india-market-analysis/

How Much Emissions Does a Solar Power System Prevent? (2020, January 10). *Solar Bay*. https://solarbay.com.au/newsroom/how-much-emissions-does-solar-power-prevent/

India: Electrifying Public Transportation in Kolkata. (2021). Public – Private Infrastructure Advisory Facility. https://ppiaf.org/feature_story/india-electrifying-public-transportation-kolkata

Irawan Zudhy, M. (2016). *PUBLIC TRANSPORT PLANNING(Frequency, Headway, and Number of Bus*. Civil and EnviromentalEngineering, GadjahMadaUniversity. http://zudhyirawan.staff.ugm.ac.id/files/2014/10/PPT-Pertemuan-13-final-2016-translate.pdf

Jaiswal, A. (2017). India Leads on Climate Action as Trump Exits Paris Agreement. *NRDC*. https://www.nrdc.org/experts/india-leads-climate-action-trump-withdraws-paris

Jha, M., Blaabjerg, F., Khan ali, M., Haque, A., & Bharath Kurukuru, V. S. (2019). *Intelligent Control of Converter for Electric Vehicles Charging Station*. mdpi. https://www.mdpi.com/1996-1073/12/12/2334/htm

khan, safa. (2021). India's transition to electric vehicles—The road ahead. *Oxford Policy Management*. https://www.opml.co.uk/blog/india-transition-electric-vehicles-road-ahead

Khandekar, A., Rajagopal, D., Abhyankar, N., Deorah, S., & Phadke, A. (2018). *The Case for All New City Buses in India to be Electric*. Energy Technologies Area Lawrence Berkeley National Laboratory. https://escholarship.org/uc/item/7d64m1cd

Kumar, B. (2021). State Wise EV Policies For Electric Bus in India | E-Bus. *E-Vehicle Info*. https://e-vehicleinfo.com/state-wise-ev-policies-for-electric-bus-in-india/

Kumar, H. K. (2021). Effect of coal crisis on Electric Vehicles industry!! Renewable energy. *Evehicleshop*. https://evehicleshop.in/how-coal-crisis-can-affect-the-electric-vehicles-market-green-energy/

Kumar, P., & Vijaykumar, A. (2021). *Unboxing the Barriers to Scaling up Electric Bus Adoption in India*. WRI India. https://wri-india.org/blog/unboxing-barriers-scaling-electric-bus-adoption-india

Kumar, P., & Vijaykumar, A. (2022). *EVALUATION OF THE TCO FOR DIESEL AND ELECTRIC BUSES IN INDIA*. https://india.busworld.org/sites/india/files/2022-01/Evolution%20of%20TCO%20for%20diesel%20and%20electric%20buses_WRI%20India.pdf

Kumar, S., Katoria, D., & Sehgal, D. (2013). *Environment Impact Assessment of Thermal Power Plant for Sustainable Development*. Research India Publications. https://www.ripublication.com/ijeem_spl/ijeemv4n6_09.pdf

Master Plan Amritsar. (n.d.). SAI Consulting Engineers Pvt. Ltd. Ahmedabad. http://www.adaamritsar.gov.in/en/master-plansapproved-master-plansadaamritsar-2010-2031/report

Ministry of Coal, & Government of India. (2022). *Generation of Thermal Power from Raw Coal.* https://coal.nic.in/en/major-statistics/generation-of-thermal-power-from-raw-coal#:~:text=However%2C%20Major%20production%20of%20Electricity,by%20the%20Central%20Electricity%20Authority.

Ministry of Heavy Industries & Public Enterprises. (2019). *Implementation of National Electric Mobility Mission Plan*. Press Information Bureau. https://pib.gov.in/newsite/PrintRelease.aspx?relid=191337

Ministry of Urban Development. (n.d.). *Traffic & Transportation Policies and Strategies in Urban Areas in India.* Wilbur smith associates. https://mohua.gov.in/upload/uploadfiles/files/traffic_transportation(1).pdf

Ministry of Urban Development, & Government of India. (2014). *National Urban Transport Policy, 2014*. https://www.changing-transport.org/wp-content/uploads/E_K_NUMP_India_2014_EN.pdf

Mittal, M. L. (n.d.). *Estimates of Emissions from Coal Fired Thermal Power Plants in India.* https://www3.epa.gov/ttnchie1/conference/ei20/session5/mmittal.pdf

Mukhopadhyay, M. K. (2011). *Issues Related to Impact on Landuse due to Mining in Power Grade Coalfields in India and Reclamation Approaches.* Balipura Foundation. https://www.researchgate.net/publication/344165785_Issues_Related_to_Impact_on_Landuse_due_to_Mining_in_Power_Grade_Coalfields_in_India_and_Reclamation_Approaches

N/A. (n.d.). Urban emissions.info. *Word Press*. https://urbanemissions.info/india-apna/amritsar-india/

Nagarkoti, R. (2021, October 8). Arrival of electric buses delayed in Chandigarh. *The Times of India*. https://timesofindia.indiatimes.com/city/chandigarh/arrival-of-electric-buses-delayed-in-city/articleshow/86849505.cms

Pavaska, G., Paladugula, A. L., & Vaidyanathan, V. (2016). *Electric Buses in India: Technology, Policy and Benefits*. Global green growth institute. https://gggi.org/site/assets/uploads/2016/10/2016-08-Electric-Buses-in-India-Technology-Policy-and-Benefits.pdf

Pawar, P. (2007). *Air Quality Monitoring Project-Indian Clean Air Programme (ICAP) Draft report on "Emission Factor development for Indian Vehicles "as a part of Ambient Air Quality Monitoring and Emission Source Apportionment Studies*.

Rambani, V. (2022, April 1). No change in electricity tariff; power subsidy to continue in Punjab. *Hindustan Times*. https://www.hindustantimes.com/cities/chandigarh-news/no-change-in-electricity-tariff-power-subsidy-to-continue-in-punjab-101648752719799.html

Roychowdhury, A., & Dubey, G. (n.d.). *THE URBAN COMMUTE AND HOW IT CONTRIBUTES TO POLLUTION AND ENERGY CONSUMPTION A CSE analysis and ranking of 14 cities in India*. Centre for Science and Environment. https://www.cseindia.org/the-urban-commute-8950

Roychowdhury, A., & Sayan, R. (2021). *ELECTRIC BUS TOWARDS ZERO-EMISSION COMMUTING*. Centre for Science and Environment. https://www.cseindia.org/electric-bus-10969

Singh, N., Mishra, T., & Banerjee, R. (2021). *Emissions inventory for road transport in India in 2020: Framework and post facto policy impact assessment*. Research Square. https://www.researchsquare.com/article/rs-297185/v1

Sinha, S., & Sharma, M. (2022). DECARBONISING TRANSPORT: REDEFINING MOBILITY POLICIES IN INDIA. *NITI Aayog*. https://www.niti.gov.in/decarbonising-transport-redefining-mobility-policies-india

Sri Harmandir Sahib (Golden Temple). (n.d.). https://amritsar.nic.in/tourist-place/sri-harmandir-sahib/

Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS. (n.d.). Urban Mobility 2019. http://urbanmobilityindia.in/Upload/Conference/f38be35e-532b-4de6-99f6-55ba09b03369.pdf

Teja, C. S. (2021, October 7). New High: Amritsar metro bus ridership hits 40K mark. *The Tribune*. https://www.tribuneindia.com/news/amritsar/new-high-amritsar-metro-bus-ridership-hits-40k-mark-321322

The New Indian Express. (2021, June 26). Fame-2 incentive scheme for electric vehicles extended by two more years. *By Express News Service*. https://www.newindianexpress.com/business/2021/jun/26/fame-2-incentive-scheme-for-electric-vehicles-extended-by-two-more-years-2321671.html

Vijaykumar, A., Kumar, P., Mulukutla, P., & Agarwal, Dr. O. (n.d.). *Procurement of Electric Buses:Insights from Total Cost of Ownership (TCO) Analysis*. WRI India. https://wri-india.org/sites/default/files/WRI_EBus_Procurement_Commentary_FINAL_0.pdf

Vijaykumar, A., Singh, Y., & Bhatia, S. (2021). More than half of all e-buses in India found on Maharashtra roads. *WRI India*. https://wri-india.org/blog/more-half-all-e-buses-india-found-maharashtra-roads

APPENDIX A

DETAIL CALCULATION OF CARBON EMISSIONS FROM DIESEL BUS

Table 14: The distance travelled by the buses on the 3 routes.

Existing Route Details	Distance traveled round trip(km)
India gate to MCA gate	32,4
India gate to Verka Canal	36,8
Verka Canal to MCA gate	26

Source - (*Technical Session 3 –Problems for Small and Medium Towns & Introduction of Public Transport Systems. AMRITSAR METRO BUS -A NEW JOURNEY BEGINS*, n.d.)

Headay = 1/ Frequency (Irawan Zudhy, 2016)

Therefore, Frequency = 1 X 4 = 4

Operational hours of public buses in Amritsar = 15hr/day.

Therefore, in 1 hr. 4 buses will come.
In 15hr, = 4 X 15 = 60 buses

Formula for calculating emissions from buses = vehicle km traveled X emission factor.
Whereas emission factor according to Indian Air quality standards for diesel buses is 602,01g/km of CO_2(Pawar, 2007). Therefore, emissions on existing routes will be -

1. India gate to MCA gate = (32,4 X 60) X 602,01

= 1170307,44g/km

2. India gate to Verka Canal = (36,8 X 60) X 602,01

= 1329238,08g/km

3. Verka canal to MCA gate = (26 X 60) X 602,01

= 939135,6g/km

APPENDIX B

DETAIL CALCULATION OF CARBON EMISSIONS FROM ELECTRIC BUS RUNNING ON COAL.

Vehicle km travelled will be the same, for calculating emissions -

Considering the electric buses already deployed in different cities in India, their mileage for 1km it requires 1.06km/kwh of electricity.(Basu et al., n.d.) *Therefore, by calculating the total vehicle km travelled in the city will give the total electricity requirement.*

After calculating total required electricity, the emissions will be calculated by – how much coal is burnt to produce the required electricity, and how much emissions are generated in burning the coal to meet the requirement.

Headway = 1/ Frequency

Therefore, Frequency = 1 X 4

= 4

Operational hours of public buses in Amritsar = 15hr/day.

Therefore, in 1 hr., 4 buses.

In 15hr, = 4 X 15 = 60 buses

Route 1 - India gate to MCA gate = 16,2km

MCA gate to India gate = 16,2km

Total length of Route 1 = 32,4km

Therefore, Bus km travelled = 60 X 32,4

= 1944km

According to existing deployed electric buses in other cities, the electricity required for 1 km it requires 1.06km/kwh

1944 X 1,06 = **2060,64km/ kwh or 195,7608kg/kwh**

Route 2 - India gate to Verka Canal = 18,4

Verka Canal to India gate = 18,4

Total Length of Route 2 = 36,8

Therefore, Bus km traveled = 36,8 X 60

= 2208

According to existing deployed electric buses in other cities, the electricity required for 1 km it requires 1,06km/kwh

2208 X 1,06 = **2340,48km/ kwh or 222,345kg/kwh**

Route 3 - Verka Canal to MCA Gate = 13km

MCA Gate to Verka Canal = 13km

Total Length of Route 3 = 26km

Therefore, Bus km traveled = 26 X 60 = 1560

According to existing deployed electric buses in other cities, the electricity required for 1 km it requires 1,06km/kwh

3120 X 1,06 = **1653,6 km/ kwh or 157,092kg/kwh**

Total required electricity – 6054,72kwh or 575,19kg/kw

EMISSIONS FROM ELECTRICITY SOURCE OF COAL.

There are 3 coal power plants, currently working around the city.

(Goenka & Guttikunda, n.d.)

Emissions from coal based power plant is – 0,95kg/kwh.

Therefore, total emissions from total required electricity would be – 575,19 X 0,95

= 546,43kg/kwh

CALCULATION OF CARBON EMISSIONS FROM SOURCE OF ELECTRICITY SOLAR.

Total required electricity - 6054,72kwh or 575,19kg/kwh

The solar plant emits 0,4kg/kwh of emissions therefore, emissions from the routes are("How Much Emissions Does a Solar Power System Prevent?," 2020) –

Table 15: Route wise emissions from solar based electricity.

Routes	Emissions
Route 1	78,30432
Route 2	88,93824
Route 3	62,8368
	230,07936kg/kwh

Source – Calculated values

APPENDIX C

Detail calculations of the scenarios used in the chapter for implementation of public transport

Table 16: Detail calculation of the scenarios of future public transport in Amritsar city.

	Total emission in kg/km
Scenario 1 - 100% Diesel	3438,6
Scenario 2 - 50% Diesel- 50% coal	2007
Scenario 3 - 50% Diesel-50% Solar	1834,33
Scenario 4 - 100% coal	575,1984
Scenario 5 - 50% coal 50% solar	403
Scenario 6 - 100% solar	230,079

The difference between emissions from Scenario 1 that is 3438,6 and scenario 2 that is 2007 is 172,67

Table 17:Infrastructure requirement based on the scenarios.

Scenario	Infrastructure	Requirement
100% Diesel	NIL	Units
50% Diesel- 50 %coal	Inverter	1 unit
	EV Charging Station	12unit
50% Diesel-50% Solar	Solar Panel	300 uit
	Charge Controller	1 unit

	Hybrid Storage Bank	1 unit
	Inverter	1 unit
	EV Charging Station	12unit
100%Coal	Inverter	2 unit
	EV Charging Station	24unit
50% coal 50 %solar	Solar Panel	300 unit
	Charge Controller	1 unit
	Hybrid Storage Bank	1 unit
	Inverter	1 unit
	EV Charging Station	12unit
100% Solar	100	
	Solar Panel	600 Unit
	Charge Controller	1 unit
	Hybrid Storage Bank	2 unit
	Inverter	1 unit
	EV Charging Station	24

Cost for the infrastructure cost is calculated using the infrastructure value for solar panels, hybrid storage bank, inverter and EV charging stations. The cost used is from the Indian site

called Indian mart, which is local site and supplies all kinds of electricity infrastructure for all kind of vehicles (*EV Charging Station*, n.d.).

Table 18: Operation and maintenance cost of diesel and electric bus.

Diesel Bus	105
EV Bus (Coal)	12.5
EV Bus (Solar)	13.3

Source - (Khandekar et al., 2018)

The operation and maintenance cost of diesel and electric bus is calculated using the cost parameters such as Fuel cost, fuel economy and maintenance cost.

Table 19: Vehicle and Battery cost of electric and diesel vehicle.

Diesel Bus	8296375
EV Bus (Coal)	101561572
EV Bus (Solar)	101561573

Source - (Khandekar et al., 2018)

The vehicle and diesel engine cost of diesel bus is calculated using the vehicle production cost and diesel engine, whereas for the electric buses it is calculated using vehicle production and battery cost.

APPENDIX D

Calculation of percentage of required electricity to charge the existing bus fleet, with the comparison to the city's total electricity requirement.

Total Electricity required for Operation of Buses = 6054,72

Total Electricity Supplied to Amritsar = 673742000 ("Amritsar State of Punjab,India,South Asia," 2013)

1 megajoule = 0,2777777778 kilowatt-hour

Percentage = 0,0008%