Deployment of Electric Road Mass Transportation in South Asia

December, 2018

SAARC Energy Centre, Islamabad

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Foreword

Hydrocarbon reserves in South Asia are limited; all SAARC Member States are net importers of petroleum products. Ever growing transport sector in SAARC Member States has been constantly exerting pressure on the oil dependence as well as resulting in the environmental externalities. This type of demand represents both a challenge and an opportunity to capitalize on new vehicle technologies, and in the process, reap substantial economic development benefits.

In this situation, an alternate source of transportation fuel – electricity – is not only a smart investment, but an inevitable one. Countries worldwide are taking an aggressive stance in order to expedite the transition to Electric Vehicles (EV). According to Global E.V. Outlook 2017 (EIA); by 2016, there were more than two million electric cars on the roads globally. New registrations of electric cars hit a new record in 2016 alone, with over 750 thousand sales worldwide. From deployment aspect Norway has been incontestably the most successful globally. Similarly, China is the biggest electric car market, by volume, in the world. Among SAARC countries, India is joining China in setting aggressive EV targets: "China, plans alternative fuel vehicles to account for at least one-fifth of its 35 million annual vehicle sales projected by 2025, whereas India is planning to support electrifying all vehicles in the country by 2032. The UK and France are also moving to the forefront of the EV movement. Both have committed to ban sale of all new diesel and petrol cars by 2040 in a bid to encourage people to switch to electric and hybrid vehicles.

Keeping in view the importance of the transformative new technology; SEC, in year 2017, conducted a comprehensive study to review deployment of Electric Road Transport in the SAARC Member States.

The study was outsourced through a competitive yet transparent process; to a team of experts from PwC (Pricewaterhouse Coopers Pvt. Ltd.) mainly comprised of Mr. Amit Kumar, Mr. Sandeep Kumar Mohanty, Mr. Jitaditya Dey and Mr. Rachit Gupta. Entire activity was supervised by Mr. Ihsanullah Marwat (Research Fellow – Energy Efficiency), who as Program Coordinator, provided overall guidance and necessary inputs on behalf of SEC. The contributions of Mr. Suresh Shrestha and Dr. Azhar-ul-haq as Peer Reviewer are highly appreciated; their critique and experienced remarks helped alot in improving and finalizing the study report.

Basic purpose to carry out this study was to assess the viability of deploying electric vehicles for the mass transit of passengers in the road transport sector in the SAARC Member States and to identify policy and infrastructure requirement for the deployment of electric mass road transport sector in the region.

The study report was disseminated among relevant regional professionals through a webinar organized by SEC on 11 April 2018. Study team and other experts from the field were engaged as resource persons. The effort was highly appreciated by the participants with no considerable changes suggested in the report. The report has been made possible with the support and advice of many individuals and organizations. SEC and PwC (Pricewaterhouse Coopers Pvt. Ltd.) team would like to thank everyone who contributed to this endeavor.

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List of Abbreviations

A	**Ampere**
AC	Alternating Current
ADB	Asian Development Bank
ADL	Alexander Dennis Limited
AER	All Electric Range
ARAI	Automotive Research Association of India
BAU	Business as Usual
BBC	British Broadcasting Corporation
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BD	Battery (Energy) Density
BEB	Battery Electric Buses
BEST	Brihanmumbai Electricity Supply and Transport
BEV	Battery Electric Vehicles
BHP	Battery Horse Power
BMC	Brihanmumbai Municipal Corporation
BMS	Battery Management System
BMTC	Bangalore Metropolitan Transport Corporation
BP	British Petroleum
BRT	Bus Rapid Transit
BS	Bharat Standards
BYD	Build Your Dreams (Chinese company)
CAFC	Corporate Average Fuel Credit
CAGR	Compound Annual Growth Rate
CMS	Central Management System
CNG	Compressed Natural Gas
CNY	Chinese Yuan
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPEC	China Pakistan Economic Corridor
CS	Charging Speed
CSETP	Centre for Study of Science, Technology and Policy
dB	Decibels
DC	Direct Current
DHI	Department of Heavy Industries
EDF	Électricité de France (French Utility Company)
EFF-TECH	Transformation to Energy Efficient Systems and Technologies
ERMT	Electric Road Mass Transportation

ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle
EVAN	Electric Vehicles Association of Nepal
EVSE	Electric Vehicle Supply Equipment
FAME	Faster Adaption and Manufacturing of (Hybrid &) Electric Vehicles
FCEB	Fuel Cell Electric Bus
FS	Fuel Savings
Ft	Feet
FY	Fiscal Year
GASELEC	Compressed Natural Gas and Electricity Conversion
GBP	British Pound
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gases
GUTS	Green Urban Transport Scheme
GWhr	Gigawatt-hour
HEB	Hybrid Electric Buses
HEV	Hybrid Electric Vehicles
HPCL	Hindustan Petroleum Corporation Limited
HRTC	Himachal Road Transport Corporation
IC	Internal Combustion
ICAT	International Centre for Automotive Technology
ICE	Internal Combustion Engine
IEA	International Energy Agency
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IOCL	Indian Oil Corporation Limited
KAIST	Korean Advanced Institute of Science and Technology
Kg	Kilo-gram
Km	Kilo-meter
Kw	Kilo-watt
kWh	Kilowatt hour
LEAP	Long Range Energy Alternatives Planning System
LEVA	Lanka Electric Vehicles Association
LFP	Lithium Iron Phosphate
LIB	Lithium Ion Battery
Li-ion	Lithium Ion

LRT	Light Rapid Transit
M	Meter
MAN	Maschinenfabrik Augsburg-Nürnberg (A German company)
MASSTRANS	Mass Transport
MJ	Mega Joule
MMRDA	Mumbai Metropolitan Region Development Authority
MoF	Ministry of Finance
MRT	Mass Rapid Transit
MTOE	Million Tonnes of Oil equivalent
NAMA	Nationally Appropriate Mitigation Actions
NASA	National Aeronautics and Space Administration
NEV	New Energy Vehicle
NGCC	Natural Gas Combined Cycle
NiMH	Nickel Metal Hydride
NITI	National Institution for Transforming India (also known as NITI Aayog)
NMMT	Navi Mumbai Municipal Transport
NTP	National Transport Policy
OEM	Original Equipment Manufacturer
PETREN	Integrated Assessment of Energy, Transportation and Environment
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
p-HEV	Parallel Hybrid Electric Vehicle
PM	Particulate Matter
Ppm	Parts per million
PPP	Purchasing Power Parity
PROMO	Minimize Oil Imports through improvement in Energy Efficiency and Fuel Substitution
PTPS	Pakistan Transport Plan Study
RATP	Régie Autonome des Transports Parisien (a French transport operator)
ROW	Right of Way
RCD	Residual Current Device
SAARC	South Asian Association for Regional Cooperation
SAE	Society of American Engineers
SDG	Sustainable Development Goals
SDF	SAARC Development Fund
SEC	SAARC Energy Centre
SEK	Swedish Krona
SFMTA	San Francisco Municipal Transportation Agency
s-HEV	series Hybrid Electric Vehicle
SMEV	Society of Manufacturers of Electric Vehicles

SoC	State of Charge
TCO	Total Cost of Ownership
TMT	Thane Municipal Transport
TTW	Tank-to-Wheel
UC	Ultra-capacitors
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
USC	Ultra-supercritical Steam Cycle
USD	United States Dollar
V	Volt
VAT	Value Added Tax
WTT	Well-to-Tank
WTW	Well-to-Wheel

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Executive Summary

SAARC Member States are growing at a historical pace and so are their needs for providing better modes of transportation to their citizens and industries. The development of transportation sector plays a crucial role in bolstering growth and providing access to larger population at an affordable rate. However, it comes with critical challenges related to climate change, rapid urbanization and motorization, accessibility and affordability, air pollution and its health impacts, and road safety. These challenges can be tackled by SAARC Member States along with meeting their ever-increasing requirements for transportation through implementation of Electric Road Mass Transportation (ERMT).

Road transport is one of the most important means of transportation for almost all SAARC Member States. Among all the countries, India has the largest road and bus network. Pakistan is a distant second, followed by Afghanistan, Nepal and Sri Lanka.

All SAARC Member States have decided upon INDC (Intended Nationally Determined Contribution) goals to reduce their GHG Emissions. Under these commitments, Afghanistan, Bangladesh, Maldives, Pakistan and Sri Lanka plan to cut their GHG emissions from business-as-usual GHG levels by 13.6%, 5%-15%, 10%-24%, 20% and 7%-23% respectively by 2030[1]. India plans to cut its emissions by 33%-35% from 2005 levels and Nepal aims to reduce its dependency on fossil fuels by 50% by 2050. Bhutan, an already carbon neutral country, has sworn to keep 60% of territory forested. Investing in ERMT would be a very effective way to work towards these goals.

Except for India and Sri Lanka, no other SAARC nation has made efforts to test or implement Electric Road Mass Transportation. In India, the Navi Mumbai Municipal Transport (NMMT), Mumbai Metropolitan Region Development Authority (MMRDA), Himachal Road Transport Communication, Bangalore Metropolitan Transport Corporation (BMTC) and Thane Municipal Transport (TMT) have ordered procurement of 8,400 hybrid, 25 hybrid, 25 electric, 150 electric and 100 electric buses, respectively. In Sri Lanka, under the Nationally Appropriate Mitigation Action (NAMA), the Government aims to run electric buses on bus priority lanes. In the initial phase 10 such buses will be operated in Galle followed by addition of 90 more buses in the next phase.

The key advantage of ERMT is in reduction of pipe tail GHG emissions which helps in decreasing pollution levels of the surrounding environment. Electric vehicles also have a better Well-to-Wheel efficiency, up to 50% more than that of diesel vehicles leading to requirement of less maintenance. ERMT implementation also leads to reduction of noise pollution which again would lead to a healthier lifestyle. However, it has its own set of challenges. Buses required for ERMT and the supporting infrastructure in the form of charging stations/overhead lines for trolley buses add up to an very expensive investment plan. To an extent this can be compensated by the low operating costs of electric buses and operating in a business model supported by battery swapping stations as

[1] The upper limit ranges are the target that can be achieved through international support. In case of Pakistan, the 20% target is also based on international support.

battery costs 50% of the total cost of a battery electric bus. Further, with technological advancements, costs of batteries are falling, along with which, manufacturers are trying to improve operating range and reduce time taken to recharge the same. Standards for mitigating the safety concerns arising due to mechanical abuse, overcharging and extreme temperatures are also being designed and implemented.

The economically viable technology options for electric buses under ERMT are hybrid buses, battery electric buses and trolley buses[2]. Of all these technology options, battery electric buses have the lowest fuel consumption and Well-to-Wheel GHG emissions. However, these results also depend on source of electricity, which should ideally be completely from renewable energy sources for best results. A battery electric bus when powered through renewable energy emits 98.36% less GHG emissions when compared to a diesel bus. But, battery electric buses have the highest total cost of ownership among the other options, whereas trolley buses are relatively inexpensive compared to diesel buses and have the lowest cost of ownership. Like bus technologies, there are also various electric storage systems, which can be classified into Batteries, Ultra-capacitors and Fuel Cells. Among the various battery type, Lithium-ion batteries are the most commonly used electrical storage system for commercial purposes.

Similarly, for setting up the charging infrastructure there are options to choose among slow, fast and rapid chargers. Among these, rapid chargers having wattage over 50 kW are the most suited ones for buses as they take 1.5-2 hours for charging a bus with a range of 300 km. However, these come with a barrier of being the most expensive amongst the rest. In order to reduce the waiting time and continue seamless operations of the buses, battery swapping can be a solution. Trolley buses also need installation of overhead lines and substations, setup of which is very expensive and comes with its own challenge of getting necessary approvals and delay in implementation due to ROW (Right Of Way) issues.

The total cost of implementation will depend on the layout plan for ERMT. While planning the same, ERMT implementation can be initiated with hybrid buses. This is primarily due to the fact that hybrid buses would allow rolling out of charging infrastructure in a gradual manner, as these buses can be powered using diesel/CNG in the meantime. As the charging infrastructure gets set, battery electric buses can be procured and introduced for operations. In case of running Trolley Buses, overhead lines needs to be installed first.

Despite these challenges, China has been successful in implementing electric buses as means for public transportation. It is home to about 99% of the global electric bus stock. The main reason for the same has been strong government intervention of providing massive subsidies on procurement of electric buses which was first limited to public vehicles and then extended for private ownership. Such subsidies have proved pivotal in the success as they help in overcoming the initial capital outlay for the prospective buyers. Subsidies were also available for installation of charging infrastructure. The Government on a larger scale has also supported its indigenous manufacturing companies and promoted research & development of efficient and cost competitive technologies,

[2] Comprehensive information of these technologies is given in section 3.2

making Chinese automobile manufactures the leading electric bus sellers across the world. Globally, governments have started providing both fiscal and non-fiscal incentives to promote usage of electric vehicles. Such incentives can include exemption from vehicle registration charges and tax credits to direct subsidies and access to high occupancy lanes. Moreover, the governments have ensured investments in the EVSE (Electric Vehicle Supply Equipment), i.e., Charging Infrastructure, for providing an exhaustive and effective charging network. This has been done by the government either directly or by providing incentives to organizations willing to do it. A successful implementation and adoption depends on interaction of innovation on parts of government, regulators, manufactures, power utilities, infrastructure providers, funding agencies and consumers.

Biggest challenge the SAARC Member States will face in deployment include the funding of high capital expenditure associated with the implementation, installation of charging infrastructure and meeting electricity requirements for operations. To overcome these challenges, support from government, investments from private sector and sustained funding to boost and support manufacturing and R&D efforts will play a key enabling factor. Each of the individual governments need to design comprehensive policies and plans, defining national targets to be achieved along with guidelines for the following:

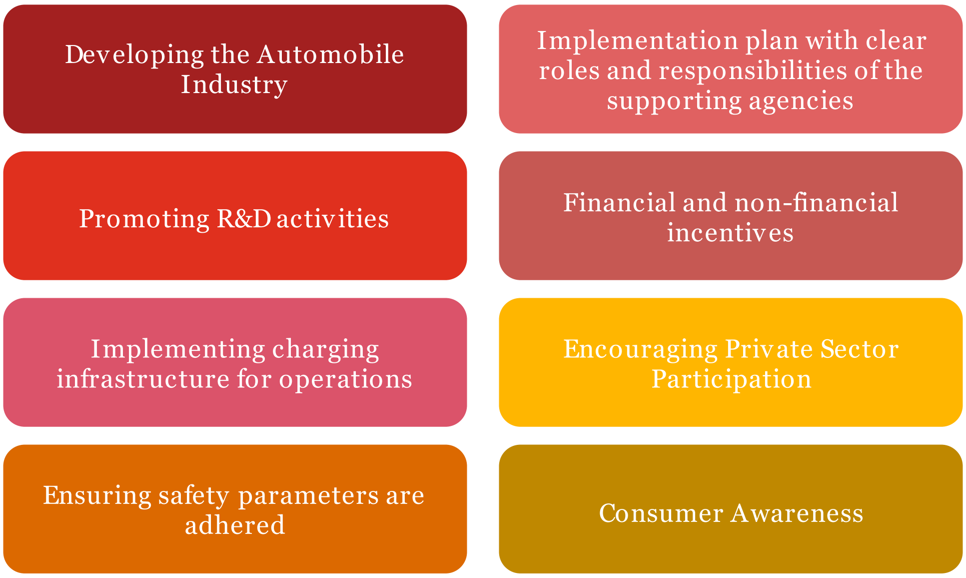

Figure 1 : Key Areas to be deliberated by Governments for development of a comprehensive policy

Further, in order to facilitate faster adoption and promote coordination among the SAARC Member States, the Countries should agree upon joint investment into development of electric vehicles and form an association to share of technology and provide support in implementation of ERMT and faster adoption of EVs across the nations. The association developed could further drive the following key areas which would benefit all participating nations.

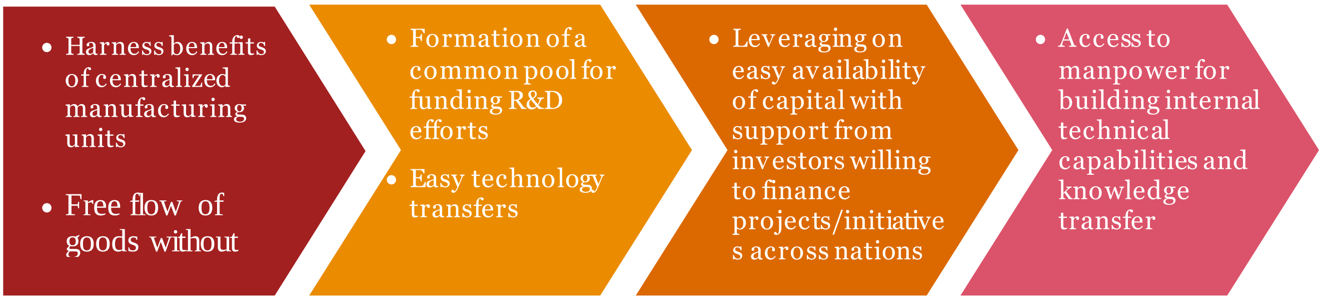

Figure 2: Probable intervention areas for proposed SAARC Association for Electric Vehicles

1. Introduction

1.1. Background

Transportation sector is a critical driver of economic and social growth of a country and is often termed as its lifeline. It forms the primary infrastructure layer on which cities are built ensuring equitable and easy access for consumers; connecting people and enabling supply of goods and services across the world. According to the World Bank[3], transportation sector is crucial in poverty alleviation, bolstering growth and prosperity, and achieving the 17 Sustainable Development Goals (SDGs)[4] - adopted by the world leaders on September 2015 at the historic UN Summit[5], as the sector falls at the core of critical development challenges:

01 — **Climate Change:** Transportation accounts for ~64% of global oil consumption, 27% *of energy use, and 23% of world's energy-related CO2 emissions. Environmental impact is expected* to grow dramatically with increased motorization.

02 — **Rapid urbanization and motorization:** Cities will be home to around 5.4 billion residents by 2050; equivalent to 2/3 of the projected global population. Number of vehicles on the roads will double to reach 2 billion by 2050.

03 — **Accessibility and affordability:** ~1 billion people in low-income countries still lack access to an all-weather roads. Traffic congestion is a major issue in big cities. High mobility costs cut the disposable income of the poor who often lack reliable and affordable public transportation.

04 — **Air pollution & impact on health:** Pollution from motorized road transport has been associated with a range of health conditions. Each year, almost 185,000 deaths can be directly attributed to pollution from vehicles.

05 — **Road safety:** More than 1.25 million people are killed and ~50 million are injured on the world's roads every year. Low and middle-income countries account for 90% of deaths although they own just half the world's motor vehicles.

Figure 3: Impact of transportation sector at the core of critical development challenges

Atmospheric carbon dioxide levels have increased from 280 ppm to 400 ppm in the last 50 years. Various panels on climate change have concluded that there is more than 95% probability that human activities have contributed to warming of our planet in the last 50 years. With rapid urbanization across the developed and developing countries, significant focus has been shifted towards building cleaner, more efficient and safe modes of transport which are accessible and affordable across various strata of population.

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3 Transport Overview, World Bank

4 The 17 SDGs agreed upon by 193 Member States are - 1. No Poverty 2. Zero Hunger 3. Good Health and Well-being 4. Quality Education 5. Gender Equality 6. Clean Water and Sanitation 7. Affordable and Clean Energy 8. Decent Work and Economic Growth 9. Industry, Innovation and Infrastructure 10. Reduced Inequalities 11. Sustainable Cities and Communities 12. Responsible Consumption and Production 13. Climate Action 14. Life below Water 15. Life on Land 16. Peace, Justice and Strong Institutions 17. Partnerships for the Goals (http://www.un.org/sustainabledevelopment/sustainable-development-goals/)

5 The Sustainable Development Agenda, United Nations

Mass transit plays a pivotal role in attaining the goal of sustainable development by providing transportation services for movement of large number of people at faster speeds and with use of limited space. Mass transit, also known as public transportation or mass transportation, is a large scale system comprising of buses, trains, metros, subways, trams, ferries, airlines etc. for movement of people within urban areas in the same vehicle (buses) or collection of vehicles (trains/metros/trams) leading to lower costs to carry each person and an opportunity for efficient expenditure of funds for providing better service. Further, pollution levels are minimized along with reduced environmental impact as greenhouse gas emissions get reduced and overall carbon footprint of operations fall.

All SAARC Member States have continuously growing transportation sector to support their increasing population, rising urbanization and developing economies. This has translated into constant pressure on their dependence on oil imports as well as resulted in environmental externalities including climate change implications and local air pollution. Further, with SAARC Member States setting challenging targets to reduce their respective greenhouse gas emissions over the upcoming years under the Paris Agreement held on December 2015 at the 21st session of the Conference of the Parties[6], it has now become imperative to assess the current mass transit systems and move towards designing of policies for providing efficient, affordable, accessible and clean mass transportation services to the citizens.

1.1.1. Overview of Mass Transit in South Asia

In the recent years, SAARC Member States have experienced consistent growth in their GDP and rapid urbanization of population. This has led to increased demand of transportation services to facilitate movement of people and goods which has helped the economies to grow at a faster rate. The most common method for this facilitation of movement has been through development of roadways. Across all countries, there are varying levels of penetration in mass transit facilities. In this section, a brief overview of the mass transportation facilities of the SAARC countries has been outlined.

1.1.1.1. Afghanistan

General Overview:

Afghanistan has a total population of about 29.2 million, and with a total area of 652,860 sq. km., it has a population density of about 45 people per sq. km, which is one of lowest population densities in Asian region. Out of the established population, 20.8 million live in rural areas and the remaining 24% in urban parts of the country[7]. In 2014, the country emitted 33.37 million tonnes of CO_2 equivalent (CO_2e) of Greenhouse Gas emissions (excluding Land Use Change and Forestry), which was the 2nd highest among SAARC Member States when compared on a per GDP (PPP) basis. The per capita GHG emissions were at 1.02 tonnes of CO_2e, the lowest among all SAARC nations[8].

[6] Paris Agreement - Status of Ratification, United Nations Framework Convention on Climate Change
[7] Afghanistan Statistical Yearbook 2016-17, Central Statistics Organization, Islamic Republic of Afghanistan
[8] CAIT Climate Data Explorer, World Resources Institute

Real GDP has grown by 1.2% in 2016 to USD 19.4 million[9]. However, per capita income has decreased to USD 581 due to faster growth rate of its population. Violence continues to have impact on security of lives of the people and economic activities in the country with suppressed business progression. Inflation has increased from -1.5% in 2015 to 4.4% in 2016[9] due to increase in price of consumer goods which are majorly been imported into the country. A brief country profile has been represented in the Table 1: Overview of General and Macro-Economic Parameters of Afghanistan.

Table 1: Overview of General and Macro-Economic Parameters of Afghanistan

General Parameters	2016[10]
Population, million	29.2
Population growth rate, % (2011-16)	2.0
Total Surface Area, '000 sq. km.	652.9
Population Density, persons per km² of total surface area	44.7

Macro-Economic Parameters	2016[9]
GDP, USD billion	19.4
GDP per capita, USD	581.0
Current Account Balance, % of GDP	6.4
Debt, % of GDP	6.5
Inflation, %	4.4

Transportation Sector Overview:

As Afghanistan is a landlocked country, roads serve as the country's main mode of transportation with a network of 39,855 km of existing roads in 2016-17[7]. This comprises of more than 8,000 km of national and regional highways, and 26,000 km of provincial and rural roads[11]. The total number of registered vehicles in 2016-17 has increased by 1% year-on-year to 1,906,938 vehicles on the road. 61% of the registered vehicles comprise of passenger cars (including taxi fleets), whereas, 106,947 buses (6% of the total registered vehicles) are running on the roads. This network has supported the travel for 154 million passengers and 7.3 million tonnes of goods in the year 2016-17[7].

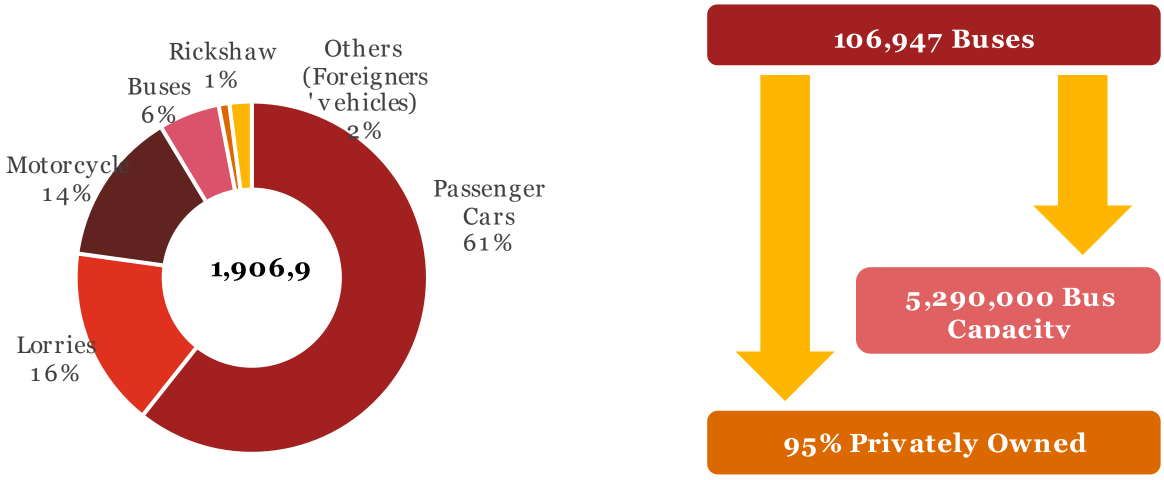

Figure 4: Breakup of total motor vehicles registered in Afghanistan

[9] South Asia Economic Focus, Spring 2017, World Bank
[10] Basic Statistics 2017, Asian Development Bank
[11] Afghanistan, A Transformation in Progress, The Embassy of the Islamic Republic of Afghanistan, Washington DC, November 2016

Further, the Transport system also comprises of railways, civil aviation and minimalistic inland waterways. Railway Operations which began in 2011 with completion of the 75 km Hairatan to Mazar-e-Sharif rail link have seen a drop in usage from 4 million tonnes of freight transferred in 2012 to 2.4 million tonnes in 2014. The traffic is almost completely one directional, generated through imports from Uzbekistan. Recently, a train link to People's Republic of China was also established carrying 84 containers equivalent to about 1,200 tonnes.

Of the five airports in Afghanistan, only those in Kabul and Herat are compliant with international standards, whereas Mazar-e-Sharif, Jalalabad and Kandahar are expected to be compliant soon[12]. 1,056,000 passengers travelled through the airways (a decline of ~60% over 2015-16) and 1,775 tonnes of goods were transported in 2016-17[7]. Inland waterways exist only between Amu Darya and the Pani River, where Shir Khan Bandar is located. Shir Khan is also the only port which exists in Afghanistan.

Investment Plan:

Apart from natural disasters and lack of peaceful conditions, the infrastructure has also been hampered majorly due to depletion of financial resources, disintegration of institutions and a weakened economy. Total official flows for infrastructure development was USD 553 million in 2015[10], majorly funded from bilateral and multilateral agencies.

1.1.1.2. Bangladesh

General Overview:

Bangladesh has a population of about 160 million, growing at an annual rate of about 1.3% over the last five years. As of 2016, with an area of about 147 thousand sq. km., the population density of Bangladesh is 1,083 people per sq. km.[13]. More than two-thirds of the population lives in the rural areas with urbanization growing steadily over the last decade[14]. In 2014, the country emitted 167.71 million tonnes of CO_2e of GHG emissions (excluding Land Use Change and Forestry), which was the 2nd lowest among SAARC Member States when compared on a per capita basis. Of these emissions, the transport sector contributed about 5% of total GHG emissions[8].

GDP of Bangladesh grew by 7.1% to USD 221.4 billion in 2016. Inflation dropped from 6.4% in FY 2015 to 5.2% in January 2017 which was supported by domestic output growth, accommodative monetary policy and controlled global commodity prices. A brief country profile has been represented in the Table 2: Overview of General and Macro-Economic Parameters of Bangladesh.

Table 2: Overview of General and Macro-Economic Parameters of Bangladesh

General Parameters	2016[10]	Macro-Economic Parameters	2016[9]
Population, million	159.9	GDP, USD billion	221.4

[12] Afghanistan Transport Sector Master Plan Update (2017–2036), ADB
[13] 2016 Statistical Year Book Bangladesh, Bangladesh Bureau of Statistics, May 2017
[14] Statistical Pocket Book, Bangladesh 2016, Bangladesh Bureau of Statistics, March 2017

Population growth rate, % (2011-16)	1.3		GDP per capita, USD	1,359.0
Total Surface Area, '000 sq. km.	147.6		Current Account Balance, % of GDP	1.7
Population Density, persons per km² of total surface area	1083.1		Debt, % of GDP	35.8
			Inflation, %	5.9

Transportation Sector Overview:

Transport sector contributes up to 15% of CO_2 emissions from energy-related sectors. The majority of this (around 70%) comes from trucks and buses, along with around 20% from cars. Roads are the backbone of Bangladesh's transportation sector, carrying over 80% of national passenger traffic, mostly via privately operated diesel buses. According to the Roads and Highways Department of Bangladesh, the country has about 21,322 km of major roads, of which national and regional highways constitute about 3,813 and 4,247 km respectively in 2016. The road density is about 0.14 km/ sq. km. The estimated number of registered vehicles on the roads of Bangladesh has increased by 11% annually from 2011 to 2,879,708 in 2016[13].

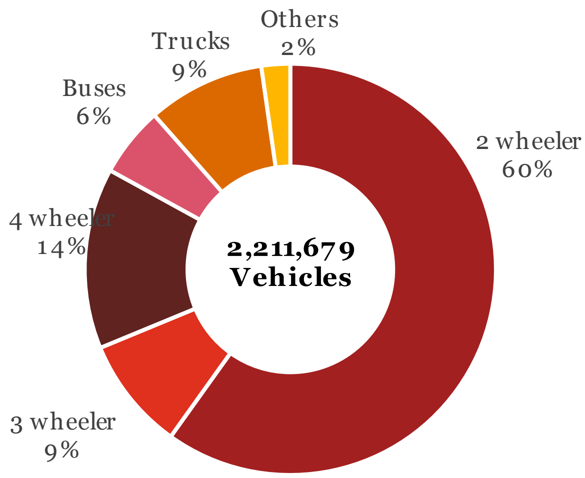

Figure 5: Breakup of total motor vehicles registered in Bangladesh

Bangladesh also has a railway network of 2,877 km. route as of 2016, out of which 23% is broad gauge and the balance being metre gauge. In the year 2014-15, the railway network carried 67 million passengers and 2.5 million tonnes of goods. Aviation infrastructure has been built over the time to meet the rising demands of the country which catered to 2,318,233 passengers in 2016, 78% being international travels majorly to Middle East counties. 97% of the total cargo handled (40,955 million tonnes) also on international routes[13]. Hazrah Shahjalal International Airport is the largest of the three international airports, the other ones being in Chittagong and Sylhet. There are 12 domestic airports, out of which 5 are always operational, 3 need prior approval for air operation and 3 airports are currently not available. A new airport, Khan Jahan Ali Airport in Bagerhat is also under construction[15].

In 2014-15, the water transport operation under Bangladesh Inland Water Transport Authority provided service to 169.16 million passengers and 22.71 million tonnes of cargo through the 6,000 km of navigable waterways. Chittagong and Mongla Ports also play a critical role in shipments from and into the country by handling 5.7 million tonnes of cargo and 3,807 vessels during 2015-16[13].

[15] Airports in Bangladesh, Civil Aviation Authority, Bangladesh

Investment Plan:

There has been a significant rise of ~38% in the budgetary allocations of FY 2017 -18 towards the transportation sector with a plan to invest USD ~590 million with road transport and highway s division getting the highest chunk (41%) followed up by the railways (33%). These funds are expected to be invested for upgrading regional and national highways, expanding the railway networks[16].

1.1.1.3. Bhutan

General Overview:

With a population of only 0.77 million, Bhutan is the second smallest country in the SAARC region. Spread in an area of about 38,394 sq. km., Bhutan has a population of about 20 persons per sq. km. with 39% of the citizens residing in the urban areas[17].In 2014, the country emitted 1.53 million tonnes of CO_2e of GHG emissions (excluding Land Use Change and Forestry). Though GHG emissions per GDP (PPP) are at lower levels when compared with other SAARC Member States (267.02 tonnes of CO_2e/million USD), the per capita emissions are quite high at 1.97 tonnes CO_2e[8].

Bhutan had attained a 6.8% GDP growth in 2016, resulting to a USD 2.2 billion economy. The same can be attributable to good agricultural harvest, ongoing investments in the hydro power sector and support from service sector. Though the debt levels of the country look alarming at 102% of the GDP, a latest debt sustainability analysis conducted in 2016 concluded that the moderate risk, as very much of the external debt is for the hydropower projects as loans from India. A brief country profile has been represented in Table 3.

Table 3: Overview of General and Macro-Economic Parameters of Bhutan

General Parameters	2016[10]
Population, million	0.77
Population growth rate, % (2011-16)	1.6
Total Surface Area, '000 sq. km.	38.4
Population Density, persons per km² of total surface area	20.0

Macro-Economic Parameters	2016[9]
GDP, USD billion	2.2
GDP per capita, USD	2,891.0
Current Account Balance, % of GDP	-38.8
Debt, % of GDP	102.1
Inflation, %	3.2

Transportation Sector Overview:

Bhutan currently has no railways or waterways, and hence roadways is almost exclusively the method of transportation in the landlocked country, stimulating growth and supporting domestic and international trade. As of December 2015, there were 75,190 registered vehicles in Bhutan, 8%

[16] Bangladesh on Development Highway: The Time is Ours, Budget Speech FY 2017-18, Ministry of Finance, Government of the People's Republic of Bangladesh, June 1, 2017
[17] Urban population (% of total), World Bank Open Data

of which were government owned. Since privatization of the passenger transport services from Bhutan Government Transport Service (BGTS) in 1985, 21 operators are managing a fleet of more than 100 buses on 73 routes[18]. As of June 2016, the country had about 2560 km length of national highways and about 11,177 km of total roadways[19], with a road density of 0.3 km/sq.km of total surface area.

Paro International Airport is currently the country's only international airport, located approximately 50 km from Thimphu. With the recent infrastructure augmentation, the airport has a capacity to handle 800,000 passengers per annum. Druk Air, the national airline held by the government and Tashi Air Pvt. Ltd. and also Bhutan's first private airline, plays a crucial role by carrying 298,188 passengers in 2015 on domestic and international routes[18][19].

Investment Plan:

As per the national budget for FY 2017-18, a sum of USD ~117 million (12% of the total allocation for the year with an increase of 36% over previous year) is apportioned for the development and maintenance of road sector which includes enhancing road connectivity, ensuring reliability and commuter's safety through double-laning of Northern East-west highway and supporting other ongoing contractions[20].

1.1.1.4. India

General Overview:

India, the second most populous country of the world with a population of about 1.29 billion, is growing at a rate of about 1.26% over the last five years. With an area of about 3.3 million sq. km., the population density of India is 395 people per sq. km. In 2014, the country emitted 3,079.81 million tonnes of CO_2e of GHG emissions (excluding Land Use Change and Forestry); highest among the SAARC Member States. The country also has high GHG emissions per GDP (PPP) of 441.63 tonnes of CO_2e/million USD and 2.38 tonnes CO_2e per capita GHG emissions. The transportation sector accounted for 8% of total GHG emissions [8].

India's GDP grew at 7.9% in FY 2015-16, fastest in the last five years, supported by domestic consumption, favourable monsoons and robust investments in various sectors. The central government has met its commitments towards fiscal consolidation and kept the fiscal deficit within its targets of 3.5% of the GDP. A brief country profile has been represented in Table 4:

Table 4: Overview of General and Macro-Economic Parameters of India

General Parameters	2016[10]
Population, million (2016)	1.29

Macro-Economic Parameters	2016[9]
GDP, USD billion	2,448.4

[18] Statistical Yearbook of Bhutan 2016, National Statistics Bureau, September 2016
[19] National Transport Policy of Bhutan 2017, Second Draft
[20] National Budget, FY 2017-18, Ministry of Finance, Bhutan, May 2017

Population growth rate, % (2011-16)	1.3
Total Surface Area, '000 sq. km.	3,287.3
Population Density, persons per km² of total surface area	395.2

GDP per capita, USD	1,847.0
Current Account Balance, % of GDP	-1.0
Debt, % of GDP	69.2
Inflation, %	5.2

Transportation Sector Overview:

India is witnessing rapid urbanization, leading to increase in demand for basic services which includes housing, water, sanitation and transportation services. The total number of registered motor vehicles in India has increased swiftly from 55 million in 2001 to 210 million in 2015, growing at a CAGR of 10%[21]. There has been rapid increase in private vehicle ownership, mainly due to lack of good public transport facilities which can be seen from only 1.5 million buses being registered in India (0.7% of the total registered vehicles).

India has the second largest road network globally, with 5.47 million km of roads as of FY 2016-17. 85.9% of the total passenger traffic and 64.5% of all goods in India are moved through roads. The road network can be divided into three major sub-categories[22]:

National Highways	State Highways	District and Rural Roads
103,933 km (2%)	**161,487 km (3%)**	**5,207,044 km (95%)**

Figure 6: Roads network across India

India also has a BRT network spanning 174 km in length, comprising of 9 corridors as of 2015 and carried a total of 340,122 passengers per day. The Ahmedabad BRT, the longest Indian BRT corridor, carries almost 40% of the total traffic across all BRTs in India. While all other BRTs in India have 1 corridor each, the Pune-Primpi-Chinchwad has 3 corridors.

Table 5: Passenger Distribution of BRTs in India (2015)

Cities	Passengers per Day	Length (km)	Number of Corridors
Ahmedabad	130,000	82	1
Bhopal	70,000	24	1
Pune - Primpi-Chinchwad	67,000	29	3
Indore	45,500	11	1
Surat	13,500	10	1

[21] Statistical Year Book India, 2017
[22] Roads Sector Overview - June 2017, Indian Brand Equity Foundation

Rajkot	7,500	11	1
Jaipur	6,622	7	1
Total	**340,122**	**174**	-

Apart from roadways, railways and airways play an important role in mass transit in India. Indian Railway has 13,313 passenger trains running daily carrying 8.10 billion passengers per annum. Further, it is estimated to have carried 1.1 billion tonnes of freight in FY 2016. The rail network is spread across 7,216 stations with a total of 66,687 route km[23]. Also, with expanding urban areas of the country, metro systems have become crucial and multiple projects are under construction besides the eight operational metro systems.

The airways mode of transportation is been pivoted on 133 airports in India, which includes 24 international airports. Air passenger traffic, both domestic and international has grown to 134.98 million passengers per annum, witnessing a CAGR of 10.1% during the last decade. Approximately 26.28 lakh MT of freight traffic is also handled in the domestic and international routes[24]. India also has a vast waterways infrastructure of 12 major ports and 200 non-major ports located strategically on world shipping routes. Cargo traffic is estimated to increase by ~64% to 1758.3 MMT being handled at all the ports[25].

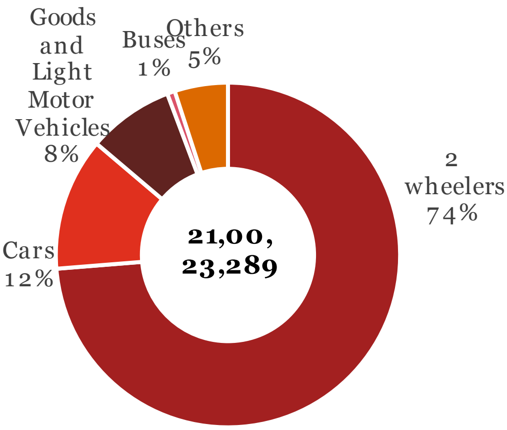

Figure 7: Breakup of total motor vehicles registered in India (2015)

Investment Plan:

A provision of USD 37 billion has been made towards the transportation sector for FY 2017-18. Major focus area of the investments lies in the railways sector with 55% of the total allocation which would lead to commissioning of 3,500 km of railway lines and re-development of at least 25 stations. The road sector has also been allocated about USD 10 billion, 12% more funds when compared to that of last year with major investment in construction of 2,000 km of coastal connectivity roads[26].

1.1.1.5. Maldives

General Overview:

Maldives, the land of Thousand Islands has a population of approx. 480,000; which is the smallest amongst the SAARC Member States, both in terms of population and area. With an area of about 300 sq. km., Maldives has the highest population density of 1,610 people per sq. km. In 2014, the

[23] Indian Railways Statistical Publications 2015-16, Ministry of Railways
[24] Handbook on Civil Aviation Statistics, 2015-16
[25] Ports Sector Overview - June 2017, Indian Brand Equity Foundation
[26] Key Features of Union Budget - 2017-2018, Ministry of Finance

country emitted 1.42 million tonnes of CO_2e of GHG emissions (excluding Land Use Change and Forestry); lowest among the SAARC Member States. However, it has the highest per capita emissions among the countries (3.55 tonnes CO_2e per capita) [8].

GDP growth rate of Maldives rebounded from 2.8% in 2015 to 4.1% in 2016, majorly due to large investment projects being implemented in various areas since 2014. The tourism sector has taken a hit because of the economic slowdown across key countries. Inflation numbers have been under check primarily due to low global food and fuel prices, as most of the products consumed are imported. A brief country profile has been represented in Table 6

Table 6: Overview of General and Macro-Economic Parameters of Maldives

General Parameters	2016[10]
Population, million (2016)	0.48
Population growth rate, % (2011-16)	3.5
Total Surface Area, '000 sq. km.	0.3
Population Density, persons per km2 of total surface area	1609.5

Macro-Economic Parameters	2016[9]
GDP, USD billion	3.6
GDP per capita, USD	8,620.0
Current Account Balance, % of GDP	-25.7
Debt, % of GDP	69.5
Inflation, %	0.5

Transportation Sector Overview:

Due to the Maldives' geographic setup, cost of transportation is higher due to lack of economies of scale and limited economic activities in many remote areas. Maritime transport holds the key to sustain the economic activities in the country with aviation sector gradually picking up. However, 4.8 million passengers travelled through Male' International Airport in 2015 which had 23,488 international flights managing the growing traffic. Majority of international trade occurs at the commercial port at Malé Commercial Harbor (MCH) which can accommodate ships up to 15,000 gross tonnes (GT) and has a capacity of handling 54,000 TEUs in 2012. About 97% of the freight volume is contributed by imports. Sea Transports for the citizens are taken care by 151 yacht Dhoni, 2,794 launches and 600 boats.

Land transport is majorly limited, with Maldives having 71,796 number of cars, motor cycles and auto cycles put together in 2016. As per the Key Indicators for Asia and the Pacific 2016, Transport Sector, ADB, only 140 buses were plying in 2013[27].

Investment Plan:

The Ministry of Finance and Treasury, Maldives intends to incur capital expenditure of USD ~527 million in three years from 2017 to 2019 towards transportation sector. The planned expenditure would be 18-19% of the total investments envisaged by the government. Approx. USD 40 million

[27] Statistical Pocketbook of Maldives - 2016, National Bureau of Statistics, Ministry of Finance & Treasury

has been allocated for land reclamation and road construction in 2017 which includes completion of existing projects and road development in 19 islands[28].

1.1.1.6. Nepal

General Overview:

Nepal has a population of 28.33 million with a total area of about 147,180 sq. km. which makes its population density at 192.5 people per sq. km. In 2014, the country emitted 37.52 million tonnes of CO_2e of GHG emissions (excluding Land Use Change and Forestry). However, the GHG emissions per GDP (PPP Basis) stand at 584.57 tonnes CO_2e per million USD which is the highest among SAARC Member States[8]. The transportation sector contributed to 7% of the total GHG emissions.

GDP growth of the country has further dropped down to 0.6% in FY 2015-16 due complete disruption of cross border trade with India. However, the growth rates are expected to rebound strongly, supported by increased agricultural output and greater investments as the country recuperates from the earthquake destructions. A brief country profile has been represented in Table 7.

Table 7: Overview of General and Macro-Economic Parameters of Nepal

General Parameters	2016[10]
Population, million (2016)	28.3
Population growth rate, % (2011-16)	1.3
Total Surface Area, '000 sq. km.	147.2
Population Density, persons per km² of total surface area	192.5

Macro-Economic Parameters	2016[9]
GDP, USD billion	21.2
GDP per capita, USD	736.0
Current Account Balance, % of GDP	6.2
Debt, % of GDP	27.9
Inflation, %	9.9

Transportation Sector Overview:

90% of passengers and goods are transported through roadways. Lack of effective connectivity had led to increased transport costs. In a study by Department of Road (2012), it was concluded that the country has an accessibility of about 77.5% in hills and 98% in Terai with an overall accessibility of 88% of population.

The country has a road network which spans across 87,157 km (in FY 2016-17) developed by the Department of Road and Local Bodies which include local level programs for rural reconstruction and rehabilitation. The urban road network in the country is of 368 km. All district headquarters, except Humla and Dopla are connected. A total of 2,602,986 vehicles have been registered till first eight months of FY 2016-17, showcasing a CAGR growth of 13.7% over the last five years. Over 85% of registrations are majorly towards motorcycles used for private consumption, and only 2% of

[28] Government Budget in Statistics, FY 2017, Ministry of Finance and Treasury, Maldives

buses run across the roads network[29]. A detailed breakup of the registered vehicles has been depicted below:

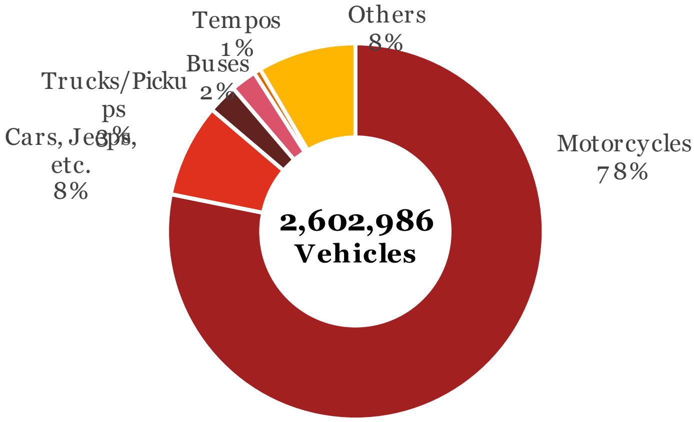

Figure 8: Breakup of total motor vehicles registered in Nepal

Additionally, 33 airports are operational in the country along with 25 airlines. In FY 2015, 266,950 passengers travelled on domestic and international routes; and 927 tonnes of cargo was being handled[29].

Investment Plan:

In order to improve connectivity across the province capitals and the nation capital, expand socio-economic activities across these areas and improve the quality of roads infrastructure, USD 868 million has been allocated for the current fiscal year. Overall expenditures on the transport sector is estimated to be at USD 1148 million which is ~9% of the total planned expenditure[30].

1.1.1.7. Pakistan

General Overview:

Pakistan is the sixth most populous country of the world with a population of about 195.4 million people, growing at a rate of about 2%. With an area of about 796 thousand sq. km., the population density of Pakistan is 245 people per sq. km. The country is facing rapid urbanization due to improvement in social, economic and demographic factors[10]. The share of urban population has increased from 37% in 2010 to 39% in 2016[31]. In 2014, the country emitted 333.38 million tonnes of CO_2e of GHG emissions (excluding Land Use Change and Forestry); second-highest among the SAARC Member States which translates into per capita emissions of 1.80 tonnes CO_2e per capita. Transportation sector accounted for 12% of total GHG emissions[8].

Growth prospects for the country continue to improve as the GDP grew at 4.7% in FY 2016 to USD 284 billion. Agricultural and industrial outputs have started improving which has been supported by construction of the China Pakistan Economic Corridor (CPEC) projects. Country risk has also

[29] Economic Survey, FY 2016-17, Ministry of Finance, Government of Nepal
[30] Budget Speech of FY 2017-18, Ministry of Finance, Government of Nepal, May 29, 2017
[31] Urban population (% of total), World Bank Open Data

improved as Standard and Poor's raised its rating to B[32] in October 2016. Inflation indicators are estimated to be contained in upcoming years however, trade deficit is expected to be strained by modest growth in exports and increase in imports to support the growing economic activities[9]. A brief country profile has been represented in the Table 8.

Table 8: Overview of General and Macro-Economic Parameters of Pakistan

General Parameters	2016[10]
Population, million (2016)	195.4
Population growth rate, % (2011-16)	2.0
Total Surface Area, '000 sq. km.	796.1
Population Density, persons per km2 of total surface area	245.5

Macro-Economic Parameters	2016[9]
GDP, USD billion	284.0
GDP per capita, USD	1473.0
Current Account Balance, % of GDP	-1.1
Debt, % of GDP	67.4
Inflation, %	2.9

Transportation Sector Overview:

Transportation sector becomes critical for the economy of Pakistan contributing ~10 per cent of the GDP and over 17 per cent of the Gross Capital Formation. The total road network is about 264,401 km, including national highways, motorways, expressway and strategic routes. The country also has two BRT corridors in Lahore and another in Islamabad-Rawalpindi. They are 27 and 23 km. in length respectively. The Lahore BRT is busier and, in 2015, carried about 180,000 passengers per day. The Islamabad-Rawalpindi carried about 125,000 passengers per day[33]. 17,715,428 motor vehicles are estimated to be registered by 2015 road vehicles, of which only 2.2% are buses, taxis and metro-cabs used majorly for mass transportation[34]. Detailed breakup of the registered vehicles has been depicted below:

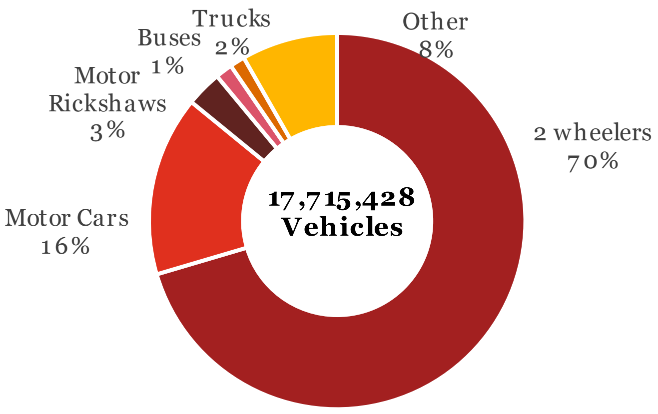

Figure 9: Breakup of total motor vehicles registered in Pakistan

[32] Standard and Poor's rates countries on a scale from AAA to D, evaluating the creditworthiness of the issuer (country or govt.) of debt. This generally determines whether the issuer would pay its debt obligations.

[33] Website of BRTdata.org

[34] Pakistan Statistical Yearbook -2015, Pakistan Bureau of Statistics

Pakistan railways have a 7,791 km route length as of FY 2015-16, which has been constant over a decade. 52.19 million Passengers travelled in FY 2015-16, showcasing a drop of 1.4% over the previous year. The total freight handled in FY 2015-16 grew more than three time in two years to 5 million tonnes, majorly driven by transportation of public goods[34]. Civil Aviation also plays a crucial role carrying 19.64 million passengers in FY 2015-16, 65% of which were for international travel. Further, 338,467 tonnes of cargo was being handled across 31 airports[35].

Investment Plan:

Infrastructure expenditures have been allocated with 67% of the total development outlay in FY 2017-18 budget of Government of Pakistan. Highest priority has been given to transport and communication sector, with an allocation of USD 3.92 billion comprising of USD 3.05 billion (~78%) for national highways, followed by USD 0.41 billion for railways and USD 0.42 billion for other projects including aviation schemes[36].

1.1.1.8. Sri Lanka

General Overview:

Sri Lanka has a population of about 21.2 million, growing at a rate of about 0.96% and has an urban population of 18.4%[37]. With an area of about 65,610 sq. km., the population density of Sri Lanka is 323.17 people per sq. km. In 2014, the country emitted 40.75 million tonnes of CO_2e of GHG emissions (excluding Land Use Change and Forestry); and had emitted the lowest GHG emissions per GDP (PPP basis) among the SAARC Member States at 184.22 tonnes of CO_2e/million USD GDP[8]. Transportation sector accounted for almost one-fifth of total GHG emissions.

The real GDP growth of Sri Lanka slowed to 4.4% reflecting the impact of floods and drought cycles faced by the country, despite being supported by policy measures towards fiscal consolidation and monetary tightening, along with the backdrop of the IMF Program. In November 2016, the first review of the funding (about USD 1.5 billion) was completed, allowing the disbursement of the second tranche. Fiscal deficit is estimated to fall to 5% in 2017 from 6.1% in 2016, due to implementation of revenue measures through changes in the VAT act increasing collections, in addition to the controlled expenditure and low oil prices. A brief country profile has been represented in the Table 9.

Table 9: Overview of General and Macro-Economic Parameters of Sri Lanka

General Parameters	2016[10]
Population, million (2016)	21.2
Population growth rate, % (2011-16)	1.0
Total Surface Area, '000 sq. km.	65.6

Macro-Economic Parameters	2016[9]
GDP, USD billion	80.6
GDP per capita, USD	3,824.0
Current Account Balance, % of GDP	-3.0

[35] Major Traffic Flows by Airports During The Year, Pakistan Civil Aviation Authority, September 22, 2016
[36] Budget speech, FY 2017-18, Ministry of Finance, Government of Pakistan
[37] Urban population (% of total), World Bank Open Data

Population Density, persons per km² of total surface area	323.2		Debt, % of GDP	79.1
			Inflation, %	4.0

Transportation Sector Overview:

The transportation sector contributed 10% of the country's GDP and generated about 4% of employment[38]. However, it is also responsible for a large majority of the country's greenhouse gas (GHG) emissions - almost half of the total emissions in the energy sector are from transportation. Sri Lanka depends heavily on its public transportation system with buses and trains forming the backbone of the system as over 70% of the traffic are served through national roads.

As of 2016, there are about 31,262 km of roadways in the country on which 4,737,314 motor vehicles with valid registrations commute. Sri Lanka Transport Board operates 5,314 buses daily, resulting in to 16,143 million passenger km across the year. Further, there are 17,131 buses being operated by private owners.

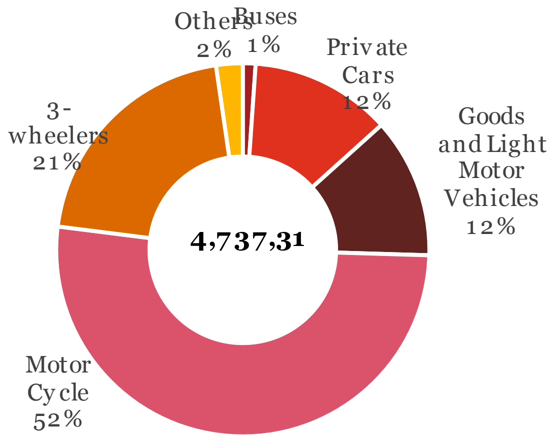

Figure 10: Breakup of Registered Motor Vehicles in Sri Lanka

Sri Lanka has about 1,562 km of railway track, in form of board gauge along with 336 stations supporting 136 million passenger journeys and handling 2.0 million tonnes goods in 2016. Sri Lanka also has 3 international airports (2 in Colombo itself) and 14 domestic airports. It has only 1 non-military airport. 4.5 million passengers and 102,734 tonnes of cargo are being transported by the airline industry. Sea Transport handles bulk of freight (import/export) through ports in Colombo, Trincomalee and Galle. However, waterways facilitate very little or no movement within Sri Lanka. As of 2016, 4,998 vessels had arrived in the ports and 51.8 million tonnes of cargo was discharged[39].

Investment Plan:

Sri Lanka plans to address the transport issues in the Western Province of the country through a Megapolis plan, developing expressways to connect various parts of the country and by building modernized railway systems. USD 6 billion is estimated to be invested in development of 2 such expressways - Central Expressway and the Ruwanpura Expressway. Further, approx. USD 31 million is being proposed to be invested in upgradation of railway network, modernization of ports for inland transport and conversion of three wheelers to electric cars[40].

[38] World Bank Analysis, 2015
[39] Economic and Social Statistics of Sri Lanka – 2017, Central Bank of Sri Lanka
[40] Budget Speech 2017, Ministry of Finance, Sri Lanka

1.1.2. Overview of Electric Road Mass Transportation in South Asia

Electric Road Mass Transportation refers to those modes of mass transport (vehicles that have greater carrying capacity than privately owned vehicles) which use road as the medium of travel and are completely or partially powered by electricity, either directly or through stored electricity. Based on this understanding, the scope of the study is limited to buses which are powered by electricity or electric batteries, completely or partially.

Across the SAARC Member states, attempts have been made by various countries to spurt the growth of electric vehicles in their respective nations. These attempts have had diversified approaches and some have achieved measurable results. For example, while the policies in Kingdom of Bhutan have been focused on promoting electric vehicles for private use, India is currently focusing on promotion of electric vehicles which are used for mass transportation. However, due to lack of proper charging infrastructure across all countries, electric vehicles have not been able to gain much traction. In this section, an overview of the policies and programmes running in the SAARC Member States has been provided.

Almost, all countries have set challenging targets under the INDC commitments made after the Paris Agreement which was adopted on 12 December 2015 at the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris, and using ERMT will assist them in meeting those targets[41]. Brief outlines of the INDC set by the SAARC Member States have been mentioned below[42].

Afghanistan	Aims to cut emissions by **13.6%** from business-as-usual levels by 2030, conditional on international support, and reduce vulnerability to climate impacts. Estimated cost USD 17.4 billion
Bangladesh	Plans to cut GHG emissions by **5%** by 2030 compared with business-as-usual levels in the power, transport and industry sectors; raising it to 15%, conditional on international support.
Bhutan	Bhutan Plans to **remain carbon neutral** as set out in 2009. Repeats commitment to keep 60% of territory forested.
India	Aims to cut GHG emissions by **33% - 35%** of the 2005 levels by 2030. Targets 40% of electricity from non-fossil fuel sources by that date. Estimated cost USD 2.5 trillion.
Maldives	Aims for **10%** emission cuts from business-as-usual levels by 2030, raising to 24% with international support.
Nepal	Aims to reduce dependency on fossil fuels by **50%** by 2050 and achieve 80% electrification through renewable energy sources. Plans to maintain 40% of the total area under forest cover.
Pakistan	Intends to reduce up to **20%** of its 2030 projected GHG emissions subject to availability of international grants. Estimated to about USD 40 billion.
Sri Lanka	Aims for a reduction in GHG emissions of **7%** from business-as-usual levels by 2030, or up to 23% with international support. Estimated cost USD 420 million.

Figure 11: INDC Commitments of SAARC Member States

[41] Paris Agreement - Status of Ratification, United Nations Framework Convention on Climate Change
[42] INDCs as communicated by Parties, United Nations Framework Convention on Climate Change

1.1.2.1. Afghanistan

While currently there is no traction for electric vehicles in Afghanistan, the nation can emerge as users of the same in the future. This is primarily due to the fact that Afghanistan has large lithium reserves worth USD 1 trillion[43], which can help in keeping down the cost of battery manufacturing, which in turn constitutes a significant portion of the overall cost of electric vehicles.

Presently, there is no policy released by the government to establish or promote use of electric vehicles in the country. However, the 2030 Contribution Plan in INDC Targets mentions transport as a key sector with focus on more efficient vehicles, clean fuels, and alternative fuels.

1.1.2.2. Bangladesh

Bangladesh too does not have much traction for electric vehicles. The country did see a surge in demand for low cost electric tuk-tuks (local name for auto-rickshaws), however, the government had to curb their usage, primarily due to widespread electricity theft caused by owners/operators of these tuk-tuks. Recently on April 27, 2017, China Shanghai Technology has offered to supply 4,000 electric buses for Dhaka city to ease out the growing traffic snarl and replace the old buses. The proposal is being currently mulled over by the government[44][45].

While there is no policy to promote or incentivize purchase of electric vehicles or buses, the government does have a Bangladesh Climate Change Strategy and Action Plan (BCCSAP). Specific actions proposed under this plan include the following:

- Promotion of low cost public transport modes such as rapid transit;
- Reduction the use of fossil fuels by improving the efficiency of energy usage;
- Review of political, institutional and fiscal planning; and
- Substitution of biofuels, fossil fuels as appropriate.

The Government of Bangladesh under the National Sustainable Development Strategy has set goals of setting up bus rapid transit systems. The government also has the Integrated Multi-modal Transport Policy agreed in 2013, which aims to create a transport system that is "safe, efficient, clean and fair by favoring greener, cleaner vehicles along with better public transport". The National Land Transport Policy which was established in 2004 also commits to reducing GHG emissions.

1.1.2.3. Bhutan

The electric vehicle story began in 2014 with the Government of Bhutan and Mahindra & Mahindra, an Indian automobile manufacturing company, signing a Memorandum of Understanding for strategic partnership to promote use of electric vehicles in Bhutan[46]. During the same year, a pilot project was also initiated together with Renault-Nissan introducing the Nissan Leaf EV in the

[43] 'U.S. Identifies Vast Mineral Riches in Afghanistan', The New York Times, Article published on 13 June 2010
[44] 'China offers 4,000 electric buses for Dhaka', Banglanews24, Article published on 27 April 2017
[45] 'Dhaka eyes transport reform with electric buses', dailyobserverbd, Article published on 30 April 2017
[46] Press release, Mahindra

capital city of Thimphu[47]. Further, Gross National Happiness Commission, Royal Government of Bhutan, in its 11th Five Year Plan had mentioned that 'Promotion of electric vehicles will be pursued to address environmental issues and reduce dependency on fossil fuel'.

However, Bhutan has had limited success in implementation of government's plan to promote electric vehicles. The capital city of Thimphu has 91 privately and government owned electric vehicles. The number is better in context when analyzed with the fact that the total car stock of Bhutan is only about 75,000[18]. The government provides direct subsidy to reduce the cost of electric vehicles. However, the lack of investment in the charging infrastructure has decreased the viability of owning an electric vehicle.

The second draft of the National Transport Policy 2017 recognizes the importance of electric vehicles in reduction of emissions and hence, outlines key objectives and plans to be set up by the Kingdom of Bhutan.

Table 10: Key objectives outlined in the second draft of the National Transport Policy, 2017

Objective	Key Policy Statements
Systematically reduce pollution from vehicles	• Differential taxes on vehicles, subsidies on electric vehicles will be continued to promote use of fuel-efficient vehicles. • Endeavor to improve the supporting infrastructure for electric vehicles such as development of charging stations to create an enabling environment for its effective use.
Support Sustainable Aviation	• Options of low emissions vehicles and electric vehicles to be considered as Ground handling vehicles in airports.

1.1.2.4. India

India currently has the highest number of electric vehicles among the SAARC Member States with an electric vehicle market share of 0.02% in the cars segment, led by a stock of about 4,800 electric cars[48]. The Indian Government has been making continuous efforts to promote use of e-vehicles in India. **A target of at least 6 million electric vehicles on its roads by 2020 and not a single petrol/diesel car to be sold in the country by 2030 has been set.**

In 2011, Government of India had unveiled the National Electric Mobility Mission Plan (NEMMP) 2020 to accelerate the growth of electric vehicles by focusing primarily on fast-tracking the manufacturing. Further, the Department of Heavy

Table 11: Components under the FAME Scheme

Components	FY 2015-16 (Million USD)	FY 2016-17 (Million USD)
Technology Platform	10.50	18.00
Demand Incentives	23.25	51.00
Charging Infrastructure	1.50	3.00
Pilot Projects	3.00	7.50
IEC/Operations	0.75	0.75
Total	**39.00**	**80.25**

47 e-Mobility as the Next Generation Solutions for Clean Air and Sustainable Transport in Asia, United Nations Centre For Regional Development, 23 December 2014
48 Global EV Outlook 2017, International Energy Agency (IEA)

Industries (DHI) had launched FAME (Faster Adaptation and Manufacturing of (Hybrid &) Electric Vehicles) in April 2015 to promote electric and hybrid vehicles in India by providing incentives to develop technology platforms and charging infrastructure along with subsidies on the demand side. Components and outlay under the FAME scheme have been outlined[49]. The scheme has been getting extensions and under the current scheme, Fully Electric Bus are eligible for up to 60% of purchase cost or INR 1 crore (approx. USD 150,000[50]), whichever is lower [51]. This would be applicable in case of localization of minimum 35% being achieved; else the amount reduces to INR 85 lakhs (approx. USD 129,000[50]) with 15% localization.

Incentive amount will be decided based on the supply order issued by the purchaser. The purchaser has to finalize supply after following due tendering process. Incentive amount will be disbursed in three equal installments to be paid in three years. First installment will be released after conclusion of supply order/contract. Incentive shall be disbursed either to a purchaser or to a supplier or manufacturer based on their mutual consent. An additional financial assistance shall be provided towards purchase of charging equipment up to 10% of total eligible demand incentive for purchase of fleet of EV buses as per the contract agreement between purchaser and OEM/manufacturer/Supplier to State Transport Undertakings/Municipal Corporations.

In May 2017, the National Institution for Transforming India (also known as NITI Aayog) had come up with probable ideas to make India's passenger mobility shared, electric, and connected, envisaging curtailment of its energy demand by 64% and reduction of carbon emissions by 37%[52]. The government is planning to bring in more types of direct and indirect benefits for EV users which are likely to be announced before then end of this fiscal year under a comprehensive policy. The government has also been focusing on creating a demand for EVs for its different transportation needs. Government agencies like EESL are procuring EVs on a mass scale thus attaining benefits of economies of scale. Their latest tender was for procurement of 10,000 EVs[53].

Recently, DHI has also released a draft 'Standardization of protocol for Charging Infrastructure' (Bharat EV Charger Specifications) in order to facilitate common specifications and standards for all categories of vehicles ensuring seamlessly growth in adoption across the country[54].

Ministry of Urban Development has also introduced a new scheme under consideration, the Green Urban Transport Scheme (GUTS) for enabling a shift towards electric vehicles for public transport and use of non-fossil fuel for powering vehicles[55]. The Scheme is expected to focus on growth of urban transport in a manner that allows for substantial and measurable reduction in pollution while providing a permanent and sustainable framework for funding Urban Transport Mobility

[49] Hybrid and Electric Vehicles in India, The International Council On Clean Transportation, December 2016
[50] Approximated at USD 1 = INR 66
[51] The Gazette of India: Extraordinary Part – II, Section 3, September 12, 2017
[52] India Leaps Ahead: Transformative Mobility Solutions For All, Niti Aayog, May 2017
[53] 'EESL to procure 10,000 electric vehicles from Tata Motors', The Hindu Business Line, Article published on September 29, 2017
[54] Standardization of protocol for charging infrastructure - Committee Report on Standardization of Public EV Chargers, Ministry of Heavy Industries and Public Enterprises, May 15, 2017
[55] Ministry of Urban Development, Government of India Press Release on November 8, 2016

Projects. The Scheme will target state capitals and cities with population of 5 lakhs and above. Expenditure of about USD 3.7 billion over the next five years has been estimated from the central government.

Some transit authorities in India have already started the procedure for procuring electric and hybrid buses.

Table 12: Procurement Plans of Transport Authorities in India

Transit Agency	ERMT Action
Navi Mumbai Municipal Transport (NMMT)	NMMT has placed an order with Volvo to procure 5 hybrid city bus. Being compliant with the central government's FAME scheme it received a subsidy of USD 100,000 on the total cost of USD 375,000.
Mumbai Metropolitan Region Development Authority (MMRDA)	MMRDA has launched a fleet of 25 hybrid buses, procured from Tata Motors. Tata Starbus Diesel Series Hybrid Electric Bus can run without the requirement of external charging infrastructures, due to integration of on-board charging.
Himachal Road Transport Corporation (HRTC)	HRTC has recently started operations of electric bus on Kullu-Manali-Rohtang pass. This was done after receiving sanction from DHI to procure full electric busses, manufactured by Goldstone Infra and BYD. The corporation had conducted trials of mini electric buses in Kullu-Manali-Rohtang pass and was quite convinced with the technology at such high altitude of 13,000 ft.
Bangalore Metropolitan Transport Corporation (BMTC)	BMTC has submitted a proposal with DHI to procure 150 electric buses on PPP model. It has proposed to set up an exclusive depot for the electric buses with the required infrastructure consisting of battery rechargeable points and workshops.
Thane Municipal Transport (TMT)	TMT has approved the plan to introduce 100 electric buses on PPP model. The private operator will purchase and operate these buses for 10 years on selected routes. The operator will have the first right to select the routes
BEST Mumbai	BEST has placed an order for retro-fitment with AV Motors and Impact Automotive Solutions Limited with a grant of INR 100 million (USD 1.5 million) from the city Municipal Corporation (BMC).

It is to be noted that adoption of electric and hybrid buses has been slow in India, mainly due to the initial capital outlay which is higher than the diesel buses. The average cost of hybrid or electric buses is 3-4 times higher than diesel buses. Further, with the decrease in the cost of diesel, there is not much incentive for the operators to shift to hybrid or electric buses. Some cities, like Delhi and Mumbai, are using clean fuel like CNG for the bus operations, which in turn brings down the operating costs. However, the government has realized that this is the ideal time to focus on ERMT. There is need to increase the supply of buses in Indian cities to develop sustainable public transport.

With initiatives like "Smart Cities", the cities are having a larger vision to curb dependence on fossil fuel and reduce CO_2 emissions. Since most of the cities are in the planning phase of becoming smart cities and are redesigning themselves to meet the future energy and transportation needs, it is the right time that public transport vehicles shift their source of power from diesel to electricity. This will ensure that the provisions required for such transport like cabling, charging stations etc. be included in the planning process.

1.1.2.5. Maldives

Maldives Climate Change Policy Framework describes the country's intent of Low Emission Development and to achieve a balanced shift towards environmentally friendly transport modes to bring about a sustainable transport and mobility system.

Since 2011, there is no import duty on electric vehicles as compared to 200% import duty being levied on cars running on petrol or diesel to promote cleaner modes of transportation. However, there is no clear policy or initiatives towards electric vehicles adoption in the country[56].

1.1.2.6. Nepal

In 1975, Nepal witnessed the use of electricity for transportation, since the Government of China first supported a 13 km long Trolley Bus System[47]. However, in 2009, the government had concluded on the trolley bus operation to be economically unviable and had shut it down. Further, the country has had good success with electric rickshaws, with regions like Bharatpur sub-metropolis having over 300 e-rickshaws[57]. Mahindra e20, imported from India, has found few buyers given the lower operating costs. Though Nepal has been giving subsidies for electric vehicles since 1999, lack of charging infrastructure has served as a strong deterrent for the prospective electric vehicle buyers.

In the 2016/17 budget, the government passed the first major progressive EV tax reforms with reduction of custom duty to 10% for private, and 1% for public electric vehicles (from existing 40%). No excise duty on import of all types of large electric vehicles used for public transportation was also continued. As per a study done by the Electric Vehicles Association of Nepal (EVAN), currently, 300 electric cars and 2,000 electric scooters are running in the country and a capacity of 350 electric three wheelers and 200 buses in primary and secondary routes of Kathmandu valley is feasible. The Kathmandu Metropolitan City has also been planning to procure electric buses on a pilot basis. Further, the country plans to increase the share of electric vehicles up to 20% by 2020 and promote transformation to environment friendly modes of transportation; as suggested in its INDC commitments made after the Paris Agreement adopted on 12 December 2015 at the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC).

Sustainable development has been discussed as a key focus area for infrastructure development by the Ministry of Finance, in the budget speech of FY 2017-18 with an emphasis on electric vehicles. However, no new plans or policies were being introduced recently.

[56] 'Climate Change Legislation In Maldives, An excerpt from the 2015 Global Climate Legislation Study
[57] 'E-rickshaw gaining popularity in Chitwan', The Himalayan Express, Article published on October 29, 2015

Trolley Buses of Nepal[58]

The trolley bus system setup in the capital city of Kathmandu was the first and the only trolley bus system built in Nepal. The 13 km. stretch of trolley bus was funded by China, in 1975, through a gift of approx. 40 million Nepalese Rupee (approx. 3.3 million USD)[59]. It connected satellite towns of Madhyapur Thimi and Bhaktapur to east of Kathmandu. China had provided 22 trolleybuses and the service became operational on December 28, 1975. In 1997, 10 additional vehicles were also provided. The trolley system was operated by a government run agency named Nepal Trolley Bus Service which was a branch of Nepal Transportation Corporation (NTC).

NTC failed to make any profits since 1990 and was ultimately dissolved as on 15 December, 2001. After 18 months of no operation, the municipalities of Kathmandu, Madhyapur Thimi and Bhaktapur reached an agreement to jointly support the trolley system. The revived system was operated by Kathmandu Metropolitan City since September 2003.

Within a year, Madhyapur Thimi and Bhaktapur municipalities backed out of agreement as the operations of trolley system was costing them up to 2 million Nepali Rupees (approx. 28,500 USD)[60] per month. The operations of the line were cut and limited to only a 5 km section within Kathmandu.

As of 2007, there were a total of 32 trolleybuses. Out of these, 22 were Shanghai SK541 models (left hand operation) delivered in 1974. The rest were Shenfeng SY D60C models (right side operation) delivered in 1997. By 2007, only 4-5 trolleybuses were in operable state, all of which were SK541 model. Of these only 3 vehicles were operated on any given day. SY D60C models were not operated due to the high maintenance cost requirements. These vehicles operated on 5 km. long line in every 20-25 minutes with a journey time 25-35 minutes between the two ends of the track.

Due to continuous losses and heavy debt, trolleybus operations were suspended in November 2008. Finally, in November 2009, Kathmandu Metropolitan City permanently shut down the trolleybus operation due to unprofitability and sold the assets of the organization to private entities.

SAFA Tempos of Nepal

SAFA tempos were first introduced in Nepal in 1993 for mass transportation. SAFA is Nepali word for clean, referring to the no-tailpipe emissions from these vehicles. These currently ply on 17 different routes in Kathmandu.

SAFA autos have twelve deep cycle batteries of 12V each, and can carry up to 12 people (including driver) at a time. The components for SAFA tempos were imported and assembled in Nepal[61]. Given the increasing urban spread, the small size of SAFA vehicles makes them perfect for congested and

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[58] Kathmandu Trolley Bus Network,
[59] Based on exchange rate of 1 NPR = 0.082 USD in 1975, based on 1 NPR = 0.69 INR and 1 INR = 0.12 USD obtained from articles 'Nepal to keep currency pegged to Indian rupee', published in Business Line on May 9, 2017, and 'Journey of Indian rupee since independence', published in the Times of India on August 15, 2013, respectively.
[60] Based on exchange rate of 1 NPR = 0.01428 in 2004 obtained from oanda.com
[61] 'Electric Vehicle in Kathmandu, Nepal', article from energyhimalya.com

narrow roads. However, new SAFA autos are rare and given the government's orders to remove vehicles older than 20 years from roads, these autos might disappear from the streets of Kathmandu in coming years[62].

1.1.2.7. Pakistan

Pakistan in its budget for 2017-18 proposed for incentivizing fully electric vehicles to promote fuel conservation and arrest environmental degradation. The budget also proposed reduction in sales tax on local supply of Hybrid Electric Vehicles. Auto Development Policy 2016-17 also incentivizes fully electric vehicles to promote fuel conservation and arrest environmental degradation. The government needs to bring in further policies aimed at creating an ecosystem for electric vehicles in general and ERMT in particular. This can be in line with the Pakistan Transport Plan Study (PTPS), a comprehensive transportation master plan for Pakistan for the period from 2005 to 2025, which suggests the initiatives required to counter the environmental adverse effects of transport.

Currently, following concessionary rate of customs duty and taxes is applicable on the import of Hybrid Electric Vehicles (HEVs):

Table 13: Exception on Custom Duty for HEVs in Pakistan[63]

Engine Capacity	Custom Duty Exceptions
up to 1800 CC	50% of the total applicable duty and taxes
1801 - 2500 CC	25% concession on total duty and taxes

1.1.2.8. Sri Lanka

Sri Lanka, under its Public Investment Program (2017-2020) plans to introduce bus priority lanes and introduction of low floor buses. Under the NAMA programme, the Sri Lankan Government aims to run electric buses on these Bus Priority Lanes. The government aims to subsidize the cost of transportation modes in Public Investment Program and seeks participation from private sector to modernize its urban transport. Under the first phase of NAMA programme, a pilot project will be carried out with 10 electric buses; owned by the central government and operated by private operators. The main purpose of this phase will be to generate awareness about NAMA and attract private sector participation. The funding for this will be from international climate financing agencies. This phase will have extensive capacity building measures including training the proponents and participants in NAMA, bus operators and on-ground personnel and raising awareness about benefits of using electric bus technology.

In the second phase, 90 buses will be added and all buses will be operated under Galle BRT. The funding for this phase will be the difference between amounts pledged by private operators and the

[62] 'Twenty Years Young', article published by Kathmandu post on June 3, 2017.
[63] Budget Speech 2017-18, Ministry of Finance, Government of Pakistan

total cost for the electric bus. However, a minimum of 30% of the total cost will be required to be covered by operators to be eligible to participate in this phase.

Both phases will provide a year of free charging to all participating private players. The cost of Phase I and Phase II is expected to be USD 10.62 million and USD 93.86 million respectively[64].

Sri Lanka already has a decent charging infrastructure in place comprising of both AC and high voltage quick DC Chargers. This has primarily been due to the relatively high usage of privately owned electric vehicles in Sri Lanka. By October 2015, Sri Lanka had a stock of 2,072 electric vehicles, with Nissan Leaf being the market leader with sales of 2,011 units[65]. The main reason of this success can be attributed to the taxation system. Further, the Lanka Electric Vehicle Association (LEVA) with support provided by the Global Environment Facility (GEF) has introduced an electric minibus to Colombo for passenger transport and taxi services[47].

The Government also plans to change 1.3 million three wheelers due to increased vulnerability towards accidents, by replacing them with electric cars. As an initial step, the government within the Colombo district plans to extend its support by introducing a loan scheme to purchase 1,000 such electric cars, through banks, where the government will bear 50% of the interest cost, towards which an allocation of USD 1.4 million has been proposed[40].

Apart from these interventions, the country's decisions are driven by the National Transport Policy (NTP) 2008 which **encourages the use of public transport**, high occupancy vehicles and non-motorized transport, **reduce dependency on petroleum fuels** for the country's mobility requirements and ensure that at least one-third of existing road space on major highways within a dense urban area be reserved for high occupancy vehicles. Such areas demarcated to be utilized **for high priority bus lanes, light transit systems (trams) or bus rapid transit (BRT) systems**. At the same time, National Action Plan for Haritha Lanka Program 2009, aims to implement mass transit systems such as MRT/LRT (Mass Rapid Transit/Light Rail Transit), BRT including premium bus service & one-way systems with centre-flow bus lanes in metropolitan regions, promoting the use of alternate transport fuel technologies that reduce GHG emissions.

1.1.3. Benefits of Electric Road Mass Transportation

Electric Road Mass Transportation (EMRT) comes with its own set of advantages and disadvantages. In this section, the advantages and disadvantages of ERMT has been analyzed and the unique set of challenges that the SAARC Member States will face in implementing ERMT have been mentioned. These challenges will be discussed in detail with respect to each nation later in the report.

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[64] Nationally Appropriate Mitigation Action: Sustainable Transport In Sri Lanka Through An Electric Bus Rapid Transit System, United Nations Development Programme, 29 March 2016

[65] 'Sri Lanka electric vehicle registrations soar to all time high in September; Leaf leads', economynext, Article published on 13 October 2015

1.1.3.1. Advantages of ERMTs

The main advantages of electric vehicles have been listed below:

- They are pipetail emission free as they run either on batteries that are powered through electricity or on direct electricity. As SAARC countries have set competitive targets to tackle climate change, it becomes essential for them to take steps towards reduction of GHG emissions. **ERMTs will be an efficient way to reduce pipe tail emission of harmful gases** and support the targets set up by the governments.
- The engines convert almost the entire chemical energy of the batteries into motion as opposed to the 20% of fuel energy converted into motion by ICEs. This leads to a **better tank-to wheel efficiency** as well as well-to-wheel efficiency for electric vehicles compared to conventional ICE vehicles.
- The electrical motors offer a smooth and soundless operation. This leads to **reduced noise pollution**, curbing down of which is a challenge for cities in SAARC region.
- The overall maintenance charges are low. As electric buses have less moving parts compared to conventional ICEs and hence require **less maintenance**. Though, the battery needs to be changed after every few years, new manufactures have been able to elongate the life of these batteries. With technological advancements and research being conducted across the globe, operation parameters related to batteries are expected to improve.
- These vehicles have a life cycle at the end of which they need to be disposed. The **battery is fully recyclable** and can be reused as well.

1.1.3.2. Disadvantages of ERMT

Using Electric buses also has its own advantages, which are explained below:

- The batteries used in ERMT are expensive leading to an increase in price of electric buses. Additionally, these batteries are big in size and occupy a lot of vehicle space.
- Electrical vehicles can cover only up to 100 miles before recharging unlike gasoline automobiles that can cover as much as 300 miles with one full tank. This can limit intercity or interstate use of these buses unless proper charging infrastructure is installed on such routes.
- Full recharge time can be as long as 8 hours. So a driver might get indefinitely stranded when the vehicle runs out of charge. Though newer fast charging techniques have reduced this time, they are quite expensive. A method of overcoming this can be battery swapping, where electric vehicle users can simply exchange their battery at swapping stations, instead of recharging them every time. The swapping station will then charge it at a charging facility, preparing it for a different user.

- Despite being pollution free, electric vehicles still procure some environmental costs as they run on electricity which may be generated by burning fossil fuels like coal. The environmental benefit will be limited as long as this electricity isn't generated from renewable energy sources like wind or solar.

1.1.3.3. Overall Challenges

Electric buses are gaining increased attraction by transport authorities through the world. Their implementation, however, comes with its own challenges.

- **High Cost of Electric Buses:** Electric buses are more expensive than buses using conventional fuels for mobility. For example, both electric and hybrid buses launched by TATA Motors (an Indian automobile Company) have indicative prices ranging from USD 0.25 million to USD 0.3 million. The cost of buses produced by western manufacturers is generally even higher. The reason for these high costs is due to the electricity storage systems (primarily batteries) installed in these buses. However, the cost of batteries has been declining rapidly in recent years, 80% in 6 years to $227 /kWh, and is expected to further decline in coming years[66].
- **Charging Infrastructure:** For an effective ERMT, installation and maintenance of a well-established charging infrastructure is of primary importance. Installation of this infrastructure needs capital investments and regular supply of electricity. For ease of use, some transit authorities have also chosen High Capacity DC charging stations for installation, which costs even more. Also, as many parts of SAARC Member States face electricity shortage in peak hours, providing electricity to these charging stations during peak hours can be a challenge in itself.
- **Safety Issues:** Electric buses have their unique safety challenges. The performance of these batteries can get affected by mechanical abuse, overcharging, extreme temperatures and thermal runaway. Mechanical abuse can be caused by vibrations or shocks sustained during shipping or regular use. Overcharging, beyond safety level can lead to decomposition causing massive battery failure. Extremely high or low temperatures can affect the battery performance too. Higher temperatures can also cause degradation of battery material (Thermal Runway). In extreme scenarios, this can also lead to fire.

1.2. Objective of Study

SAARC region is undergoing a period of sustained growth and continuous urbanization. This has made it very important for the governments of the respective SAARC countries to provide enhanced connectivity. At the same time, the ever increasing of CO_2 levels, and their widely evident effects on global climate conditions, build a strong case for use Electric Road Mass Transportation. SAARC

[66] 'Electric vehicle battery cost dropped 80% in 6 years down to $227/kWh – Tesla claims to be below $190/kWh', electrek, Article published on 30 January 2017

Energy Centre (SEC), had proposed this study on Electric Road Mass Transportation under "Integrated Assessment of Energy, Transport and Environment" and "Minimize Oil Imports through improvement in Energy Efficiency and Fuel Substitution (PROMO)" with the following objectives:

- Assessment of viability of deploying Electric Vehicles for Mass transit of passengers in the road transport sector in the SAARC Member states.
- Identification of policy and infrastructure requirement for deployment of electric road mass transportation in the region.

1.3. Scope of the Study

This report covers following broad topics for evaluation of Electric Road Mass Transportation for SAARC region.

- Review of existing mass transportation in South Asia
- Review of the present scenario of Electric Road Transportation and the EV Programs in South Asia.
- Assessment of the available technology options in electric road mass transportation
- Identification of the opportunities and challenges in electric road mass transportation
- Identification of critical driving factors for these markets
- Estimation of Infrastructure and Investment Requirements
- Review of global case studies where Electric Road Mass Transportation has been implemented successfully
- Summarizing of the finding of report, and providing recommendations to SAARC policy makers, Government and Industry for the deployment of Electric Road Mass Transportation.

1.4. Methodology of Study

The study is based on easy to understand and time tested framework for delivering value in new markets and businesses. The broad approach and methodology has been outlined below.

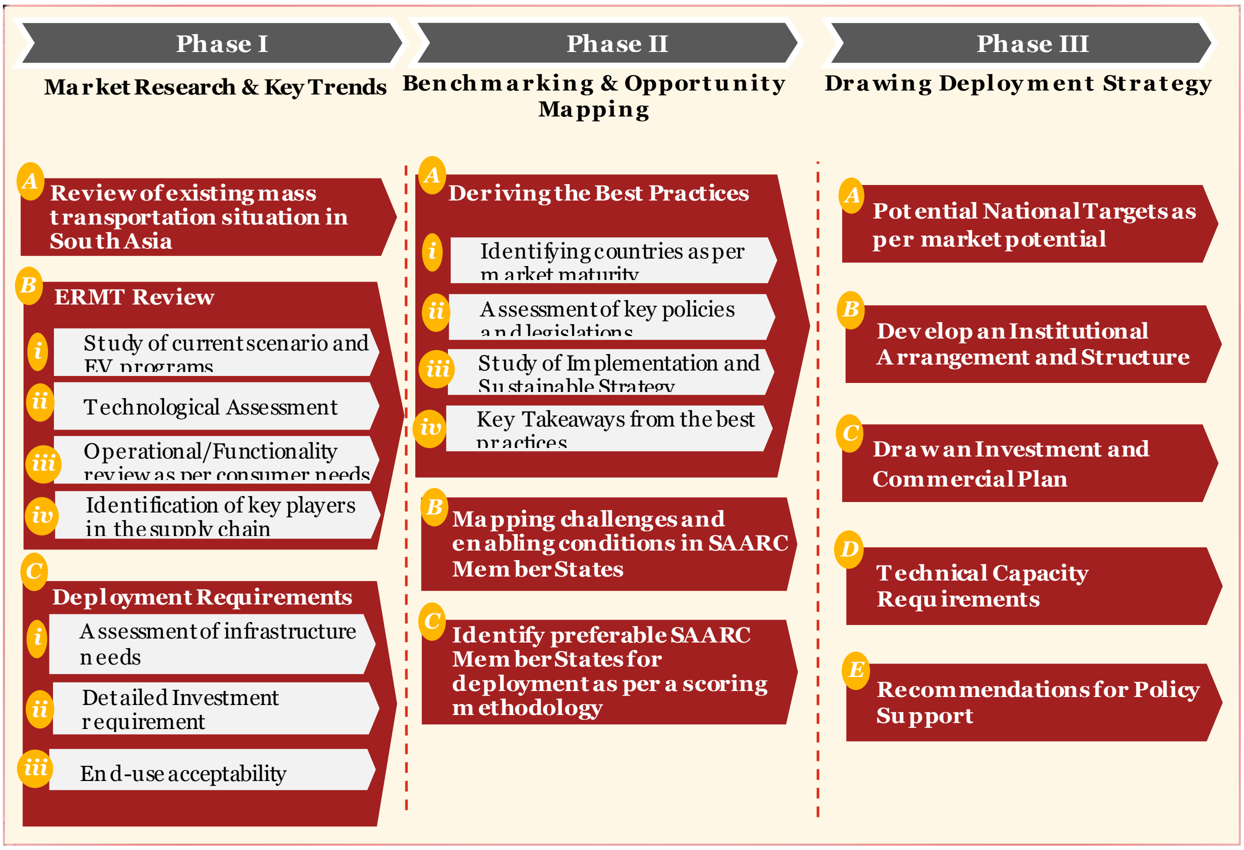


Figure 12: Methodology of the study

1.5. Limitations of Study

- It is to be understood that road mass transportation includes various forms of services including trams, taxi services, shared vehicles, etc. which may also be operated on electricity or through the use of electrical storage systems. However, this study focuses on the use of electric buses only;

- Buses can have varying seating capacity and dimensions. While the technology discussed in the report is universally applicable to all sizes of buses, certain operational features including costs and battery sizes will vary. For the purpose of calculations and estimates presented in this report, a bus is supposed to have a seating capacity between 30-35 passengers. Such a bus is generally 12 m long, has a width between 2.5 m and 2.6 m, and breadth between 3.2 and 3.5 m.

- The analysis and data collection is based on public sources of information such as industry studies, journals, publications and various research databases. During the course of analysis and benchmarking widely acceptable norms have been relied upon in case the actual information is unavailable.

- The study undertaken is primarily from secondary sources and discussions. Primary research has not been undertaken. However, di.oscussions with SAARC Energy Centre in the context of the scope of work has been ensured.

2. Literature Review on Electric Road Mass Transport

The literature review includes study of publications ranging from government documents of various SAARC nations to international studies and journals. Various technical reports were also reviewed to get a comprehensive understanding of the involved technology challenges and solutions to overcome them. This chapter discusses the various sources and provides a brief description of their importance.

2.1. Global Demand

Globally, there has been a recent increase in adaption of electric buses. By 2016, the global electric bus stock had grown to approximately 345,000 vehicles, a 100% growth over the stock of 2015. China, the global leader in electric vehicles, in terms of volume, has about 343,500 electric buses leading to 99.5% of the global electric bus stock. Europe has about 1,200 electric buses and US has about 200. Electric buses are also replacing the existing conventional bus fleet in China with cities like Shenzhen soon to have a 100% electric bus fleet and the public transport operator of the city of Paris planning to replace 80% of its electric fleet of 5,000 buses by 2025.[67]

2.2. SAARC Predictions

As road transportation is expected to continue its domination in movement of passengers and freight, and thereby use of fossil fuels, in the SAARC region, it's extremely important to make it energy efficient and environment friendly. By considering different scenarios, namely Business As Usual (BAU), GASELEC (Compressed Natural Gas and Electricity Conversion), EFF-TECH (Transformation to Energy Efficient Systems and Technologies), MASSTRANS (Mass Transport) and using the Long Range Energy Alternatives Planning System (LEAP), it has been concluded that a 35% energy saving was possible in SAARC region by 2040 if best practices for energy efficiency in road transport sector are been applied. (*Energy Efficiency in Road Transport Sector in the SAARC Member States, SEC 2015*).

2.3. Technology Overview

The technology involved in Electric Buses varies from that used in conventional ICE (Internal Combustion Engines) buses. According to CALSTART, a member supported organization of more than 175 firms; an electric vehicle can have up to 70% different components than a gasoline powered vehicle. A Battery Electric Bus doesn't have any moving parts in its engine (Poullikkas A. Sustainable options for electric vehicle technologies. Renew Sustain Energy Rev 2015). Table 14 gives a list of components of an electric bus which are different from the conventional gasoline

[67] Global EV Outlook 2017, International Energy Agency (IEA)

buses, along with the function of these components *(Advanced Vehicle Testing Activity, Idaho National Testing Laboratory).*

Table 14: Differences between gasoline and electric vehicles

Gasoline Vehicle	Function	Electric Vehicle
Gasoline Tank	Stores the energy to run the vehicle	Battery
Gasoline Pump	Replaces the energy to run the vehicle	Charger
Gasoline Engine	Provides the force to move the vehicle	Electric Motor
Carburetor	Controls Acceleration and speed	Controller
Alternator	Provides Power to accessories	DC/DC converter
	Converts DC to AC to power AC motor	DC/AC converter
Smog Controls	Lowers the toxicity of exhaust gasses	-

To qualify as an electric bus, it must have an electric powertrain. Electric powertrains will have a power source that is either completely electric, as in case of Battery Electric Vehicles (BEVs), or a hybrid of conventional ICE or electric source (HEVs). HEVs can have series, parallel or series-parallel configuration. *(Electric Powertrains, MIT Electric Vehicle Team, 2008)*. When compared in terms of efficiency, while operating in electric mode, all configurations achieve similar characteristics. Unlike parallel configuration, series and spilt configurations don't have multi-gear transmission. However, parallel configurations makes up for this loss, by operating at higher efficiency points. (*Comparison of Powertrain Configuration for Plug-in HEVs from a Fuel Economy Perspective, Vincent Freyermount et. al., 2008*). Due to increased high demand of hybrid vehicles, Plug-in Hybrid Vehicles (PHEVs) have been developed. These plug-in hybrids are like series-Hybrids with enhanced ability of charging the battery through external chargers. *(Hannan MA, et al. Hybrid electric vehicles and their challenges: a review. Renew Sustain Energy Rev 2014).*

2.4. Electric Storage Systems

Energy Storage Systems (ESS) are the sole source of energy in Battery Electric Vehicles (BEVs) and play an important role in deciding range of both BEVs and Hybrid Electric Vehicles (HEVs). Hence, choosing the right technology can play a determining role in implementing electric buses. The efficiency of electric buses is highly dependent on their Energy Storage Systems (ESS). *(Catenacci M, et. al. Going electric: expert survey on the future of battery technologies for electric vehicles. Energy Policy 2013)*. The efficiency of ESS in turn depends on energy density, power density and cost. The three main types of Energy storage systems are Ultra Capacitors, Fuel Cells and Batteries. Of all these types, Ultra Capacitor cells last the longest, primarily because they store energy by separating positive and negative charges and no chemical variations are involved. This also allows them to have high power density and low energy density. They are highly useful for battery electric buses as they are efficient for regenerative breaking. *(Khaligh A, et. al. Battery, Ultra Capacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles: state of the art. IEEE Trans Veh Technol 2010)*.

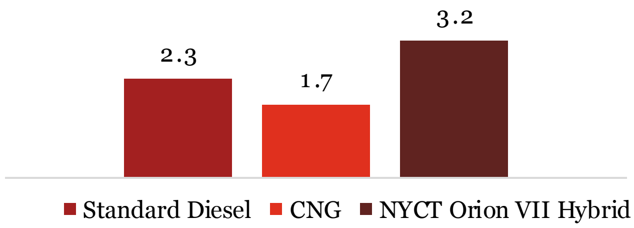


Figure 13: Average fuel economy comparisons (miles/gallon)
Note: The Average Fuel Economy for CNG is in miles/gallon equivalent

Among the existing battery technologies, based on the energy and power densities for Battery Electric Bus (BEB), Lithium-ion is the most suited technology, while for Hybrid Electric Bus (HEB) Nickel Metal Hydride (NiMH) is most suited. Among the regular battery technology options, Lithium Iron Phosphate (LFP) battery technology is expected to lose some of its market share, with non-LFP technologies expected to capture 48% of the market by 2025. *(Lithium-ion Batteries for Electric Buses 2016-2026, IDTechEx).*

2.5. Operational Costs

Electric buses have low travel cost per kilometer, primarily due to the lower cost of electricity as compared to the running costs of vehicles running on conventional fuel sources. However, the price of electric buses are way more than conventional buses. The net result of these factors is that the time period for recovery of initial investment is longer for electric bus than an ICE bus (S. R. Adheesh, et. al, Air-pollution and Economics: Diesel bus versus electric bus). In comparison to CNG, hybrids have a fuel efficiency which is higher by 88% (*Robb A. Barnitt, In-Use Performance Comparison of Hybrid Electric, CNG, and Diesel Buses at New York City Transit, 2008*). Hybrids are also more efficient than diesel buses.

2.6. Electric Vehicle Supply Equipment

Along with batteries, charging equipment too plays a critical role in determining success of electric buses. Before installation of the Electric Vehicle Supply Equipment (EVSE), the impact of these installations on the utility grid should also be considered. As hybrid buses do not require any special infrastructure, they allow time to set up the infrastructure required for electric buses, operating with the existing structure in meantime *(Jr.M. Grütter, Real World Performance of Hybrid and Electric Buses. Grütter Consulting; 2014).* Buses operated by hydrogen fuel cells will require hydrogen filling stations. These should ideally be placed at on-site at depots to minimize cost and greenhouse gases of Hydrogen pathways. *(Eudy L, et. al., U.S. Transit Fleets: Current Status 2012 Colorado: National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-5600–56406; 2012).* BEBs, however, require additional infrastructure investment. They can need an infrastructure set-up of fast charging stations and an additional supply of batteries if a battery-swapping scheme is implemented. Alternative charging approaches include overhead charging poles and inductive charging. *(Kakuhama Y, et. al., Next- generation public transportation: electric bus infrastructure project, Mitsubishi Heavy Ind Tech Rev 2011).*

2.7. Environmental Effects

Buses which run on fossil fuels are also source of emission of many air pollutants, which lead to health related issues for people inhaling them. These pollutants include carbon monoxide, nitrogen oxides, benzene, 1,3 buta-di-ene and primary particulate matter, harming the environment and causing respiratory problems in humans *(Chen, H, et. al, Classification of road traffic and roadside pollution concentration for assessment of personal exposure. Environ. Modell. Software, 2008)*. Electric buses have lesser moving parts and therefore produce less or no noise with relatively acceptable acceleration, 10s 0-30 km/hr. compared to 7.5s for Diesel. *(FCH-JU. Urban Buses: Alternative Powertrains for Europe. The Fuel Cells and Hydrogen Joint Undertaking FCH JU; 2012.)*. Battery electric bus also provide a better availability, i.e. operation as per planned schedule, than diesel and hybrid bus *(Hua T., et. al, Status of hydrogen fuel cell electric buses worldwide. J Power Sources 2014)*.

2.8. Safety Issues with Electric Buses

Another major concern with the usage of electric buses is the safety of these buses, and thereby the safety of the passengers. This primarily arises due to the use of batteries which can be affected by :

1. Mechanical abuse

2. Overcharging

3. Extreme temperatures.

Mechanical abuse is hard to prevent and happens mostly due to shocks and vibrations in transportation of batteries and their daily operations. Battery Overcharging imparts a higher voltage to cathode and can lead to plating and generation of CO_2 at cathode. LIBs use non-aqueous flammable electrolytes which are vulnerable to catching fire due to high-temperature. (*Casey 2015*). As batteries have typical temperature operating range between -20 degrees Celsius and 60 degrees Celsius (*McDowall, n.d.*) they are also vulnerable to higher charging temperatures on either side. While low temperature impact is generally limited to decrease of battery performance, higher temperatures can even lead to fire hazards. Thermal management is used to ascertain that the operating temperature stays within certain limits for power electronics. This is usually done by using a liquid coolant and integrated cooling channels. (*Delucchi 2001, Chan and Chau 1997*). Another approach is to install a Battery Management System (BMS) to ensure that each cell in the module function within various operating windows, thus enabling real-time monitoring and control of cells within a battery pack. This can help increase the battery life, while ensuring safety at all times.

3. Electric Road Mass Transport Technologies

3.1. Overview of Different Technologies

The technology for all electric vehicles in general and for electric buses in particular is at an evolving stage. The existing electric buses, which are available commercially, on the basis of their propulsion systems, can be categorized into three categories: Direct Electric Bus, Hybrid Electric Bus or Plug-in Hybrid Electric Bus and Pure Electric Bus (also known as Battery Electric Bus).

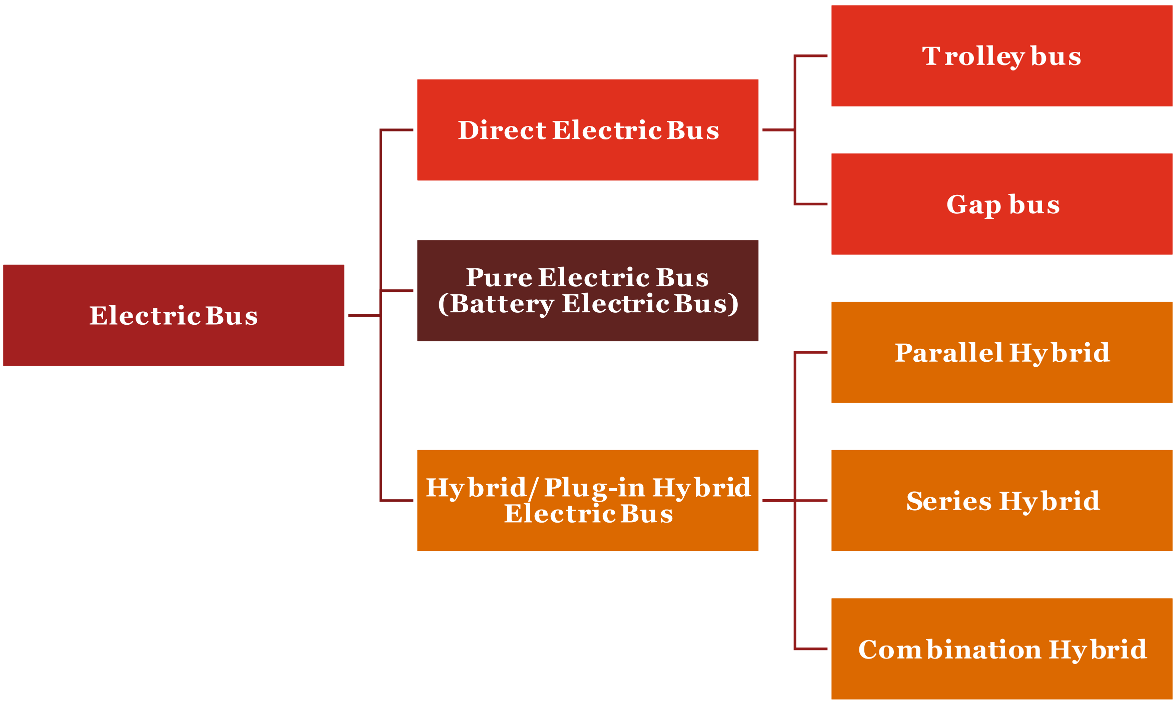


Figure 14: Types of electric buses

The Direct Electric Bus definition for the purpose of this report, refers to those buses which need to be connected to an electric supply continuously while travelling. Such buses can be either Trolley bus or Gap bus. Trolley buses are those which are powered through overhead lines while Gap buses are powered through electric powers or threads underneath the road. Currently, Trolley buses are the only commercially viable and relatively established technology, as Gap bus technology is still in nascent stage.

Between the balance types of ERMTs, both hybrid electric buses and battery electric buses have on-board energy storage mechanisms in place and are classified on the basis of the fuel they use. While battery electric buses are solely dependent on the electric charging stations for their operations, hybrid buses always have a parallel fuel (generally diesel or CNG) to ensure their continuous operations. The hybrid buses can be further classified into parallel hybrid, series hybrid and combination (series-parallel) hybrid based on the differences in their transmission paths. We will look more into the differences between these technologies in the upcoming sections.

While trolley buses, battery electric buses and hybrid buses are the only technology options that are viable right now, few other technologies like Gap buses and Gyro buses are in their nascent development stages.

Gap buses are currently being developed by a Boston based start-up called OLEV technologies. Though the company has license to operate in North and South America too, currently it has only been tested in Korea, in trials led by Korean Advanced Institute of Science and Technology (KAIST), in small fleets of generally 2 buses.

Implementation of this type of technology needs re-structuring of roads which have to be dug and fitted with electric supply in fish bone structures. The buses also need 100 kW of electricity at 85% maximum power transmission efficiency rate and maintain a 17 cm air gap between the vehicle's underbody and the road surface[68].

Gyro buses, on the other hand do not use continuous electric supply, rather they have freewheel electric storage and charging storage. This system was first tested around 1950s in some European countries; however, it was taken off-road for reasons ranging from high maintenance costs to inefficient economics[69].

Therefore, the study focuses only on Hybrid Buses, Battery Electric Buses and Trolleybuses for which various parameters have been evaluated.

3.2. Technical Features of Different Technologies

3.2.1. Hybrid Electric Bus or Plug-in Hybrid Electric Bus

Hybrid Buses are the combination of a conventional Internal Combustion Engine (ICE) and an electric engine. In hybrid electric buses, the primary fuel continues to be the conventional fuel whereas the electric powertrain helps reduce the amount of fuel consumed. In Plug-in Hybrid Buses, however, both electricity, stored in batteries, and the conventional fuel, either CNG or diesel, can be used as primary source. This is due to the fact that Plug-in Hybrid buses have the option of external electrical charging, unlike regular hybrid buses which are dependent just on regenerative breaking.

Plug-in Hybrid Electric Buses are those hybrid buses which have an external charging point through which their batteries can be charged through either dedicated charging stations or private chargers. As their battery is expected to retain more charge, and therefore provide a longer All Electric Range (AER), the batteries in these vehicles are generally of a bigger size. Conversion kits can also be purchased to convert a standard hybrid electric bus to a plugin hybrid bus.

[68] 'First 'electric' road charges buses in S Korea Public Transport Can Be Powered Wirelessly Through Buried Cables While Being Driven', Time of India Article published on Aug 9, 2013
[69] 'How the Swiss Developed an Emissions Free Bus without Using Batteries', Jalponik, Article published on 30 September 2013

They can further be classified into parallel, series and combination based on the alignment of ICE and electric engines.

3.2.1.1. Parallel Hybrid Electric Buses

In the parallel arrangement called p-HEV (parallel Hybrid Electric Vehicle), the ICE and the battery/motor are connected in a parallel configuration, leading to two paths of power transmission. The first path is the conventional ICE to wheels path while the second one is from battery to wheels via an electric motor. While the conventional fuel path converts chemical energy from conventional fuel, like CNG or diesel, to mechanical energy for the vehicle, the alternate path converts electrical energy to mechanical energy through the electric motor. This electric motor can also serve as a generator and charge the battery during deceleration and braking.

These buses are efficient in long-range drives where constant speed can be anticipated. This is because the fuel efficiency does not decrease as all the energy generated in the ICE is directly fed to wheels of the vehicle, and no multiple energy conversions are present[87].

It can be operated in the following five modes:

1. Engine Only Traction
2. Electric Only Traction
3. Hybrid Traction
4. Regenerative Breaking
5. Battery Charging from Engine

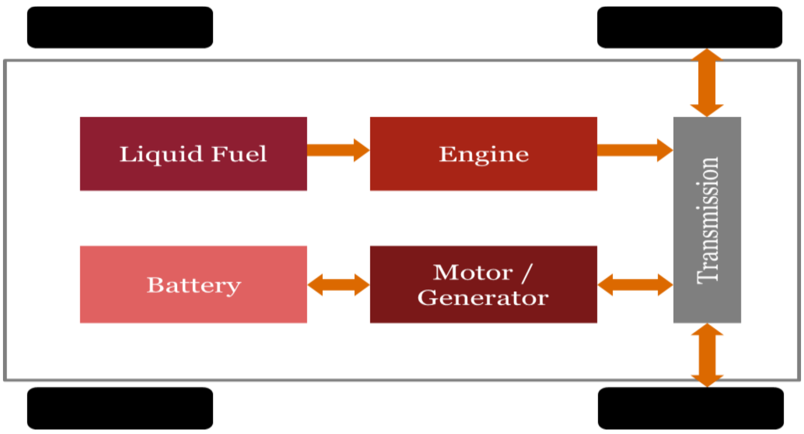


Figure 15: Schematic of a Parallel Hybrid[70]

3.2.1.2. Series Hybrid Electric Buses

In the series arrangement, s-HEV (series Hybrid Electric Vehicle), the ICE is directly connected to a convertor which charges the battery, propelling the electric engine. The process starts with conversion of petrol (Motor Spirit), diesel or CNG, to mechanical energy through an engine. This mechanical energy is then converted to electrical energy through a generator. This electrical energy is stored in the battery and is then converted to mechanical energy through the motor. This essentially leads to a single path of flow despite using two energy sources. Like parallel

[70] Electric Powertrains, MIT Electric Vehicle Team, April 2008

configuration, regenerative breaking leads to charging of electric battery, thus increasing the efficiency of the vehicle. The batteries in s-HEVs store more energy than those in p-HEVs. Consequently, s-HEVs have larger batteries than p-HEVs.

The extra energy conversions in this process reduces the efficiency, particularly in the long range drives. As energy is converted from mechanical to electric in the generator, electric to chemical in the battery, and electric to mechanical in the electric motor. This, however, is compensated by the regenerative breaking, at slow speeds or in areas with heavy traffic. Thus, such vehicles are more suited for driving in densely populated areas, like cities[87].

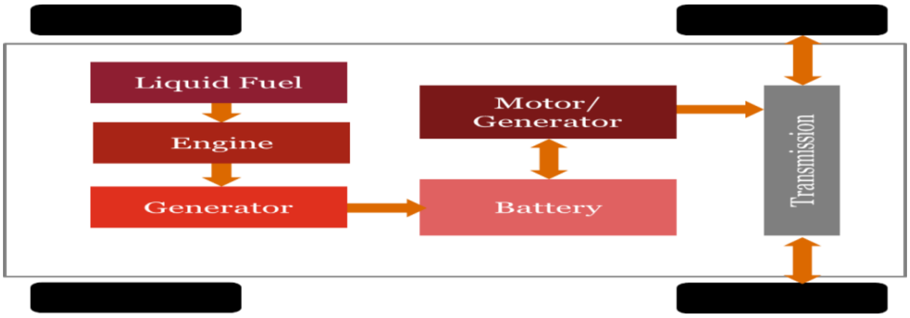


Figure 16: Schematic of a Series Hybrid Electric Vehicle[70]

3.2.1.3. Combination Hybrid Electric Buses

Combination Hybrid is a combination of series and parallel drive. The ICE and battery exist in three configurations, which are series, parallel and simultaneous series-parallel. This implies that there are three possible transmission paths – from ICE to wheels, from battery to wheels, and a combination of these two. The connection of ICE is with transmission and also aids in charging of the battery. This energy can then be fed to the wheels using electric motor and transmission. Thus, there are two main paths. On one hand, liquid fuel can either be directly converted to mechanical energy through the engine, on the other hand, electrical energy from battery can be converted to mechanical energy through the motor. Apart from these direct paths, energy stored in liquid fuel, can also be transferred from engine to motor and then to battery where it is stored as electrical energy. Similarly, electrical energy from battery may also be transferred through motor and engine and converted to mechanical energy. Apart from these, regenerative breaking also allows energy generated while braking to be converted to electrical energy through generator. The direct ICE Transmission helps in maintaining high efficiency in long range drives. At slow speeds, the electric-only mode helps in increasing the efficiency by using the energy that is created during re-generative breaking.

The fuel efficiency does not decrease during the long drives as all the energy from the ICE is directly fed to the wheels of the vehicle. Similarly, at slow speeds the series mode takes over. Therefore, the series-parallel buses are fuel-efficient in both slow and fast traffics[87].

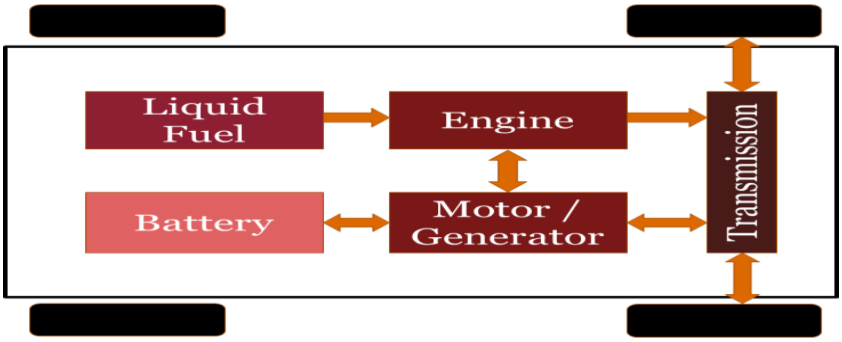


Figure 17: Schematic of a Series Parallel Electric Vehicle[70]

All three types of hybrids have their own unique set of advantages and disadvantages. While series hybrids are better suited for stop-and-go traffic, the parallel hybrids are better suited for the long range traffics. Though the combination hybrids have the option to use and adapt as in both series/ parallel modes, it is the most expensive of all three variants. A comprehensive comparison of the variants has been given in Table 15.

Table 15: Comparison of different types of hybrids[87]

Feature	Series Hybrid	Parallel Hybrid	Combination Hybrid
ICE Design	Narrow range for ICE (simple ICE design)	Broad RPM range for ICE makes it complicated and expensive	Smaller, lighter, efficient, ICE design
Energy Efficiency	Energy efficiency is low in long-distance drive and high in stop-and-go traffic	Energy efficiency is high in long-distance drive and low in stop-and-go traffic	Maximum flexibility to switch between electric and ICE power which can increase efficiency. Multiple conversions lead to a lower efficiency in particular driving mode.
Transmission Design	Transmission system design is simple.	Complicated design due to 2 power transmission paths.	Most complicated design due to both series and parallel features
Cost	More expensive than parallel and lesser expensive than series parallel hybrids.	Battery and Engine is smaller making this least expensive of all hybrids	Most expensive of all hybrids

3.2.2. Battery Electric Vehicle

Pure Electric Bus, also known as Battery Electric Vehicles (BEVs) do not have ICE and are completely dependent on battery operation. Thus, these vehicles have only one transmission path. They do, however, recharge the battery during de-acceleration and braking. Due to their complete dependence on the electric battery, the batteries used in these vehicles need to have more capacity, generally leading to a bigger size, compared to the ones used in hybrid vehicles. The battery constitute a significant part of investment for battery electric vehicles.

They also require large re-charging time, once that distance is covered. This can be overcome by using frequent recharging, in addition to longer charging hours, to full capacity of battery which can take place at night/off-peak hours. This practice has been successfully used in Vienna by Siemens[71].

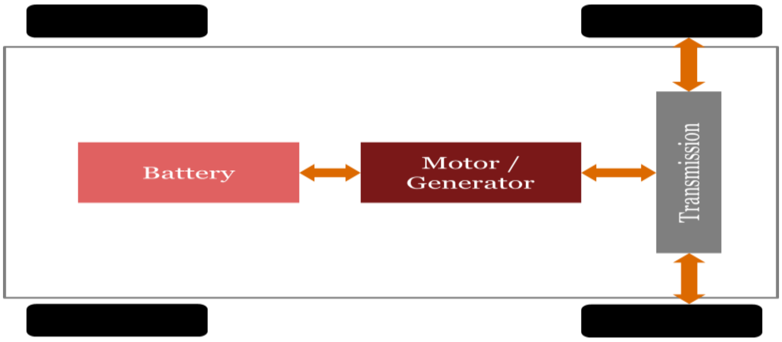
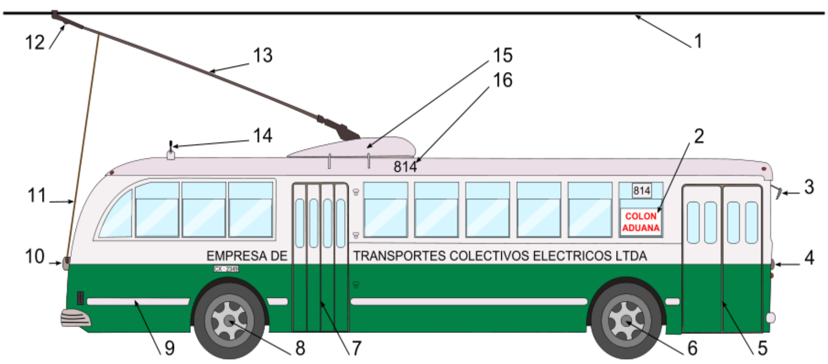


Figure 18: Schematic of Battery Electric Vehicle[58]

3.2.3. Trolley Buses

Trolley buses receive electrical energy from two contact conductors, generally receiving 600 or 750 Volts, which are in constant contact with the two trolley poles on the bus. This happens because the rubber pneumatics on the bus cannot close the circuit. These trolley poles generally have a length of about 6m and are swivel-attached to the roof. This allows for a lateral movement of up to 4.5 m. Due to the electric nature of the motor, it is able to survive overloading. It can also use excess supply for higher acceleration and easier uphill performance. The propulsion of such systems is generally built using a single traction engine. The installed power on such buses is generally between 110 and 180 kW. Trolley buses are usually designed as double-axles and have a body that is 11-12 m long, or three axle body which is 15-18m long. They are able to generate high torque due to their motor design. Their operating speeds generally average between 15 and 35 km/hr.[72].



1. Overhead line (overhead wires)
2. Destination or route sign
3. Rear view mirror
4. Headlights
5. Boarding (entry) doors
6. Direction (turning) wheels
7. Exit doors
8. Traction wheels
9. Decorative elements
10. Retractors/retrievers
11. Pole rope
12. Contact shoes
13. Trolley poles (power collector)
14. Pole storage hooks
15. Trolley pole base and fairing/shroud
16. Bus Number

Figure 19: Trolleybus

3.3. Operational Features of Different Technologies

In this section, an overview of the different operational features of the technologies has been provided along with a comparison with conventional buses, primarily diesel and CNG buses.

[71] 'Electric Buses: Rapid Charging in Vienna, Siemens
[72] Conditions for Implementing Trolleybuses in Public Urban Transport, Josip Zavada, et. al., PROMET -Traffic & Transportation, Vol. 22, 2010

Primary focus has been on assessment of Fuel Efficiency, Range, Charging Time, Safety Issues and Lifetime Cost Ownership associated with different technologies of buses. Table 16 summarizes the comparison of various kinds of buses.

Table 16: Summary of Various Bus Technologies[73]

Technology	Diesel Bus	CNG Bus	Hybrid Electric Bus	Battery Electric Bus	Trolley Bus
Seats	32	18*	32	31	-
L x W x H (m)	12.3 x 2.5 3.2	12 x 2.5 x 3.35	12 x 2.55 x 3.35	12 x 2.55x 3.49	12
Gross weight (kg)	16,200	16,000	16,200	18,500	-
Fuel efficiency	2.2 km/L	2–3 km/kg	2.2–4km/kg	1.5 kWh/km	1.9 kWh/km
Range (km)	484	260–390	286–520	249	-
Fuel tank size (litre)	220	720	720	-	-
Charging time	–	–	–	3–6 hours	-
Max power	290 BHP	230 BHP	230 BHP engine 44 kW battery	180 kW	-
Battery type	–	–	Li-ion batteries	Li-ion Iron (300 kWh)	-

* Note: The number of seats in CNG when compared to a similar size bus is lower due to the presence of the CNG kit

3.3.1. Technology Efficiency

A diesel engine is inherently less efficient than an electrical engine. This is because of the processes involved in conversion of chemical energy to mechanical energy. The process starts with constant heat compression of air leading to rise in temperature up to the ignition temperature fume. This process is followed by a constant combustion process, a constant heat expansion and a constant volume exhaust, releasing energy which is used for operating the vehicle. These diesel engines can have an efficiency of about 50% in low speed vehicles, like ships. In higher speed vehicles, the efficiency are generally is much lesser[74]. On the contrary, electrical vehicles have a much higher efficiency, due to lack of these processes. Electric motors designed for premium processes can

[73] The buses used as standard for Diesel Bus, CNG Bus, Hybrid Electric bus and Battery Electric Bus are Volvo8400, Tata Starbus LE CNG 18 (AC), Tata Starbus Hybrid (AC), BYD K9 (AC) respectively. Trolley bus assumptions are analyzed by the financial modelling used in report titled Transport Mode Efficiency Analysis: Comparison of financial and economic efficiency between bus and trolleybus systems.
[74] Approach to High Efficiency Diesel and Gas Engines, Mitsubishi Heavy Industries Ltd. Technical Review, March 2008

provide efficiency of even up to 96%. However, in both cases, efficiency is delayed due to realistic losses like friction.

A good measure to analyze efficiency of different technologies is to consider the net volume of energy required for 1 km of travel through each technology. This is done by calculating Well-to-Wheel (WTW) energy efficiency. This requires assessment of the fuel cycle stage, called Well-to-Tank technology (WTT), which includes energy generation, delivery pathway and energy storage, and the powertrain stage, called Tank-to-Wheel technology (TTW), which includes energy used for traction power[75]. The output of WTT and TTW are then integrated to single output called Well-to-Wheel (WTW) efficiency.

In WTT analysis, there can be significant variations in efficiency of electricity depending on source for production of electricity. While, renewable energy based production methods are considered to be 100% energy efficient, Natural Gas Combined Cycle (NGCC), and Coal Ultra Supercritical Steam Cycle (USC) production methods provide an average of 50% efficiency. Mixed method production which are very common in Europe and also in other regions, generally provide an efficiency of 40%[76]. WTT energy efficiency analysis is a calculation of the ratio of net volume of energy generated to energy consumed during the process. The unit for same is generally one mega-joules (1 MJ) of fuel or energy as liquid, gas, electricity. Oil based fuel are the most efficient source of energy, giving an average of 3.82 MJ/km. Next to this is hydrogen with 7 MJ/km and electricity 11.9 MJ/km[77].

TTW energy consumption, like WTT, is measured in mega-joules for each km (MJ/km) or in form of diesel equivalent mile per gallon (mpg). Battery Electric Buses provide the highest energy efficiency of 6.76 MJ/km on TTW bases. FCEB with 10.48 MJ/km and series HEB 10.81 MJ/km. TTW energy consumption analysis can vary depending on driving conditions and propulsion configurations[78].

Table 17 shows the WTW energy efficiency comparison of all the technologies. As it can be seen that Battery Electric Buses when operated through energy generated from Renewable Energy leads to a 50% reduction of energy consumption relative to Diesel Buses. It should also be noted that Battery Electric Buses which operate on electricity obtained from grid supplying through conventional sources, save about 10% energy consumption when compared to their diesel counter parts.

[75] Energy, environmental and economic comparison of different powertrain/fuel options using Well-to-Wheel assessment, energy and external costs, European market Analysis, Marco F. Torchio, Massimo G. Santarelli, Elsevier Ltd., 2010
[76] Energy Analysis of Electric Vehicles using batteries or fuel cells through Well-to-Wheel driving cycle simulations, Power Sources, Stefano Campanari, Giampaolo Manzolin, Fernando Garcia de la Iglesia, 2009
[77] Impact of Spanish Electricity mix, over the period 2008-2030, on the life-cycle energy consumption and GHG emissions of electric, hybrid, diesel-electric, fuel-cell hybrid and diesel bus of Madrid Transport, Energy Conversion and Management, Juan Antonio García Sánchez, José María López Martínez, Julio Lumbreras, Maria Nuria Flores Holgado, Hansel Aguilar Morales, 2013
[78] Going Electric: expert survey on future of battery technologies for electric Vehicles, Energy Policy, Michela Catenacci, Elena Verdolini, Valentina Bosetti, Giulia Fiorese, 2013.

Table 17: Well-to-Wheel Energy Consumptions (MJ/km) across different bus technologies

Powertrains	Energy source	WTT (MJ/ km)	TTW (MJ/ km)	WTW (MJ/ km)	Average % reduction of energy consumption relative to DB
Diesel Bus	Diesel	3.82	16.84	20.66	-
Diesel Hybrid Electric Bus – series	Diesel	3.45	10.81	15.26	**26.14%**
Diesel Hybrid Electric Bus - parallel	Diesel	3.31	12.81	16.12	**21.97%**
Battery Electric Bus	Electricity – EU mix	11.90	6.76	18.66	**9.68%**
	Electricity – renewable	3.57		10.33	**50.00%**

3.3.2. Fuel Cost Efficiency

In terms of fuel cost / km. electric buses seem to emerge as the fuel efficient technology. However, these rates are variable based on the price of electricity in a particular region. For calculation of these fuel cost, the inverse of mileage of a bus, in terms of l/km for diesel, kg/km for CNG and kWh/km for electricity are used. These mileages are then multiplied by the cost of fuel required per km, i.e. the cost of a liter of diesel, a kg of CNG or a kWh for electricity. After the battery electric bus, the obvious choice is the hybrid bus which too will have the same fuel cost efficiency as the battery electric bus when operating completely on electricity. However, as the proportion of diesel used increases, the fuel cost goes up, making it less viable than trolley bus and eventually even a CNG operated bus.

Table 18: Fuel economy of various bus technologies[79]

Technology	Diesel Bus	CNG Bus	Hybrid Electric Bus	Battery Electric Bus	Trolley Bus
Fuel efficiency	2.2 km/L	2–3 km/kg	2.2–4 km/kg	1.5 kWh/km	1.9 kWh/km
Fuel cost (USD / km)	0.34	0.19-0.28	0.15-0.25	0.15	0.19[80]

[79] Based on Analysis done by CSETP India in August 2016. The INR to USD conversion rate used here is taken as 1 USD = 67 INR, approximately the average conversion rate for August 2016.
[80] The electricity rate used for electric charging/electricity supply is assumed to be constant for all buses and is same as that used by CSETP India for its analysis.

3.3.3. Range

Range is generally not an issue for conventional ICE buses, due to both the required tank size and the easy availability of fuel stations for diesel and CNG buses. The primary advantage of using hybrid electric buses, any of the three kinds, over the battery electric buses is that the user does not have to bother about the range of the vehicle as they can easily depend upon the conventional fuel, used by the ICE engine as a backup.

It is to be noted that the hybrid electric buses, apart from the plug-in hybrid electric versions, have limited range that is generated through the batteries. The energy stored in non-plug hybrid electric buses is generated during de-acceleration and slowing down of vehicle. Therefore, the amount of charge stored in such batteries is not only hard to predict but is also of limited utility.

For battery electric buses, the battery becomes the sole determinant of range. This range is essentially limited by the amount of charge in the battery. For similar batteries, the range generated for the vehicle, however, will not depend upon the type of vehicle it is being used in, be it hybrid electric or battery electric buses. The range of a bus is primarily dependent on the chemical composition of the battery, the size of battery and the bus load. It is also affected by multiple factors like traffic, road type, passenger load, age and prior use of the vehicle. Given their ability to use diesel as alternative fuel, hybrid electric buses do have smaller battery packs installed, which essentially limits their electric storage capacity.

Table 19: Comparison of range of various bus technologies

Technology	Diesel Bus	CNG Bus	Hybrid Electric Bus	Battery Electric Bus	Trolley Bus
Range (km)	484	260–390	286–520	249	-

Further, a brief analysis of different kinds of electrical energy storage systems has been presented including the most common electrical energy storage systems, batteries and of the upcoming technologies - Ultra capacitors and Fuel Cells.

3.3.3.1. Overview of Electrical Energy Storage Systems

Batteries:

Batteries are the most commonly used electrical energy storage systems today. They are composed of galvanic cells (chemical devices consisting of anodes and cathodes) which are electrically connected to each other. The electrolyte present in the galvanic cell converts the electric energy into chemical energy. During discharging (usage of battery) this chemical energy turns back to electric energy. This leads to transfer of ions to anode and cations to cathode. This process gets reversed once the battery is discharged.

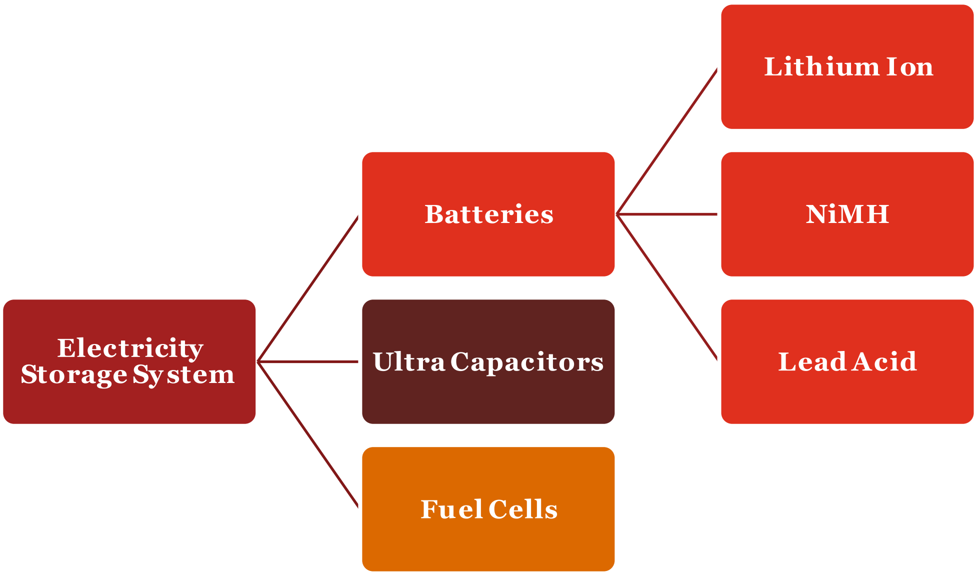


Figure 20: Types of electricity storage systems

The most promising technology evolved till now is the lithium (li)-ion technology. They have the capability to combine high specific power (300 Wh/kg), high energy density (90-140 Wh/kg) and low self-discharge. The low weight and ability to survive moderately high temperatures also adds to their advantage. These cells use lithium salt as an electrolyte. Though the price of lithium batteries has been consistently coming down, they still are very expensive. It also requires battery management system to safeguard against accidents that can be caused due to the highly flammable nature of the electrolyte.

Among other batteries, lead-acid battery has reached a mature stage and has low manufacturing costs. However, it also has very low energy density (20-30 Wh/kg). It uses lead as negative and lead oxide as positive active material and diluted sulphuric acid as electrolyte. Another common technology is NiMH (Nickel-metal Hydride). These batteries have energy density of about 40-55 Wh/kg and can operate at higher voltage. Though the NiMH batteries also have a life expectancy of 2000 cycles, which is more than that of Li-ion batteries, their tendency to discharge at high load currents and reduction of storage capacity after 200-300 cycles make them unfavorable. Also, these batteries have lower storage and need more time to discharge[81].

Ultra-Capacitors (UCs):

The energy stored in UCs is through mechanically separated parallel capacitor plates. Like any capacitor, these plates too have an electrolyte between them for storage of charge on electrodes. UCs have longer life cycles than batteries as, unlike batteries, the process of charge storage and depletion does not involve chemical variation on the electrodes. UCs also have higher power densities and can be charged and discharged within a shorter period. Despite these advantages, UCs have much smaller energy density and can only store about 10% of energy that lithium-ion batteries can store.

[81] "Batterietechnologien – jenseits von Lithium and Blei." Energie-Effizienz-Technologien, C. Doetsch, and J. Burfeind, 2014

Fuel Cells

Fuel Cells combine a fuel at anode with an oxide at cathode, thus generating electricity. Unlike batteries, a continuous source of fuel and oxygen is required to sustain this chemical reaction. While hydrogen has the highest energy density, hydrocarbons or alcohols can also be used as fuel. High conversion efficiency, low noise emission and almost no GHG emissions add to its attractiveness as an energy storage system.

Fuel cell vehicles also have to be refilled in the same manner as conventional vehicles. Hydrogen refueling station would supply pressurized hydrogen and take around 10 minutes to fill. Once filled to their maximum capacity hydrogen fuel cells can be expected to give a range of 320 - 480 km[82]. Fuel cells are essentially electric vehicles which do not directly consume electricity but consume chemicals which generate electricity. Therefore, they have following components which are different from other EVs.

Table 20: Additional Components in Hydrogen Fuel Cell EV[83]

Component	Feature
Fuel Cell Stack	An assembly of individual membrane electrodes that use Hydrogen and Oxygen to produce electricity
Fuel Filler	A filler or "nozzle" used to add fuel to the tank
Hydrogen Fuel Tank	Stores hydrogen gas on board the vehicle until it's needed by fuel cell

Hydrogen fuel cells have tanks which are considerably larger and more expensive than petrol equivalents. This is due to the fabrication process which requires filaments of carbon fiber wound around a metal or polymer liner. The fuel tank has to be built in such a manner that it can store hydrogen at pressures up to 700 atmosphere, which will give a range of 500 km. The biggest concerns with this technology are the cost of the fuel-cell stack and the costs associated with its production, transportation and fuel dispensing. According to the U.S. Department of Energy , the stack cost would be around USD 50 per kilometer, if there is a mass production in volumes of 500,000 units a year. The technical grade purity required for EVs is 99.999% and in the USA pump price is estimated at USD 13 - 15 per kilogram which in turn costs around 6 times the price of petrol of same density. While there are no operational fuel-cell operated buses on a commercial scale, there are three fuel cell based cars in the market - Honda Clarity, Toyota Mira and Hyundai Tuscon FC. These are all being tested only in California. With 34 hydrogen fueling stations, it is the only city in the world with any hydrogen fueling station[84].

[82] 'How do Hydrogen Fuel Cells Work', Union of Concerned Scientists
[83] 'How Do Fuel Cell Electric Vehicles Work Using Hydrogen?' Alternative Fuels Data Center, U.S. Department of Energy
[84] 'Electric Vehicles powered by fuel cells get a second look', The Economist, Article published on 25 September, 2017

Despite the benefits, these cells also have low energy density and have long response times. Their prices are also generally high as it uses components like Platinum. Currently, hydrogen-fuel bases are economically unviable for operational purposes for buses and are only used for testing purposes[85]. TATA Motors, in association with Indian Space Research Organization, has launched Tata Starbus Fuel-Cell this year. However, the technology is yet to receive orders for mass-scale procurements[86].

3.3.4. Charging Time

One of the most important concerns with adoption of the electric buses is the longer charging time associated with refueling (charging their batteries). This is not a concern for conventional buses using diesel or CNG. Also, trolley buses are powered almost instantly using electricity. Therefore, this section focuses exclusively on battery electric buses and the charging time required for the same. The findings of this section are also applicable on plug-in hybrid electric buses operating in electric mode.

All Energy Storage Systems need a method of recharging. The infrastructure required for charging electric buses can be categorized as plug-in, inductive and overhead charging. The conventional method of charging battery electric buses and plug-in hybrid buses are through plug-in charging stations which are generally placed at bus depots and at long-haul stations.

Electric buses can be charged both through AC and DC based charging stations. While for AC charging, electricity is supplied to the on-board AC charger which converts the supplied AC current to DC that can be used for charging the battery. According to SAE (Society of American Engineers), an AC charger, with a maximum continuous input < 8 kW charging station, is capable of providing 8-25 km of electric range per 30 minute charge. A DC charger with higher voltage and current and maximum continuous input power 240 kW supplies current directly to the battery and can give a charge to last up to a range of 125 km in 30 minutes.

The available chargers can be divided into 3 categories, slow, fast and rapid chargers[87]. Slow Chargers provide an output of 220v, 13 A and are therefore too slow to charge buses. Fast Chargers refer to AC chargers which provide an output of 220 V, 32 A. Such chargers can charge a battery of 70 kWh in 12 hours. Rapid Chargers are those chargers that provide an output greater than 50 kW and can charge a battery of 70 kWh in less than 2 hours. Another alternative is battery swapping which might take as less as 2-5 minutes. This approach is discussed further in the section focused on charging infrastructure.

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[85] Hydrogen and Fuel Cell Technologies for Heating: A Review, International Journal of hydrogen, Paul E. Dodds, Iain Staffell, Adam D. Hawkes, Francis Li, Philipp Gru¨newald, Will McDowall, Paul Ekins, 2014
[86] 'The future of Mass Public Transportation is here: Tata Motors launches Hybrid & Electric buses', Press release by TATA Motors on 25 January, 2017
[87] Electric Buses in India: Technology, Policy and Benefits, 2016, Global Green Growth Institute and Center for Study of Science, Technology and Policy

Table 21 summarizes the different type of charging stations and their advantages and disadvantages. For charging of electric buses only Fast Chargers, Rapid Chargers and Battery Swapping can be used.

Table 21: Comparison among types of Battery Charging (CSETP India)

Type of Charging	Charging Time*	Advantages	Disadvantages	Ideal Segment
Slow (220 V, 13 A)	24 hour	Easy to Implement	Slow	Private Cars, two-wheeler
Fast (220 V, 32 A)	12 hour	Moderate, flexibility of a single phase or three phases	More investment	Public cars, public buses
Rapid (50 kW+)	90 min	Fast	Restricted to three phases, high cost, loading issue, low efficiency	Public buses, public cars
Battery swapping	2–5 min	Very fast	Cost of battery, space requirement, robotics	Public buses

*Charging time is the time taken to fully charge a completely discharged battery having capacity of 70 kWh.

3.3.4.1. Other Charging Infrastructure Option – Inductive charging

Apart from the charging options mentioned above, there are a few other options which are still in developing stage. The most prominent among them is inductive charging. The system involves setting up of alternating electromagnetic field in a road and an induction coil in the vehicle which can harvest energy from it. Qualcomm is the major player in this technology and was brought to wide public attention; when it along with Volkswagen and Mercedes Benz announced inductive charging cars last year[88]. Qualcomm had built a 100 meter test track near Paris, France to test this technology. An 80 foot test track has also been built by an Israeli firm, ElectRoad to test inductive charging.

The main issues with the technology is that is requires tearing up sections of roads to lay the infrastructure for electromagnetic field. This will be expensive and will also cause inconvenience due to disruptions involved. Further, a phase-wise implementation might be a challenge leading to only parts of a city having access to such technology. The electromagnetic systems too are costly and will be required along the entire length of the road[89]. This makes inductive charging too capital

[88] 'Mercedes-Benz debuts Qualcomm's wireless charging for the hybrid S Class', article published on November 10, 2016 in arsTechnica
[89] 'The Case for Building Electric Roads' article published in Sustainable Energy on May 18, 2017

intensive a technology to be implemented in SAARC nations at the current stage. Also, the technology is in very early stages of development and its dependability can be concern.

3.3.5. Safety Issues

Standard ICE technology has been in existence for a long time and has relatively been accident free. Therefore, there are no concerns in usage of these batteries. However, Lithium ion batteries, which are used in various categories of the products around the world, have only become recently popular for Electric Vehicles. It also finds uses in consumer electrical and electronic devices, medical devices, and industrial equipment. Given the wide application of lithium ion batteries, the total numbers of recalls and incidents related to these batteries have been very low. Most of these have been related to electronics like laptops and toys. There a number of standards facilitated to ensure high safety measures. More tests are still evolving as the knowledge of this intricate technology continues to grow. The major challenges in performance and safety arise due to issues with thermal stability of active materials within the battery at high temperatures and internal short circuits that can lead to thermal runway.

Lithium batteries have various standards and testing protocols that are used to assess the safety of battery. These are decided by institutes like Institute of Electrical and Electronics Engineers, National Electrical Manufacturers Association, Society of Automotive Engineers, International Electro technical Commission, Japanese Standards Association, etc.

The safety of batteries needs to be given highest priority as batteries used in electric buses need to manage high power and energy under various operating conditions. The battery performance is a function of its operating conditions, most importantly, temperature, charging/discharging current and State of Charge (SoC). Battery safety is generally impacted by mechanical abuse, overcharging and effect of extreme temperature, any of which can lead to thermal runaway, thermal degradation of batteries.

Mechanical Abuse | **Overcharging** | **Extreme Temperature**

Figure 21: Types of impact on batteries

Mechanical abuse is generally caused by vibrations and shocks during the shipping of batteries or in daily operations of buses. They can potentially result in short circuits in cells. Bus manufacturers are now using stronger chassis and shock absorbing materials to hold batteries around packs.

Overcharging is a state of reaching beyond 100% State of Charge. This leads to a higher voltage to Cathode and, thereby, the cell. In Lithium-Ion batteries, this can lead to plating of metallic lithium on anode and to generation of CO_2 at cathode, resulting in battery explosion. This happens after a certain safety level is crossed and battery materials decompose leading to battery failure. The decomposition reaction leads to high temperature rise. And since Lithium Ion batteries use non-aqueous flammable electrolyte, this leads to fire hazard[90]. For controlling overcharging, Battery Management Systems are used by sending signals to battery to start or stop charging. This is done through safety valves and vents. Similar hazards and solutions are applicable for Lead Acid and Nickel-based batteries.

Extreme temperatures also affect the safety of battery as their operating range is generally between -20 Degree Celsius and 60 Degree Celsius[91]. Challenges in battery function can, however, arise when batteries are exposed to temperature 0 Degree Celsius[92]. This happens because the ionic conductivity of the electrolyte decreases t lower temperatures and reduces battery performance. Warmer places with temperature ranges between 40 Degree Celsius and 50 Degree Celsius also have higher risks of battery failure. Also charging at higher temperature can result in higher ohmic losses, thereby damaging the battery. To ensure maximum performance, battery compartments should be well insulated in winters and temperatures should always be controlled through active cooling-heating systems.

3.4. Environmental Properties of Different Technologies

3.4.1. Air Quality Aspects

With increasing environmental awareness, a number of studies have been recently conducted to assess the impact of different technologies on surrounding environment. This is also important since environmental friendliness is one of the main reasons for preference of electric buses. In order to assess the true extent of emissions of the Greenhouse Emission Gases (GHGs), the Well-to-Wheel (WTW) emissions have been analyzed. Well-to-Wheel emissions are an integration of emissions generated at two stages, Well-to-Tank (WTT) and Tank-To-Wheel (TTW). WTT measures production and distribution stage emissions of fuel, the emissions of this stage provide an estimate of the emissions involved in energy production and distribution. WTT assessment primarily involves identification of energy production and distribution methods, along with identification of feedstock. TTW measures usage stage emissions which are local emissions produced during bus operations.

Table 22 shows results of a study conducted to measure GHG emissions for various technologies of buses. In the TTW results obtained for a standard SD-12 bus, it can be observed that buses operating as battery electric bus and as fuel cell powered buses have zero GHG Emissions. The GHG emissions of HEV depends on the powertrain used. Series Hybrid produced lesser emissions

[90] Proterra Diesel-Killing Electric Bus is Ready for Prime Time (CT Exclusive Interview), CleanTechnica, Casey, Tina, 2015
[91] A Guide to Lithium Ion Battery Safety, Jacksonville: Saft America Inc., Jim McDowall, n.d.
[92] Charging at High and Low Temperatures, Battery University, 2015

compared to Parallel Hybrid. Also, the Diesel-Hybrid produced an average GHG of 790-970 gCO_2eq/km and CNG-HEB produced an average of 700-800 gCO_2eq/km[93].

Table 22: GHG emissions of different bus technologies

Powertrains	Energy Source	WTT GHG (gCO_2eq/km)	TTW GHG (gCO_2eq/km)	WTW GHG (gCO_2eq/km)	Average % reduction of GHG compared to DB
Diesel Bus	Diesel	218	1004	**1222**	-
CNG Bus	H2 – mix	157	1014	**1171**	4.17%
Diesel Hybrid Electric Bus - Serial	Diesel	172	796	**968**	20.79%
Diesel Hybrid Electric Bus - Parallel	Diesel	188	870	**1058**	13.42%
Battery Electric Bus	Electricity - EU mix (Electricity from grid)	720	0	**720**	41.08%
Battery Electric Bus	Electricity - Renewable	20	0	**20**	98.36%

The study does not mention the WTW emissions of Trolleybuses. However, we can estimate this, by splitting WTW emissions into WTT and TTW emissions. As Battery Electric Buses and Fuel Cell Electric Buses have 0 TTW GHG, so should be the case for Trolleybuses. Similarly, the WTT for trolley buses can be expected to be similar to that of Battery Electric Bus which uses Electricity – EU mix (electricity from grid) as its energy source. Therefore, the total emission of a Trolleybus is also expected to be similar to that of a Battery Electric Bus obtaining its energy from EU mix. This shows that a Battery Electricity Bus that gets powered from grid electricity and not completely renewable energy produces 36 times more CO_2/km than one that is powered completely by renewable electricity.

3.4.1.1. Emission Standards and compliance

To tackle the global climate challenges, all nations around the world are coming up with increasingly stringent conditions on the kind of pollutants vehicles can release. In Table 23, some of the emission standards used across the nation have been described.

93 Electric Buses: A review of alternative powertrains, Moataz Mohamed, Ryan Garnett, Mark R. Ferguson, Pavlos Kanaroglou, 2016

Table 23: Emission Standards applicable across nations for buses [in grams per bhp (Brake Horsepower)][94][95]

Geography	Standard	Date	CO	HC	Nox	PM
European Union	Euro VI	2013	1.50	0.13	0.40	0.01
North America	US EPA	2015	15.50	0.14	0.02	0.01
Japan	-	2016	2.22	0.17	0.4	0.01
China	China V	2015	4.0	-	2.0	0.03
India	BS IV	2010	4.0	0.55	3.50	0.03
South Korea	-	2014	4.0	0.16	0.46	0.01

While CNG and Diesel Buses cause of a lot of harmful pollution and pose risks of not fitting into the stringent emission standards in the future, electric buses are safeguarded against this as they emit almost no harmful pollutants.

Table 24: Average Annual Emission for various technologies[94]

Vehicle type	CO_2 (kg)	CH_4 (g)	CO (kg)	NOx (kg)	HC (g)	PM (g)
Diesel	94,710	61	23	27	4,200	423
CNG	97,749	38,843	360	108	1,000	102
Hybrid	69,626	45.7	17	20.6	3,200	298
Electric vehicle	0	0	0	0	0	0

3.4.2. Noise Pollution

Noise pollution can lead to health issues like stroke, dementia and hypertension. In less serious cases it can still cause sleep disruption and other types of mental disturbances. Being severely sleep deprived due to noise reduces individual's well-being by about 7%[96]. Due to an absence of moving parts, electric buses operate with lower noise and vibration. Battery electric buses operate using electric motor and are thus able to produce low torque at high speeds[97]. Electric buses tend to

94 Global Electric Bus Market 2016-2020, Technavio, April 2016
95 The emission standards for European Union, Japan, China, India and South Korea are based on WHSC (World Harmonized Stationary Cycle), WHTC (World Harmonized Transient Cycle), ETC (European Transient Cycle), ETC and WHTC tests.
96 World Health Organisation & European Centre for Environment and Health, 2004
97 Urban Buses: Alternative Powertrains for Europe, The Fuel Cells and Hydrogen Joint Undertaking, FCH JU, 2012

generally produce about 17 decibels (dB) lesser sound than diesel buses of comparable size. While diesel buses can be as loud as 70 dB, electric buses rarely exceed 60 dB. The fact that dB is on a logarithmic scale implies that electric buses produce half the noise produced by diesel buses.

The noise difference between buses becomes most significant around 40 km per hour, as shown in graph below[98]. As most public buses aren't expected to exceed this speed, electric buses can make a significant difference in bus noise pollution. As these results are dependent on the type of motor, and hence the transmission path being used, the result for trolleybus will be the same as that for battery electric bus. Similarly, a hybrid bus will be expected to produce noise comparable to a diesel bus when operating on diesel, and thereby using engine, and a noise comparable to a battery electric bus when using electricity, and thereby using electric motor. At higher speeds, the difference in noise reduces and slowly becomes nil, as the primary source of noise at higher speeds is the noise of tires on movement and not the engine.

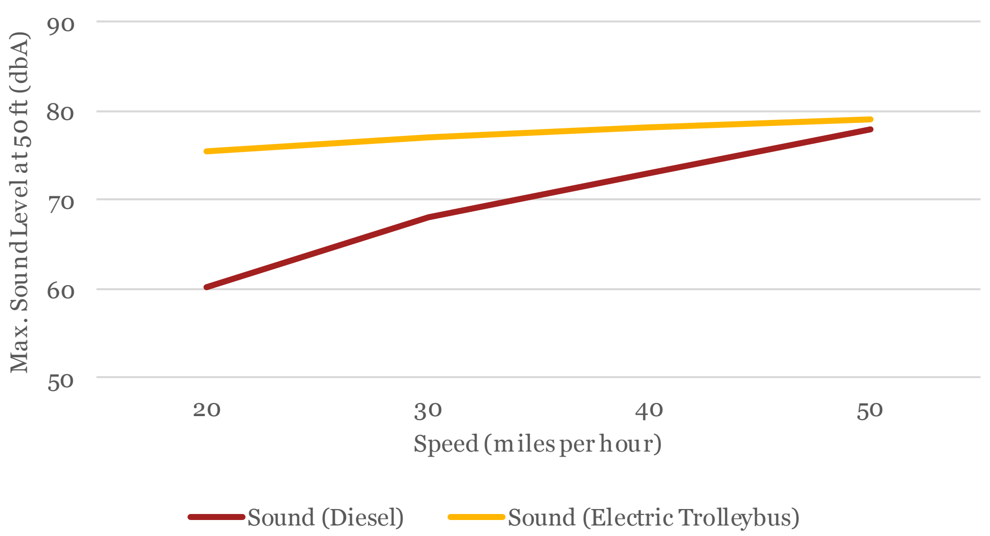


Figure 22: Diesel and Electric bus noise levels

3.4.3. Other health issues due to vehicle emissions

Apart from the effects of pollution discussed above, vehicle emissions also have other health implications. This pollution can be specifically dangerous to kids and can cause lifetime damage to their respiratory systems. Pollution caused by vehicles can cause cardio-vascular disease, asthma, chronic obstructive pulmonary disease and lung cancer. Conventional vehicles in general and diesel vehicles in particular, emit extremely fine particles that can penetrate lungs deeply and inflame circulatory system, damage cells and cause respiratory problems. Short term exposure to vehicle exhausts too can harm asthmatics. Similarly, mortality and hospital admissions for myocardial infraction, congestive cardiac failure and cardiac arrhythmia increase with a rise in concentrations of particulate matter and gaseous pollutants.

[98] A comparison of Green and Conventional Diesel Bus Noise Levels, In. Reno, Nevada, Rose, Jason C, and Michael A Staiano, 2007

Vehicles, especially diesel vehicles, are also responsible for causing cancer. Diesel contains benzene, formaldehyde, and 1,3-butadiene, all three of which are carcinogens. It is estimated that vehicle emissions account for as many as half of all cancers attributed to outdoor air pollution[99].

The emissions increase due to improper maintenance of vehicles and their continued use beyond the expected lifetime. These lead to incomplete burning of the fuel and make their emissions more harmful. This is clearly noticeable in case of older diesel buses which emit black smog and are easily visible in many countries in the SAARC region. A transmission to electric road mass transportation and e-vehicles as a whole would have a substantial impact on improving such qualitative aspects of environment and human life.

3.5. Total Cost of Ownership of Different Technologies

Calculation of Total Cost of Ownership (TCO) of buses is very intricate. It involves many variables which are hard to quantify and calculate. This also needs inputs from various stakeholders including transit authorities, OEM, Vehicle manufacturers, infrastructure providers and local authorities. This TCO calculation is based on the following assumptions.

1. Price of buses vary across countries and regions, depending on various factors like raw material availability, scale of production and maturity of the technology. The price of diesel, hybrid and electric buses across various regions/countries have been mentioned below:

Table 25: Price comparison of diesel, hybrid, and electric bus (in USD) [94]

Region	Diesel Bus	Hybrid Bus	Electric Bus
North America	300,000 - 450,000	450,000 - 600,000	650,000 - 750,000
Europe	300,000 - 400,000	450,000 - 550,000	600,000 - 700,000
China	80,000 - 120,000	140,000 -220,000	400,000 -500000
India	75,000 - 100,000	200,000 - 250,000	350,000 - 400,000

As Chinese manufacturers and sales of battery electric buses dominate the global market, the average cost of diesel, hybrid and battery electric buses have been considered, i.e. USD 100,000 for diesel bus, USD 180,000 for hybrid bus and USD 450,000 for electric bus. Further, the cost of trolley bus has been taken as USD 250,000[100].

It is to be noted that prices of different types of hybrid buses (series, parallel and combination) would be similar in nature and dependent on pricing structure of the manufacturer as per the drivetrain being used. Ideally a series hybrid bus would be slightly more expensive than the other two variants due to presence of an additional

[99] The Harmful effects of Vehicles Exhaust, Environment and Human Health Incorporate, 2006
[100] Transport Mode Efficiency Analysis: Comparison of financial and economic efficiency between bus and trolleybus systems, Trolley Project

motor/generator. For computational purposes, this difference in cost of hybrid buses has not been considered.

2. An average of 180 km per day has been considered. This is based on operational data of a large public transportation body operating in a metropolitan city of South Asia.
3. The life of buses has been considered as 10 years and has been kept constant for all technologies. A salvage value of 10% has been considered.
4. Fuel cost efficiencies are based on the analysis from the above sections.
5. Diesel cost has been considered at USD 0.94/liter with an escalation factor of 3.88% (Linked to CAGR of crude oil prices from January 2000 to January 2017 [101])
6. Electricity cost of charging the hybrid and battery electric buses has been assumed at USD 0.10/kWh with an escalation of 2.61% (Linked to CAGR of average electricity price in a developed economy from 2000 to 2016[102])
7. Other operating and maintenance costs in the tune of USD 0.19/km, USD 0.20/km and USD 0.09/km has been considered for diesel buses, hybrid buses, battery electric and trolley buses, respectively. The cost includes cost of spares required during maintenance, cost towards employee required for conducting the activities and cost towards administrative activities.
8. Cost of funds has been anticipated at 10% and a discount factor of 7 % has been considered.
9. Costs pertaining to charging infrastructure and overhead lines, as applicable have not been considered in the analysis. This is because, the charging infrastructure and overhead lines may not be setup by the operator of hybrid/battery electric/ trolley buses and the same could be installed by government bodies or private players which in turn would be used by multiple operators/e-vehicle owners, etc. in an ideal case. Thus, the operator would be paying a tariff as per usage, which has been reflected in the cost of electricity which has been considered in the analysis.
10. It is to be noted that electric buses last longer than the diesel buses (15 years vs. 10 years respectively) due to a simpler mechanical system with lesser moving parts. Also, during the lifetime of battery electric buses, battery installed in the buses would need to be replaced /refilled after a period of 10-12 years. This completely depends on the manufacturers' built quality and usage of the buses; and varies from case-to-case basis. Hence, the total cost of ownership computation has been done for a lifetime of 10 years, which ideally balances out the need of replacement cost towards batteries in battery electric/hybrid buses and procurement of new diesel buses applicable for the transportation authority after 10 years when its lifecycle is over.

Based on the above mentioned assumptions the TCO which comprises of the total capital cost, fuel cost, and maintenance cost and interest expenses was computed. As can be seen from Figure 23, the total cost of ownership of hybrid bus and battery electric bus are 15% and 48%

[101] Crude Oil Prices - 70 Year Historical Chart, Macrotrends
[102] Monthly Energy Review, U.S. Energy Information Administration, August 2017

higher than that of the diesel bus. However, the TCO for trolley bus is similar to that of the diesel bus.

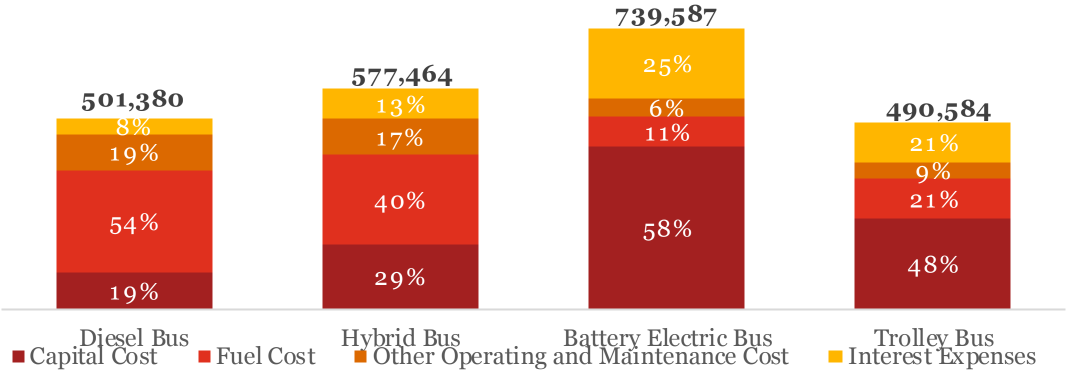


Figure 23: Estimations for Lifetime Cost of Ownership (in USD)

The TCO for battery electric bus is higher due to the greater capital cost incurred for procurement of buses and the related interest expenses. Both these components comprise 83% of the total cost of ownership as compared to only 27% in case of a diesel bus. Further, fuel and maintenance costs are substantially lower, thus incentivizing the adoption of the same through reduction in capital cost borne by the transportation agency. Trolley buses do emerge as a suitable alternative. However, the same would require significant capital cost for setting up of new overhead lines to feed-in electricity required for its operation. Thus, it becomes evident that newer, environment friendly and sustainable technologies currently come with a significant price tag which additionally requires setup of infrastructure.

Also, to address the challenge of higher capital outlay in case of battery electric vehicles, option of battery swapping (discussed in Section 4.2.2 in detail) are being explored across the world. This refers to the practice of replacing a discharged battery with a charged battery. In this system, the bus owner doesn't own the batteries used in the bus. Instead they are transferred on lease/renting basis. This brings down the cost of electric buses substantially as the battery constitutes about 50% of the total cost. In such a case, the total cost of ownership from the current levels of USD 739,587 (Figure 23) reduces by 41% to USD 432,913; making it the most suitable options amongst the rest.

Summarizing the findings in Section 3.1 – 3.5, on comparative analysis of available options:

Feature	Diesel	Hybrid	Battery Electric	Trolley
Price	Low	Medium	High	Medium
Operation Cost	High	Medium	Low	Medium

Feature	Diesel	Hybrid	Battery Electric	Trolley
Infrastructure Cost	Low	Low	Medium	High
Energy Efficiency	Low	Medium	Low (Normal Grid)	Low (Normal Grid)
			High (Renewable Grid)	High (Renewable Grid)
Acceleration	High	High	Low	Medium
Technological Maturity	High	Medium	Low	Medium
Noise	High	Medium	Low	Low
Range	High	Medium	Low	High
GHG Emissions	High	Medium	Low	Low
Total Cost of Ownership	Low	Medium	High	Low

3.6. Market Overview of Different Technologies

3.6.1. Hybrid Buses

Hybrid bus technology is a relatively mature technology when compared to battery electric buses. They are suitable for stop-and-go driving and low speeds, as demonstrated by the New York City Transit bus operations through hybrids buses which have shown about 30% fuel economy improvement. North America has been the leading market for this technology (in terms of total % of bus sales), with hybrid buses capturing 30%-40% of annual bus sales[103].

Europe is catching up with more government funding across countries. United Kingdom, for example has spurred a 50% increase in sales of hybrid buses over the last few years. Germany had a hybrid bus demonstration program, although results have been mixed. Volvo, Scania, Daimler, MAN, Optare, ADL, and Iveco are the major OEMs present in the region.

Annual sales of hybrid buses in China had surpassed that of North America in 2011. Although, they capture a much lower market share than in the United States, the sheer size of China's bus market means it will likely continue having the largest hybrid bus sales annually. The adoption of technology has been quick and the Chinese market has already moved into procurement of battery electric buses. More than 20 major bus manufacturers like Yutong, Wuzhoulong, King Long, and FAW are based out of China which have partnered with the Chinese government to electrify public

[103] Executive Summary: Electric Drive Buses, PikeResearch, 3Q 2012

transport. The Chinese government also runs a program which supports the private sector bus operators to replace a diesel-powered bus with hybrid electric bus[94].

3.6.2. Battery Electric Buses

The number of battery electric buses doubled in the year of 2016 with 345,000 buses currently present across the globe. China is the global leader in this market with 343,500 units in 2016. The Figure 24 depicts the exponential growth of battery electric buses. A key point to be noted is that, sales of hybrid buses were significantly high during 2011-2014, after which the focus shifted completely to battery electric buses.

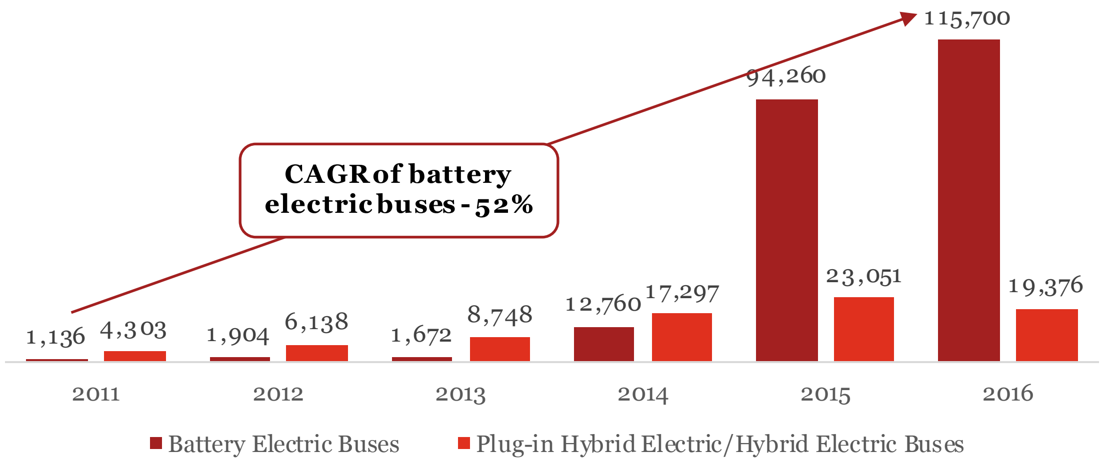


Figure 24: Yearly Electric Bus Sales in China[104]

Shanghai, Shenzhen and Beijing account for maximum electric vehicle sales and contribute heavily in terms of electric buses too. For example, Shenzhen city had 4,887 pure electric buses in 2016 supported hugely by the financial incentives provided on the purchase of electric buses[105].

Table 26: Key regional programs and incentives in cities of China

City	Key Regional Programs / Incentives
Shanghai	• Priority to operate electric buses in the city • 800 charging points dedicated to buses • Pure electric public buses received a 165,000 CNY (USD 26,400) operation subsidy per year from 2013 to 2015[106]
Shenzhen	• 4,887 buses in the city along with a target of 100% electric vehicles by 2017 • Subsidies for operation of electric public buses • An online portal designed to facilitate users to suggest new routes - Currently 410 routes with 22,000 passengers per day; 100 new routes planned before the end of 2016)
Beijing	• Regional subsidies of 300,000-500,000 CNY (USD 45,000-75,000) for battery electric buses • Priority to operate electric buses in the city

[104] China Electric Bus Sales Still Exploding, CleanTechnia, Article Published on 25 February 2017
[105] Global Electric Bus Market to Witness 33.5% CAGR by 2025: P&S Market Research, 20 June 2017
[106] Electric Vehicle Capitals Of The World, The International Council On Clean Transportation, March 2017

The Indian government has also shown keen interest with electrification of public mobility. Currently many municipal corporations have started pilot projects on electric buses and have placed orders for procurement and operations in specified areas of key metropolitan cities.

Europe accounted for 1,273 pure electric buses in the global market which also doubled from 2015 inventory, demonstrating a phase of commercial development. In Paris, for example, transport operator Régie Autonome des Transports Parisien (RATP) has started trials using 16 BYD electric buses and ~3,600 electric buses are expected to ply in the Greater Paris network by 2025. Even Amsterdam's Schiphol airport has started the deployment of 35 electric buses charged with solar energy from the largest charging station for electric buses in Europe. In the Zürich metropolitan area, Switzerland diesel trolley buses are getting replaced with electric buses (cross reference with IEA outlook).

Currently, Southeast Brabant, a district in Netherlands has 43 electric buses operating across 8 zero-emission routes since December 2016. The fleet had surpassed 1 million km in May 2017 with several buses covering 340 km in a day. This becomes a critical factor to note as long distance travel with full passenger capacity is soon expected to become a reality. It is estimated that these buses have eliminated 4.7 tonnes of NOx and over 1,000 tonnes of CO_2 in a period of four months of operation from some of the densest parts of cities, which in turn translates into improved health for the people living in the area[107]. Brazil, Côte d'Ivoire and Uruguay are some of the other countries expected to be early beginners in using of electric buses in the Rest of the World region.

Several global and regional bus manufacturers have forayed into the market for development and commercial sales of battery electric buses. With the technology still under development phase and countries trying out various pilot projects, there is a lack of clear leadership of manufacturers in this segment. Manufacturers have exported their product lines across the globe to support the testing phases which has led to countries initiating procurement deals. However, Chinese players lead the number of electric bus deliveries in 2016 with approximately 53,600 bus deliveries in[108] [109].

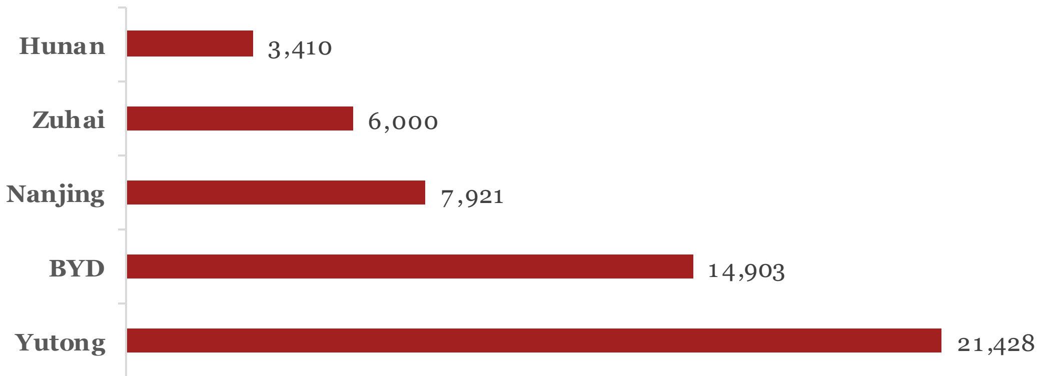


Figure 25: Electric bus deliveries by Leading Chinese manufacturers in 2016

[107] Dutch Transit Agency Hermes Achieves 1,000,000 All-Electric Kilometers, EVObsession, Article Published on 8 May 2017
[108] Extract from the study: Buses - Global Market Trends, SCI Verkehr
[109] China 100% Electric Bus Sales Grew To ~115,700 In 2016, CleanTechnia, Article Published on 3 February 2017

Some of the key players foraying in this market include AB Volvo, Alexander Dennis, Ashok Leyland, Daimler, Ebusco, Proterra, Solaris, and Tata Motors.

3.6.3. Trolley Buses

Trolley buses have been present in the European Union since World War II. The fuel crisis of 1974 and increasing cost of fuel further led to the rise in public awareness of environmental issues steering the development of trolley bus transport and modernization of the same. In the 1990s, low floor trolley buses were introduced. Over the period of time, many authorities across Europe were also shut down due to difficult economic condition of the country or because of financial distress of operators. As of 2013, largest number of trolleybus networks in Europe can be found within countries like Bulgaria, Czech Republic, Italy, Romania, Switzerland and Ukraine. A brief overview of the trolley bus network (as of 2011) in selected cities has been represented in Table 27.

Table 27: Overview of trolley bus network in selected cities

Parameter	City (Country)					
	Salzburg (Austria)	Eberswalde (Germany)	Gdynia (Poland)	Brno (Czech Republic)	Parma (Italy)	Szeged (Hungary)
Route length (km)	64	16	44	54	18.6	30.4
Number of lines	9	2	12	13	4	5
Number of vehicles in fleet	94	13	85	147	29	44
Average vehicle age	8	2	8.9	14.7	20.9	16.6
Total vehicle-kilometers in a year (million)	5	0.75	5	6.2	0.60	2
Number of passengers in a year (million)	40	2.8	22.7	42.7	7.1	12.9

More than 300 electric trolley buses and an additional number of hybrid buses operate in the San Francisco metropolitan area, which also is the electric vehicle hub of United States. Approximately, 200,000 trolley boarding a day is observed, with trolley customers constituting 30% of the total ridership on 15 routes in the network. Currently, older fleet of trolley buses (rolled out in 2001) is getting replaced in a phase-wise manner by hybrid as well as newer trolley buses[110].

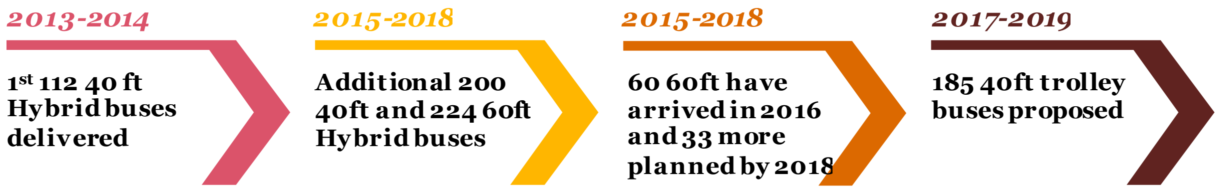


Figure 26: Procurement plan of electric buses, San Francisco Municipal Transport Agency

[110] Completing a new generation of Investment for our bus fleet, SFMTA Board of Directors, April 2017

4. Deployment Requirements of ERMT

4.1. Electricity Requirement

As all SAARC Member States are net importers of oil, shifting to electric buses makes an economic sense as it will help them curb their oil import bills and reduce their current account deficits. At the same time, adoption of electric buses will spur electricity demand. Meeting electricity requirements is a challenge for the SAARC region as many of the countries are still trying to reach the 100% electrification targets. It is, therefore, necessary to analyze the demand of electricity that will arise through implementation of Electric Road Mass Transportation.

Case Study: Example of minimum requirements given certain conditions

As the SAARC Member States have varying landscapes, ranging from deserts to mountains, and have different population densities, rate and spread of urbanization; the frequency and need for bus operations will vary greatly. In order to design a bus network of ERMT sufficing the needs of the countries, micro-level studies will have to be conducted by respective agencies. However, an estimate can be arrived at, on the requirements for operating in a region/area using battery electric, hybrid and trolley buses.

In order to derive the requirements for setup of ERMT, the case considered assumes 144 buses covering 48 routes in the region. Of these, it is supposed that 96 buses will operate across 24 routes and the remaining 48 buses will be operating across remaining 24 routes. All the buses will need to be charged once every day. Accordingly, 24 routes will have 96 charging stations (4 stations on each route) and the remaining 24 routes will have 48 charging stations (2 stations on each route). It is assumed that all buses will have battery capacity which is just enough to allow them to make exactly 8 trips (covering the length of the route twice during each trip). We assume that these buses have capacity of 300 kWh which is just enough to help them cover those 8 round trips, say, of 12 km each side, at approximately 1.5 kWh/km. This will lead to total trips done by all buses in a day to be 27,648 km.

Table 28: Assumptions for analyzing bus technologies

Assumption	Battery Electric Bus	Hybrid Bus	Trolley Bus
Number	144	144	144
Routes Covered	48	48	48
Length of One-Side Trip	12 km	12 km	12 km
Total Trips in a Day	8 (16 one-side trips)	8 (16 one-side trips)	8 (16 one-side trips)
Electricity Tariff	0.1 USD/kWh	0.1 USD/kWh	0.1 USD/kWh
Electricity Based Operation	100%	20%	100%
Charging Stations	144	29 (for 20% operation through electricity)	-
Battery Capacity	300 kWh	60 kWh (for 20% operation through electricity)	-

Therefore, these buses will need 300 kWh every time they are charged. Thus, the electricity consumption will be equal to 43,200 kWh every day. The total cost of ownership computations in the section above considers 0.1 USD/kWh as the electricity tariff which leads to the cost of electricity for the buses to be around USD 4,320 daily and USD 1.58 million in a year.

The analysis for hybrid buses is a bit more complicated. Assuming these buses will have 80% operation powered by diesel and 20% by electricity, the buses will need 20% electricity of the daily electricity requirement of a battery electric bus. This will take the electricity required to 8,640 kWh every day, which will cost 864 USD. The remaining distance will be covered by diesel.

The analysis of trolleybuses is relatively easier. Assuming, 0.52 km/kWh (1.92 kWh/km) we get the cost of electricity per km as 0.19 USD/km. Therefore for the buses in the case, total electricity consumed daily would be 53,084.16 kWh.

It is clear from the analysis that a fleet of Trolleybuses would consume more electricity than Battery Electric Buses. Therefore, it's efficient and cheaper to use Battery Electric Buses for ERMT operations.

Table 29: Assumptions pertaining towards electricity requirements of different technologies

Technology	Battery Electric Bus	Hybrid Bus	Trolleybus
Efficiency (kWh/km)	1.5	1.5	1.92
Electricity Consumed/ Day (kWh)	43,200	8,640 (20% runs on electricity)	53,084
Electricity Consumed / Year (MUs)*	15.76	3.15	19.37
Cost of Annual Electricity (USD million)	1.58	0.31	1.94

*assuming all days working

4.1.1. Sourcing the energy requirements

The SAARC Member States are going through rapid expansion of their energy infrastructure with new generation units being installed, transmission networks being laid down and distribution infrastructure getting set up to ensure last mile connectivity to the consumers. As nations decide their ERMT policy, it will be necessary for them to decide the source for generation of electricity required to power the electric buses which will be operating in the decided routes and areas.

There are two ways to fulfill the electricity requirement. It can either be fulfilled through the current grid mixture, which is dominated by conventional sources of generation, or through a supply from only renewable energy sources installed at the charging stations. As analyzed in the previous section, using renewable energy to generate electricity gives the highest Well-To-Wheel fuel efficiency. Electricity generated from renewable energy gives 50% reduction in consumption of energy compared to diesel bus, which is much more than the 9.68% reduction from electricity from grid. Electricity generated completely from conventional sources will have even lesser reduction, and will thereby be less efficient. Further, electricity generated from renewable sources will have about just one-sixth of the GHG emissions till the WTT stage compared to the electricity that is taken from the current grid supply. In this case too, it can be extrapolated that electricity from thermal (predominantly coal based power) will generate even more GHG emissions. Hence, supply of the electricity to the charging point from thermal resources may hamper the intended impact of using electric buses in reducing harmful GHG emissions.

4.2. Infrastructure Requirement

To ensure optimum utilization of electric buses, it is essential to set up a charging infrastructure, also known as Electric Vehicle Supply Equipment, which is convenient, affordable and accessible. In this section we will look into the various options available for setting up charging infrastructure.

All the options for EVSEs have three main points of consideration:

1. Level: describes the power output of an EVSE outlet;
2. Type: refers to the socket and connector used for charging; and
3. Mode: describes the communication protocol between vehicle and charger.

As different countries started developing their own charging infrastructure which suited their existing electricity infrastructure, differences started emerging in the EVSE equipment around the world. To ensure universality of electric vehicles, IEC (International Electro-technical Commission) came up with nomenclature for different chargers. The conventional plug in charger has been standardized by IEC as IEC 61851-1 for mode and IEC 62196-1 for plug.

Modes are the most important component for setting up the charging infrastructure. There are 4 modes (Mode 1- 4). Mode 1 refers to connection using a non-specialized infrastructure, say a household circuit. Though such circuits generally have a fuse, the safety of the RCD (Residual

Current Device) cannot be guaranteed. Mode 2 refers to those connections which have a non-dedicated socket and circuit outlet but have a cable-incorporated RCD. The output of this mode is general limited to 3kW in residential use and 7.4 kW for industrial use. Mode 3 refers to dedicated EV charging systems based on AC supply. The control, communication and charging functions are incorporated in the charging outlet. While Mode 1-3 are AC charging stations, Mode-4 refers to dedicated DC charging stations. The output range is generally from ~10 kW to over 100 kW[111]. Of these modes, Mode 3 is the most common method and mode 4 is the fastest charging method[112].

To calculate the cost of setting up the charging infrastructure, the above scenario of setting up an electric bus network has been considered with a network of 48 routes, serviced by 144 buses. Of these 48 routes, half have buses with a frequency of one bus in every half an hour, and the rest have buses at a frequency of one bus in one hour. Buses operate for 16 hours each and it takes exactly one hour for each bus to reach from one end of the route to another. In the following sections cost of such a bus service has been analyzed.

4.2.1. Fast Charging

For charging of electric buses which can satisfy public needs, there are only two possible methods, Mode 3 and Mode 4. While Mode 4 stations can be installed at trip ends or relatively longer-haul stations for quick charging, it will be economical to use Mode 3 stations for overnight charging[112].

Electric buses can be charged through both AC and DC based charging stations. For AC charging, electricity is supplied to the on-board AC charger (on the bus), which converts the supplied AC current to DC that can be used for charging the battery. According to Society of American Engineers (SAE), an AC charger, with a maximum continuous input of < 8 kW charging station, is capable of providing 8-25 km of electric range per 30 minute charge. A DC charger with higher voltage, current and maximum continuous input power of 240 kW supplies current directly to the battery and can give a charge to last up to a range of 125 km in 30 minutes.

The actual charging time for any bus will depend on both the charger and the battery type in the bus. Thus, the charging time cannot be determined solely by just charger type. However, for ease of planning and implementation, a broad classification of charging type is useful. To ensure the same, the Department of Heavy Industries under Government of India has recently come up with a classification for DC chargers. The department has also recommended use of DC chargers instead of AC chargers to eliminate the need for on-board AC to DC converters, thereby reducing the cost of electric buses. Accordingly, the two types of DC chargers are:

- Level 1 Charger providing output between 10kW and 15 kW

[111] A Guide to Electric Vehicle Infrastructure: Beama, 2015
[112] Techview Report: Electric Buses, Fraunhofer MOEZ

- Level 2 Charger providing output between 30 kW and 150 kW

Currently, the Government has identified specifications for only Level 1 chargers which are estimated to cost around USD 2,500. The technical specification for the same is as follows:

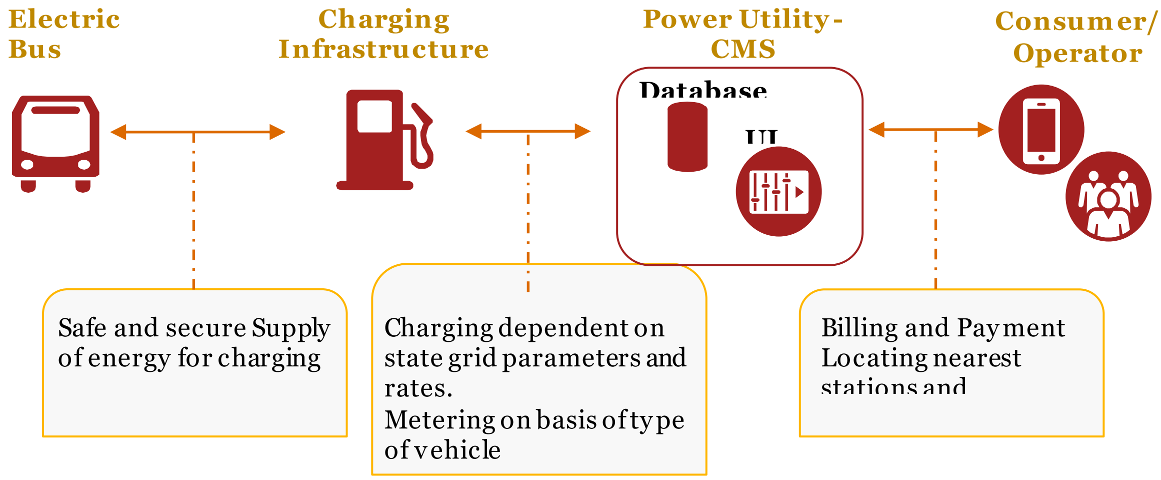
Table 30: Specifications of Level 1 chargers, Department of Heavy Industries under Government of India

Input Requirements		
1	AC Supply System	3-Phase, 5 Wire AC system (3Ph+N+E)
2	Nominal Input voltage	3-Phase, 415V (+6% and -10%) as per IS 12360
3	Input Frequency	50 Hz ± 1.5 Hz
4	Supply side AC Connector for Input	IEC 62196 Type 2 as per Annex 1
5	Input Supply Failure backup	Battery backup for minimum 1 hour for control system and billing unit, to enable activities such as billing, to be provided.
Output Requirements		
1	Output Details	Suitable for 48V and 72V vehicle battery configuration
2	Charger Configuration Types	i. Type 1: Single vehicle charging at 48V or 72V with a maximum of 10kW power, or a 2W vehicle charging at 48V with maximum power of 3.3 kW. ii. Type 2: Single vehicle charging at 48V with a maximum of 10kW power or 72V with a maximum of 15 kW power or a 2W vehicle charging at 48V with maximum power of 3.3 kW.
3	Output Current	200 Amp Max
4	Number of Outputs	2
5	Output Connectors	2 output connectors
6	Output Connector Compatibility	One connector with GB/T 20234.3 as per Annex 1 + 1 connectors to be defined
7	Converter Efficiency	> 92 % at nominal output power
8	Power factor	≥ 0.90 (Full load)

In the test case, this would lead to a total investment of approximately USD 360,000 for setting up a charging infrastructure built completely using DC (mode 4) level 1 chargers.

Setting up of complete and comprehensive Electric Vehicle Supply Equipment needs integration of multiple level of services through a Central Management System (CMS). While the chargers can be just responsible for ensuring safe and secure supply of electricity to the electric buses, they have to be integrated with the database of a power utility to ensure and enable continuous supply from the grid. This will bring enhanced stability to the charging infrastructure. The data can also be used to provide bus operators statistics about their vehicles, maintain their billing cycles and locate charging stations. Utilities can use this data to monitor grid stabilities and for planning installation

Figure 27: Network for setup of charging infrastructure, DHI



of locations for charging stations. Further, provision for supply of electricity from localized renewable sources can be integrated into the system which would supply parallel to the grid electricity.

4.2.2. Battery Swapping

Battery swapping refers to the practice of replacing a discharged battery with a charged battery. In this system, the bus owner doesn't own the batteries used in the bus. Instead they are transferred on lease/rental basis. The main advantage of using this is reduction in haul time for buses. Also, the cost of electric buses would come down substantially as the battery constitutes about 50% of the total cost[113]. With standardized batteries available for swapping, the total cost of ownership would come down significantly.

The main challenge with this technique is the increased cost of setting up the infrastructure required for the increased number of batteries. This is because the number of batteries required for maintaining the battery swapping infrastructure will increase. Additional cost will also be incurred due to additional storage requirements and procurement of sophisticated equipment like robots which are required at service station to handle high volume of swapping operations.

Rome has one of the largest fleet of electric buses in Europe. The fleet has been completely composed of electric buses since 1982[114]. The bus system carries about 945 million passengers per year[115]. 60 minibuses in this fleet operate on 5 routes using battery swapping. This is a part of a project in the "Limited Access Zones" which aims to make the city centre a zero emission area. Apart from these, the city also has a setup of trolley bus lines.

Battery swapping has recently become common in some Chinese cities like Shenzhen and Beijing. In Hangzhou, a fleet of about 500 electric taxis use battery swapping. Starting its operations in 2009, the fleet has already covered about 34 million km. The average distance covered by the fleet

[113] "E-bus cost not finalized; BMTC consults experts", article published in Times of India on Oct 31, 2016
[114] Electric minibuses, Eltis, The urban mobility observatory, Article Published on 29 August 2014
[115] EV City Casebook: 50 Big Ideas: Shaping the future of Electric Mobility, Toyota i-Drive, 2014

is approximately 230 km per taxi per day. During this operation, a taxi has to switch batteries twice or thrice a day. These swapping stations are provided by the state's largest power provider, State Grid Corporation of China[116]. The semi-automatic process uses two workers and a mechanical arm, completing the swapping exercise in 5 minutes. These recharged batteries can also be used to store power and, if need be, supply it back to the grid.

Battery swapping has been gaining attention in other countries too. Tesla has plans to open swapping stations in California. Greenway, a Slovakian company, has built a network of swapping stations for the delivery vehicles it operates. In Taiwan, a battery exchange system has been built for battery electric buses.

Recently in India, the ACME Group launched a battery charging and swapping station in Nagpur. The station is a Pilot Project servicing about 200 vehicles including buses, autos and cars. While swapping, the station accepts and provides batteries which are ICAT (International Centre for Automotive Technology) and ARAI (Automotive Research Association of India) approved. It also has an option to provide power to grid from batteries. ACME claims that the battery swapping time is lesser than the time taken for filling fuels[117]. It is important to note that ACME is also a retailer of lithium batteries which have BMS (Battery Management System). It has a manufacturing facility of 28 acres at Rudrapur, Uttarakhand.

4.2.3. Overhead Lines

While Charging Stations and Battery swapping stations are necessary for battery electric and hybrid buses, trolley buses need an investment in overhead wires[118] and substations. The power in these lines generally ranges between 110kW to 180 kW. In case such power lines exist in the vicinity, the same can be used to operate trolleybuses. However, while planning the use of trolleybus, a determining factor can be obtaining the necessary permits for its operation. The network of electric lines required to provide electricity to trolleybuses can hamper the aesthetics of the city and can also lead to safety concerns. The estimated cost of installing trolley bus overhead wires and substations in Poland was around USD 47,232.5/km and USD 0.91/km[119], respectively. However, it can be noted that existing substations can also be utilized for powering up the overhead lines for the operations. Another challenge associated with installation of overhead lines are the ROW (Right Of Way) issues. These are generally related to land acquisition and environment clearance.

[116] Battery swapping becoming common practice for commercial vehicles, Electronics News, Article Published on 22 May 2013

[117] ACME launched India's 1st Battery Swapping & Charging Station with Lithium Batteries at Multi Model Electric Vehicle Launch on 26th May at Nagpur, ACME Group Press Release

[118] Overhead wire network here refers two way direction connection between any two points.

[119] Costs are calculated by a study on TROLLEY Transport Mode Efficiency Analysis conducted by Trolley Company on August 2013. The costs have been converted to USD by taking conversion rate of 1 PLN = 0.31 USD which is the average of value of PLN during August 2013.

4.3. Investment Requirement

4.3.1. Capital Costs Required

In this section, the capital costs required for setting up the network of the Electric Road Mass Transportation for the case considered above have been calculated.

The first analysis is of the battery electric bus technology. For setting up a battery bus network, there will be two major requirements, battery buses and charging infrastructure. The cost of the battery buses will be decided majorly by whether a country imports such buses or manufactures them indigenously. Further, the manufacturing cost will also depend on factors like availability of raw material, level of R&D technology available in country and availability of semi and fully skilled persons.

The cost of importing **battery electric buses** will depend on countries from which they are imported. While a bus from North America and Europe generally costs around USD 650,000 – USD 750,000 and USD 600,000-700,000 respectively, battery electric buses from India and China cost around USD 350,000 -400,000 and USD 400,000-500,000 respectively. Taking the cost of Chinese buses as the cost of procurement, in the case considered above, cost of entire fleet, of 144 electric buses, will be USD 64.8 million.

Similarly, in the case of charging stations the costs will depend on whether the buses are being produced indigenously or they are being imported. The cost for charging stations, which have about 50kW capacity can be around USD 33,000[120]. Such a DC charger (rapid charger) will allow the electric buses considered in the above case to be charged in approximately 6 hours. The cost of implementing charging infrastructure in this case will accordingly be USD 4,950,000, approximately 5 million USD. Therefore, the capital cost in the above case will be approximately 70 million USD.

For **hybrid buses**, the cost is around USD 450,000 - 600,000 in North America, USD 450,000 – 550,000 in Europe, USD 140,000 – 220,000 in China and USD 200,000- 250,000 in India. Importing from these countries is an option for those SAARC countries which currently do not have manufacturing setups. The cost for the entire fleet in the case considered above would be around USD 25.9 million. The advantage of implementing hybrid infrastructure is that it gives the country time to phase out the setting up of charging infrastructure gradually as hybrid buses can operate using conventional fuels in the absence of charging infrastructure. Assuming an operation which is 20% electricity based, there will be a requirement of 29 charging stations for the case considered above. This will take the cost of charging infrastructure to USD 957,000. This makes the total cost of implementing hybrid bus based system for our considered case to be approximately USD 27 million.

For **trolleybuses**, the cost of investments include the cost of purchase of buses and installation of the overhead lines. A regular trolleybus costs around USD 250,000. The transmission line for same

[120] Based on prices of ChargePoint CPE 200 Fast Charger-CHAdeMO & CC and BTC Power Chargion

would also cost about USD 47,000/km (two-way). There will be an additional cost for obtaining licenses, like Right of Way, due to the presence of electrical wires which can cause safety hazards, and other indirect expenditures. For the case considered above, the cost for implementing this infrastructure would be USD 36 million for buses and USD 27 million for the overhead wires. The total cost for same would be around USD 63 million. However, in these considerations for a trolleybus infrastructure the cost for associated permits has not been considered.

Table 31: Investments costs involved towards various technologies for the case considered

Technology	Battery Electric Bus	Hybrid Bus	Trolley Bus
Number	144	144	144
Electricity Based Operation	100%	20%	100%
Cost of Buses (USD million)	65	26	36
Cost of Infrastructure (USD million)	5	1	27
Total Cost (USD million)	**70**	**27**	**63**

4.3.2. Operational and Maintenance Costs

Apart from the initial infrastructure costs, the ERMT infrastructure will also incur operational and maintenance costs. These costs can vary greatly across different countries and locations across SAARC Member States. In this section, the different costs have been analyzed which will be incurred in operations and maintenance of these buses.

Operational Cost:

- Fuel Costs: These generally constitute the largest share of operational costs. Fuel costs can be greatly reduced for daily operations by moving from diesel operated buses to electricity operated buses. The actual savings will vary based on the price of electricity and diesel in a particular region.
- Salaries: Salaries of drivers, conductors, administration staff, etc., generally constitute the second largest segment of the operational costs. Salaries will generally be determined by an interplay of government guidelines and the difference in demand and supply of required labour.
- Permits, Tax and Insurance: Cost of permits, taxes and insurance can vary greatly between countries. These can vary in different parts of the countries as well. It can also be a way for the government to incentivize purchase and/or operations of electric buses. The government can directly reduce costs of permits and taxes and can indirectly subsidize insurance for ERMT buses.

Maintenance Costs:

- Annual Maintenance Contract: The bus operator can decide to outsource the maintenance cost to a third-party service provider. In such a case, an annual maintenance contract cost will be incurred to the operator. In case the vendor decides not to outsource this task, there will be two key cost components, namely spares and regular inspection.

- Spares: Various parts of a bus can experience wear and tear, or may need replacement due to mishandling of the vehicle. As electric buses have lesser moving parts, they are expected to require less part replacements over the course of their lifetime.
- Regular inspection: To ensure safety of passengers during the course of entire operations, it is necessary to hold inspection at regular intervals. During such inspections various parts of the buses are checked and repaired, if need be.

4.4. Technical Capacity Requirement

With adoption of new electric bus technologies, training the related personnel is very important. The training imparted should cover the basic two aspects: understanding the vehicle being used and understanding the external environment under which the same is being run. The bus drivers hold the key as they experience tough conditions. They may have to drive for long hours and need to be attentive along the journey which may have traffic congestions and deteriorated road conditions. If proper attention is not being paid to them, stressful conditions may impact the operations and, further, on safety of passenger along with their perception of the transportation services. Additionally, with adoption of ERMT, new employees may have to be recruited for operation and maintenance of charging stations who should have the know-how of these stations as well as the vehicle in use. Ideally, these employees could have the joint responsibility of maintenance of buses and operation of charging stations.

Keeping these aspects in mind, training sessions need to be designed to build the technical capacity supporting the ERMT infrastructure. These training sessions should encompass three components: Motivation, Technology and Driving technique.

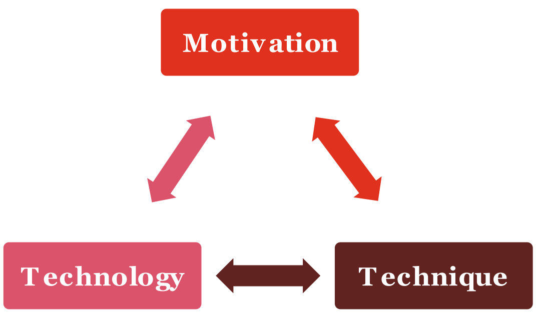


Figure 28: Key parameters of Technical capacity building

Motivation:

It is necessary to understand that the drivers choose this profession as a source of livelihood only. Social and environmental benefits from change in technology may not be widely accepted. Thus, fundamental focus on motivation and ways to reduce their stress should be central to the trainings imparted. Some key points to be considered are as follows:

- Acknowledgement of the challenges they face while driving
- Focus on their roles and responsibilities, majorly on passenger safety and comfort
- Building importance of their role and developing a sense of pride as they are contributing towards improvement of social and environmental factors
- Introduction of incentive schemes to encourage continued performance. The incentives can be linked to various components like on-time services, reduced maintenance required, fuel efficiency gained, etc.

Technology:

With the change in the bus technology, the bus drivers need to be made aware of the bus operations in detail. Bus characteristics related to the battery units in case of battery electric buses, change in transmission and drivability, need for charging and frequency of the same need to be made clear to them. The training sessions should include techniques to recover from mechanical problems in advance along with basic knowledge on repairs and maintenance. Hence the training should incorporate functional properties of the buses in detail.

Technique:

Driving technique affects the vehicle conditions, efficiency, passenger safety and comfort. Emphasizing on these factors in the training sessions practicing on the new buses in a controlled environment should be mandated. In order to facilitate the same, training institutions across important locations can be built to support the adoption of the new technology. Further, these institutions would also provide skilled manpower who could be recruited by various operators or implementing agencies for responsibilities ranging from operations to maintenance of the buses and charging infrastructure.

4.5. End User Acceptability

Transportation services being the primary infrastructure services in any part of the country, serves the purpose of movement of goods and people. The quality of the transportation services is derived around solving demographics, socio-economic, environmental, technological and financial challenges. This leads to efficient, resilient and sustainable performance of the services and makes the region, city or country, a provider of a better quality of life to its citizens.

In order to build end user acceptability, performance of the electric road mass transport system in an area would be a key. Hence, pilot projects need to be started across various regions/cities to demonstrate the same. These pilot projects, post improvement and acceptance from users, can be then implemented on a large scale.

Further, there needs to be a holistic approach in monitoring the performance by examining the transport mode and the operator. Two key dimensions which are important in doing the same are: Efficiency and Attractiveness.

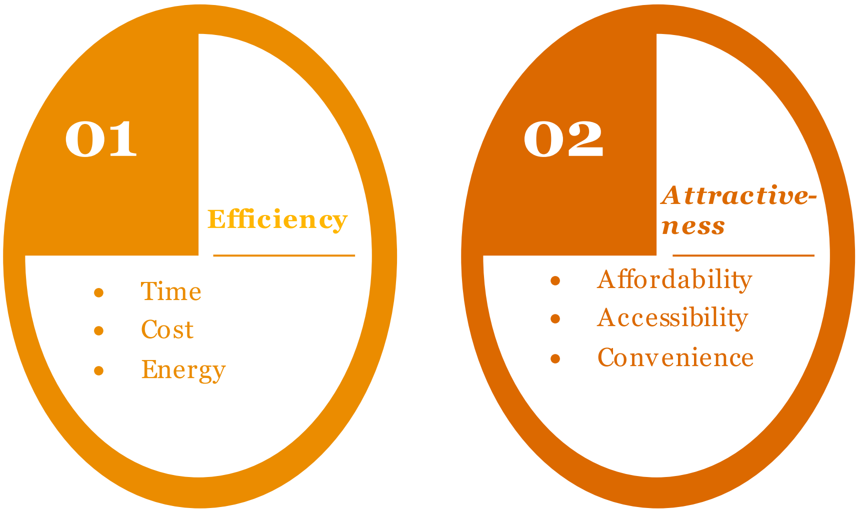


Figure 29: Key parameters of end-user acceptability

Efficiency:

This refers to how efficiently the electric road mass transport is functioning. It can be evaluated through measuring time, cost and energy efficiency.

Time efficiency would be assessed with reference to the time taken to travel from one point to other and whether the same was reduced or not by the adoption of ERMT. This further translates down into the impacts it had on reduction of traffic congestion and ensuring time reliability, i.e., certainty of reaching the destination in foreseen time.

Cost efficiency is a crucial indicator and measure for effective acceptability. It would be important to measure whether ERMT design is providing services at costs lower to or at par with current fares to the larger section of the population. Also, if the cost parameters are not attainable due to increased capital cost of the services, provisions of subsidies from government or public authorities would be needed to be built into the same.

As discussed in the above sections, energy efficiency would be attained through the implementation of ERMT, replacing the diesel buses plying across cities. Users would need to be made aware of the benefits of adopting the enhanced public transportation network and impacts it could bring on the environment by reduction of pollution levels in their regions and cities. Consumers who have the capacity to pay should feel that adopting such public transportation services would contribute to the greater good of the society.

Consumer awareness can be enhanced through various marketing tools using print media (newspapers, magazines, etc.) and social media to create a strong impact on people's perception and change the current mindset. The communication should be effective in generating awareness and building long term relationship with the transportation service. However, it is to be noted that everything would be dependent on the time and cost efficiency levels motivating users to adopt it as a way of life.

Attractiveness:

Performance of the ERMT as compared to existing public and private transportation solutions would determine the attractiveness for the end-users. A thriving ERMT service would enable current users to keep using the new transportation services and also attract new users who currently use their own private transport. If the ERMT solution is more accessible, more affordable and more convenient than the current modes, the services would become desirable for the users. Some of the key points for consideration to build attractiveness are as follows:

- ERMT solution to be accessible to the users from their home or workplace, with respect to ease of reaching nodal points
- Affordable to majority section of users with a goal of maximizing the public transport use
- Convenience to the user, in terms of experience during traveling is a must. Basic factors like sense of security and cleanliness being maintained are crucial.

Inter-modality of ERMT with existing modes of transportation will also play an important role so that the transfer of passengers from one mode to other is smooth and is supported through easy to use interfaces having integrated timetables and ticketing systems. Hence, designing of the ERMT solutions in a city or region will be the most important factor for enhanced end user acceptability.

4.6. Market Potential

Various technologies discussed in the sections above vary in terms of the benefits realized and amount of investment required to set up the same. The technologies have been mapped according to the potential of impact (benefits gained in terms of thermal efficiency, decrease in fuel cost, reduced GHG emissions and range parameters) vis-à-vis ease of implementation (total cost of ownership, setup of extra charging infrastructure or overhead lines and training needs) to understand the relative standings of the same.

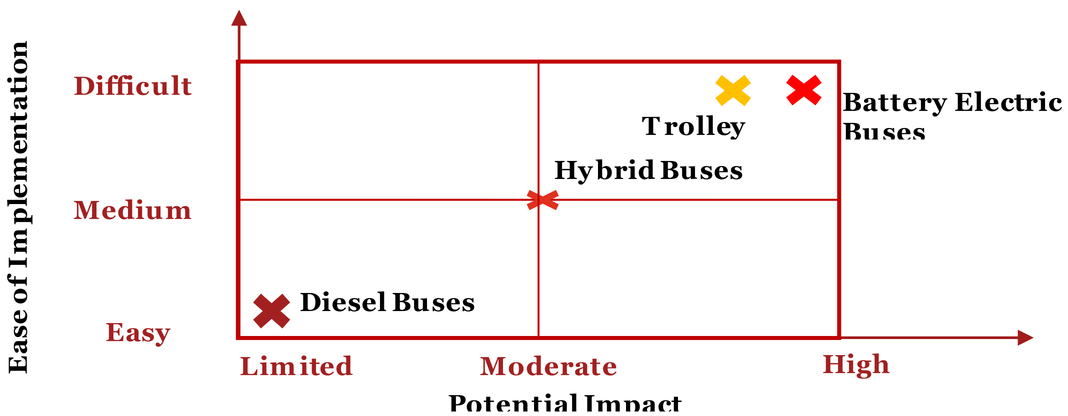


Figure 30: Potential Impact of technology vis-à-vis Ease of Implementation

As can be seen from Figure 30, the potential impact of battery electric and trolley buses are significantly high. However, implementation challenges in terms of higher procurement cost, setting up charging infrastructure and overhead lines act as a hindrance for faster adoption across the globe.

With the stock of electric buses in 2016 being twice the amount in 2015, a shift in procurement pattern has slowly started. The social and environment benefits surpass that of the traditional buses and hence, an increase in adoption of the new technologies has been witnessed. Though trolley buses have been a part of the public transportation system, hybrid and battery electric buses have made inroads in the market.

The global electric bus market is expected to grow at ~30% in the next few years till 2020, led by China which is currently supported by government interventions. North America and Europe also expect fast adoption of the electric buses with new orders for adding buses to their existing fleet or replacing the same. The market potential and targets for SAARC Member States would be discussed in Section 7.

However, the growing size is dependent on multiple factors which includes the following:

- Incentives or subsidies provided by the respective governments to cover the incremental cost of ownership;
- Support from International Institutions for financing various segments of the value chain like charging station infrastructure, setup of manufacturing units, etc.;
- Strong commitment shown by the governments by having aggressive targets and designing of policies and regulations to support the same; and
- Decreasing cost of technology, specifically falling prices of batteries that can accelerate the rate of adoption and market penetration of battery electric buses.

5. Lessons learnt from the Success Stories

The section covers two relevant case studies on China and San Francisco, which have had reasonable success in public use and adoption of electric vehicles. While China has seen more support from its Central Government, Government of the People's Republic of China; the success in San Francisco is mainly attributed to the efforts of the State Government. This section also summarizes various types of enabling policy frameworks in European countries and key learnings from it, which can be introduced in deployment of electric vehicles or electric buses across a region or a country.

5.1. China

China is home to more than 99% of all electric bus stock in the world. The huge success in implementing electric road mass transportation has been due to well laid out government policies and sustained long term efforts to promote both electric buses and other electric modes of transportation for the citizens.

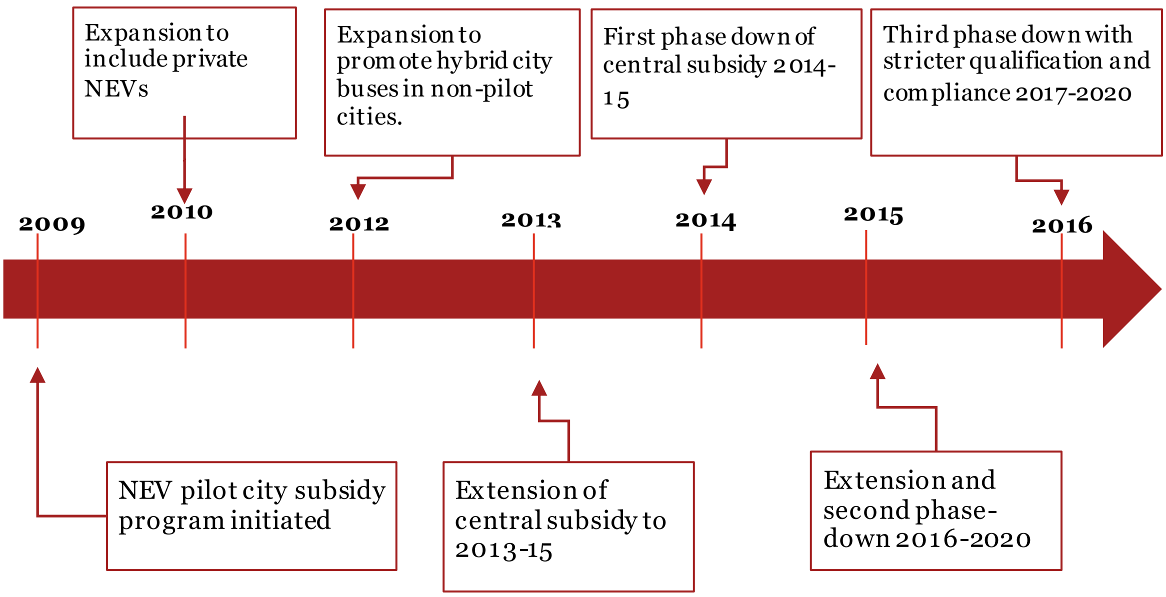


Figure 31: Timeline of policies for electric vehicle adoption by China

China has a target of deploying 5 million New Electric Vehicles (NEVs) by 2020[121]. By the end of 2014, the Central Government had already spent approximately 33.4 billion Yuan (~ USD 4.84 billion) on NEV subsidies.

[121] Chinese State Council. (2012). Energy-saving and new energy vehicles industry development planning (2012-2020). Retrieved

Policies and Legislation:

The Chinese electric vehicle market growth has largely been due to the subsidies and incentives provided by the Central Government. The government started investments in Research & Development from 2001, through the Tenth Five-Year Plan (2001-2005) and then also introduced the Auto Industry Development Policy, in May 2004, with an aim to prioritize development in hybrid technology and other Plug-in Electric Vehicles (PEVs). A similar focus was also described in the document named China Medium and Long-Term Science and Technology Planning (2006-2020) introduced in February 2005. Eventually government policies became more focused on vehicle demonstration, evident in the form of the program "Ten Cities and Thousands Energy-Saving & New Energy Vehicles Demonstration Application Project". The main focus of the program was to promote the PEV demonstration through subsidies. To symbolically emphasize the importance of electric vehicles for the government, Jinping Xi in May 2014, even visited a PEV company based in Shanghai and later stressed that the development of PEVs will be key for the Chinese automotive industry in upcoming years. Though policies for subsidies did exist earlier, the PEV market started to accelerate since 2014 when massive incentives were announced by the government.

- In February 2014, exemption of certain electric vehicle models from vehicle purchase tax (which accounted up to even 40% of the vehicle's purchase cost) was announced.
- In July 2014, Chinese PEV models were listed in the directory for government vehicle purchases. Policies on incentives and subsidies for EV charging stations were introduced later in 2014.
- In November 2014, consumption tax on petroleum products was increased, increasing prices of diesel/gasoline products and thus indirectly promoting adoption of electric vehicles.
- **The government also introduced many incentives and subsidies focused solely on electric buses. Though initial subsidies, introduced in 2009, were available only for vehicles procured by government agencies, these incentives were extended to all in 2013.** Table 32 provides a list of such subsidies allocated from 2013 till 2015. Though there was a continuous decline in subsidies for electric cars/light duty vehicles from 2013 to 2015, the subsidies for electric buses, except for those powered using fuel cell technology, remained constant.

Table 32: Central Government subsidies for electric Buses in China

Type Bus	Bus Length	2013 – 2015
Plug-in Hybrid Electric Bus (Includes Extended Range EV)	> 10 meters	CNY 250,000 (USD 38,527)
Electric Bus	6 - 8 meters	CNY 300,000 (USD 46,232)
	8 -10 meters	CNY 400,000 (USD 61,643)

	> 10 meters	CNY 500,000 (USD 77,053)	
	2013	**2014**	**2015**
Fuel Cell Commercial Vehicle	500,000 CNY (USD 77,053)	450,000 CNY (USD 69,348)	400,000 CNY (USD 61,643)

- Manufacturers further received tax exemptions from local governments and priority loans from state-owned banks. PEVs assembled in cities like Beijing, Tianjin and Guangzhou qualified for both state and central subsidies. In such cities, a manufacturer of a 10-m bus might have even qualified for up to USD 154,000 per vehicle. These subsidies were generally given directly to manufacturers.

Along with the subsidies from the central government, many incentives were also by the state governments for both manufacturers and the market. Major incentives by state governments can generally be categorized into one of the five categories below:

- **Priority Registration**: In cities like Beijing, Shanghai and Hangzhou, PEVs are exempted from the letter of vehicle registration. This is a stark contrast from the rigid regulations of obtaining license plate for conventional vehicles. The same was done to promote adoption of e-vehicle population on roads of cities.
- **Exemption of traffic restrictions**: In cities like Beijing and Wuhan, in order to mitigate congestion, space rationing and traffic restrictions are forced on workdays. Such restrictions are not applicable for electric vehicles.
- **Toll exemptions**: In Wuhan, toll bridges/highways do not charge toll to electric vehicles. In Shenzhen, EV owners get first hour free parking in municipal parking lots.
- **Fiscal Subsidy and Tax exemption for municipal facilities**: To encourage installing of Electrical Vehicle Charging Infrastructure, subsidies on equipment purchases and installations are provided by many local governments. In Shenzhen, subsidies between USD 1,541 and USD 3,082 are provided by the local government for vehicle insurance and installation & purchase of home charging outlets.
- **Support for PEV manufacturers:** Banks owned by the government provide priority for obtaining concessional loans to auto manufacturers that invest directly in PEV industry or upgrade PEV production lines.

Deployment Strategy:

The primary policy based thrust was provided by the Chinese Government during 2009-2012. Though, the target of 500,000 electric vehicles was unmet by the end of this period, the PEVs gained significant traction for the first time. In this duration, the “Ten Cities – Thousand Vehicles” demonstration was carried out by the government. This resulted in sales of thousands of PEVs. Initially, the subsidies provided were only for public vehicles like electric buses. In 2013, 6 cities extended subsidies to private vehicles as well. Majority of the PEVs sales was of public fleet vehicles. This included public bus transits, taxis, government vehicles, sanitation vehicles, etc. Subsidies of about USD 462, were also extended to Hybrid Electric Vehicles. Despite the limited success of the program, the government was able to sell only 40,000 electric vehicles (including hybrids) compared to its target of 500 thousand units by 2012. However, the focus and intent of the government was clearly set[122].

The government noticed the need for investing in charging infrastructure and to boost the same it also set specific targets for cities or city clusters to receive fiscal reward for charging infrastructure construction. In Beijing-Tianjin-Hebei region, the Yangtze River Delta Region and the Pearl River delta region, this target was 2,500 in 2013, 5,000 in 2014, and 10,000 in 2015[123]. Table 33 lists the reward incentives that were provided to the local governments on meeting these targets. The use of these funds were allowed only for operation and up gradation of charging infrastructure and construction of charging/battery swap stations. These funds could not be used for subsidy to purchase EVs.

Table 33: Subsidy plan towards charging infrastructure in various regions of China

Region	2013		2014		2015	
	No. of EV registered	Reward standard ('10000)	No. of EV registered	Reward standard ('10000)	No. of EV registered	Reward standard ('10000)
City or city cluster in Beijing-Tianjin-Hebei region, the Yangtze River delta region and the Pearl River delta region	2500≤Q< 5,000	CNY 2,000 (USD 300)	5,000≤Q< 7,000	CNY 2,700 (USD 410)	10,000≤Q< 15,000	CNY 5,000 (USD 760)
	5,000≤Q< 7,000	CNY 3,000 (USD 450)	7,000≤Q< 10,000	CNY 3,800 (USD 580)	15,000≤Q< 20,000	CNY 7,000 (USD 1,060)
	7,000≤Q< 10,000	CNY 4,500 (USD 680)	10,000≤Q< 15,000	CNY 5,500 (USD 840)	20,000≤Q< 25,000	CNY 9,000 (USD 1,370)
	Q≥10,000	CNY 7,500 (USD 1130)	Q≥15,000	CNY 9,000 (USD 1360)	Q≥25,000	CNY 12,000 (USD 1,820)
City or city cluster in other regions	1,500≤Q< 2,500	CNY 1,000 (USD 150)	3,000≤Q< 5,000	CNY 1,800 (USD 270)	5,000≤Q< 7,000	CNY 2,400 (USD 360)
	2,500≤Q< 5,000	CNY 2,000 (USD 300)	5,000≤Q< 7,000	CNY 2,700 (USD 410)	7,000≤Q< 10,000	CNY 3,400 (USD 520)
	5,000≤Q< 7,000	CNY 3,000 (USD 450)	7,000≤Q< 10,000	CNY 3,800 (USD 580)	10,000≤Q< 15,000	CNY 5,000 (USD 760)
	Q≥7,000	CNY 5,000 (USD 750)	Q≥10,000	CNY 6,700 (USD 1,020)	Q≥15,000	CNY 8,000 (USD 1,220)

[122] Leapfrogging or Stalling Out? Electric Vehicles in China, Sabrina Howell, Henry Lee, and Adam Heal, HKS Working Paper, 2014.
[123] Case study of System of Innovation in China: The Case of Electric Vehicles, OECD. Approximate USD conversion rates.

Implementation Strategy:

Till 2015, the Government of People' Republic of China had spent about USD 4.84 billion on NEV subsidies[124]. It had been decided to extend incentives to all electric vehicles purchasers in 2013. To further incentivize the buyers, The Purchase Tax Catalogue, issued in 2014, exempted all Plug in Electric Vehicles from vehicle purchase tax. The Ministry of Finance (MoF) also started allocating new budgets for sustaining the financial support required to continue subsidies for electric vehicles for the three years after the conclusion of the "Ten Cities Thousand Vehicles" program. Hybrid electric vehicles, however, were no longer eligible for government subsidies[125]. The government also issued standards for EV charging station infrastructure. Waving of registration charges and access to High Occupancy Vehicle Lanes was also included in the government incentives.

One of the challenges faced by the government during deployment was the misuse of subsidies by the electric vehicle manufacturers, particularly by the bus manufacturers. Some of them raised the MSRP (Manufacturer Suggested Retail Price) while others falsified sales records. This was done in order to generate revenues from subsidies. It was revealed by the Ministry of Industry and Information Technology (MIIT) that the accumulated PEV sales were 174,000 in the first ten months of 2015 while the registered number of PEVs was just 108,000. The mismatch in the two figures suggested that not all produced buses were on road. The government conducted an enquiry in 2016 and based on the results decided to curb the excessive subsidies and released a new list of subsidies in 2016. The central government also requested the state governments to ensure that the total subsidy from both the levels do not exceed 60% of the total cost. The government continues to plan heavy investments in the charging infrastructure. The target is to set up a network of 800,000 public charging points, including the 100,000 charging stations built this year[126].

Sustaining Strategy

In 2015, the government introduced more financial subsidies plans. Non-monetary benefits were provided to further incentivize the PEV segment. The old Subsidy Catalogue was repealed and vehicle models for subsidies were re-evaluated in 2016, after the frauds in PEV subsidies was caught. For buses, the following subsidies were made applicable for 2017-18.

Table 34: National subsidies in China for new energy buses and coaches in 2017–2018

Vehicle type	**Subsidy Amount (CNY/kwh)**	**Adjustment Factors**			**National subsidy ceilings ('1,000/vehicle)**		
					6<LH≤8	**8<LH≤10**	**LH>10**
Fast-charging BEV	CNY 3000 (USD 455)	Charging Speed of batteries (CS)			CNY 60 (USD 9.1)	CNY 120 (USD 18.3)	CNY 200 (USD 30.45)
		3C<CS≤5C	5C<CS≤15C	CS≥15C			

[124] Notice on Special Inspection of Local Budget and Final Accounts and Special Application for New Energy Vehicles, Ministry of Finance press office, 2016
[125] A study of China's explosive growth in Electric Vehicle Market, Oak Ridge National Laboratory, Shiqi Ou, Zhenhong Lin, Zhixin Wu, Jihu Zheng, Renzhi Lyu, Steven Przesmitzki, Xin He, January 2017
[126] China to build more charging points for electric vehicles, The State Council, The People's Republic of China, Article Published on 9 February 2017

		0.8	1	1.4			
Non-fast charging BEV	CNY 1800 (USD 273)	Battery Energy Density (BD, Wh/kg)			CNY 90 (USD 13.7)	CNY 200 (USD 30.4)	CNY 300 (USD 45.7)
		85<BD≤95	95<BD≤115	BD≥115			
		0.8	1	1.2			
PHEV	CNY 3000 (USD 455)	Fuel Saving Rate (FS, %)			CNY 45 (USD 6.8)	CNY 90 (USD 13.7)	CNY 150 (USD 23.0)
		40<FS≤45	45<FS≤60	FS≥60			
		0.8	1	1.2			

To incentivize the battery manufacturers to achieve higher efficiency designs, the government in the 2016 policy of EV subsidies mentioned that - to consume the subsidies, battery electric buses and coaches must consume less than 0.7 Wh/km.kg of energy (electricity) and have a range of at least 150 km. In the 2017-2020 Policy Adjustment, these bars have been set higher at 0.24 Wh/km.kg and 200 km respectively. Restrictions also include those placed on the battery mass and density. A cap of 20% has been placed on the battery mass ratio (battery system mass as a percentage of vehicle curb weight). For plug-in hybrid electric buses, a minimum fuel-saving rate of 40% has been set as a requirement. Also, a minimum battery energy density requirement of 85 Wh/kg has been placed for non-fast charging electric buses. Such targets directly force the companies to make sustained efforts in the R&D department to ensure that they do not lag behind their competitors in meeting the targets set by the government. A failure to meet these targets will lead to a forfeiture of government subsidies, leading to a steep increase in retail prices of these vehicles. This will directly impact the sales of these manufacturers.

A lot of focus has been placed on setting up domestic manufacturing units for Li-Ion batteries with approval given to domestically manufactured batteries to be used in e-vehicles. By 2020 China's production will be approximately 3.5 times the Giga-Factory, a venture of Tesla & Panasonic. Further, Goldman Sachs estimates China to dominate the Li-ion factory by 2025. The Battery manufacturers must have at least 8GWhr of battery production facilities in China to qualify for subsidies[127].

800,000 public charging points have been planned to be set up including the 100,000 that were built during 2016. In the 13th five year plan, it has been planned to setup a charging infrastructure which can service the target of 500,000 EVs by 2020[128].

In 2016, drafts regulations for CAFC (Cooperate Average Fuel Consumptions) regulations Credits and New Energy Vehicle Credits[129] were published. These incentives are expected to replace the

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127 "Electric cars: China's battle for the battery market" published by March 5, 2017

128 China to build more charging points for electric vehicles, The State Council, The People's Republic of China, Article Published on 9 February 2017

government subsidies by 2021. While companies aren't allowed to borrow their future CAFC credits to offset current year's CAFC deficit, they are allowed to transfer credits, albeit only to shareholding/affiliated manufacturers[130]. On the other hand, NEV credits can be traded between any two auto companies, however, they cannot be carried forward to the next year or re-sold. They must be used in the year of purchase itself. In many ways, this is similar to the Renewable Energy Certificates used in India, which can be traded among companies to ensure compliance of government set targets for renewable energy generation.

New Energy Vehicle (NEV) credit refer to the transferrable credits which are the sum product of the annual manufacturing or import volume of each EV and their per-NEV score. The per-NEV score refers to the score of the EVs based on their range. NEV credit targets are only mandatory for automakers who manufacture or import 50,000 or more traditional fuel passenger cars.

Corporate Average Fuel Consumption (CAFC) regulations are applicable on all enterprises selling cars in China. It includes domestic manufacturers and importers. Each auto company gets an annual CAFC target based on its production models. The primary purpose of these targets is to limit fuel consumption (L/100 km) for all vehicles. The penalty includes suspension of production of high fuel consumption models.

Key Enablers for the Success Story:

Key enablers have been derived by analyzing the successful development of the electric vehicle market including the adoption of electric buses in China. It can be seen that the focus and efforts of the Central Government have been supported by the set-up of adjoining infrastructure and development of the automobile industry as a whole. The key enabling factors have been listed below:

[129] Proposed Temporary Management Regulation for Corporate Average Fuel Consumption and New-Energy Vehicle Credits for New Passenger Cars in China, The International Council On Clean Transportation, October 2016

[130] According to ICCT October 2016, Policy update, this arrangement states that if two enterprises meet any one of three conditions, they can be regarded as affiliated enterprises. (1) Both are domestic enterprises and hold no less than 25% of shares in each other directly or indirectly. (2) Both are domestic enterprises and a third domestic enterprise owns both of them or holds no less than 25% of shares in both of them. (3) One is a domestic enterprise while the other is a sales agent of an importer of passenger cars. The foreign enterprise producing these imported passenger cars must hold no less than 25% of shares in the domestic enterprise

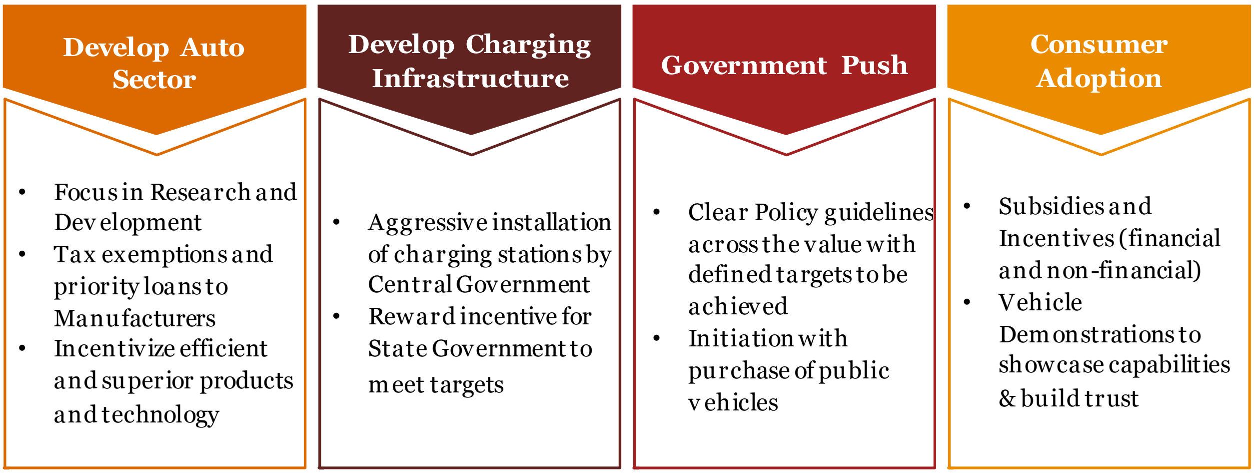


Figure 32: Key enablers for the success story in China

5.2. San Francisco

San Francisco has an electric vehicle share of about 5%, more than 7.5 times the national average of US[131]. In US, most EVSE (Electric Vehicle Supply Equipment) support is driven at the state level[48]. Under the rebate program of the state of California, a subsidy of USD 2,500 is provided for most battery electric modes and of USD 1,500 for hybrid electric vehicles. The state of California, along with the states of Washington and Oregon, has organized an extensive network of DC fast-charging stations in the West Coast Electric Highway, which connects the three states, through stations which are located every 40-80 km.

The San Francisco Municipal Transportation Agency (SFMTA) has a strong focus on its trolley bus networks. These buses account for approximately 200,000 boarding a day. Trolleybuses account for about 30% of the total ridership and cover 15 routes. The buses successfully serve some of the highest ridership routes including one California, 14 Mission and 30 Stockton. The primary reasons for same have been as follows:

- Topography – The regional topography makes it easier for trolley coaches to operate on hills compared to motor coaches.
- Smoother and Quieter Round – Trolleybuses do not produce noise that can disturb the neighborhood.
- No Air Pollution – Trolleybuses do not contribute any greenhouse gases to the community.
- Low Fuel Costs – Operational costs, in terms of fuel consumption costs, are very low for trolleybuses compared to diesel buses.
- Existence of Required Infrastructure – San Francisco already had existing overhead wiring throughout city.

[131] Electric Vehicle Capitals Of The World, The International Council On Clean Transportation, March 2017

In 2008, San Francisco, San Jose, and Oakland formed a joint policy initiative to make Bay Area the EV capital of the nation. The state of California had also adopted property laws to simplify and accelerate the process of approval for electric car owners to deploy charging infrastructure. The SFMTA has been replacing its old fleet with state-of-the-art vehicles since 2013. The fleet deployment target is of over 800 new vehicles, of which approximately 400 have arrived. The transit agency has set following guiding principles, which has led to this transition and modernization of fleet.

- Average Fleet Age: Establishing a consistent average fleet age of 5-8 years.
- Sustainability: Supporting San Francisco Climate Action Plan and related policies by continuing investments in low and zero emission vehicles.
- Reliability: Continuing to improve service and prioritizing reliability when procuring vehicles and designing enhancements.
- Performance Based Procurements: Prioritizing vehicle safety and reliability and encouraging industry innovation and maintainability.
- Maintenance Standards: Continuing robust maintenance standards and practices established in 2014 including maintaining or exceeding Original Equipment Manufacturer (OEM) schedules.

To meet these goals over 814 New Buses are planned. In 2013-14, the first fleets of 112 buses each 40ft long were delivered. An additional fleet of 200 40ft buses and 224 60ft Hybrids are being delivered in installments and will be completely delivered by 2015-18. A total of 93 60 ft. trolley buses are also arriving during the same period. The San Francisco Municipal Transportation Agency has further ordered 185 trolley buses which will arrive by 2017-2019.

SFMTA claims that the trolleybuses have delivered enhanced reliability with current operating and infrastructure requirements. Additionally, the newly acquired buses have common parts with existing fleets of hybrids to streamline maintenance. The 185 trolleybuses ordered lately have been for a total of USD 244,618,583. Going forward, though the SFMTA has already ordered a fleet of trolley and hybrid buses, it is planning to experiment with battery electric buses. However, battery electric buses, compared to trolley buses, will have difficulty serving routes which are in hilly areas, like 1 California and 30 Stockton, which are often the most crowded too. This is primarily due to the fact that trolley buses can increase or decrease the energy they receive from the electric wires, making it easier for them, than battery electric buses which completely depend on the motors to deliver the required power. Also, as Battery Electric Buses need time for charging, they won't be able to provide a 24 hour service which is currently existing on routes like 22 Fillmore and 24 Divisadero. Therefore, multiple battery electric buses will be needed to service routes which can be serviced by just a single trolley bus.

Key Enablers for the Success Story:

Similar to the case in China, the key enabling factors in San Francisco revolve around government's push and development of related infrastructure to provide better services to the customers.

Drive from the State Level Government:

1. Guidelines for EV adoption
2. Simplification of laws to reduce approval procedures

Development of Supporting Infrastrucutre:

1. Extensive charging infrastructure (1 charging station in every 40-80 km)
2. Use of existing infrastructure for overhead lines

Consumer Adoption:

1. Incentive structure to ensure parity with traditional vehicles
2. Continuous improvement of services to ensure reliability and safety standards

Figure 33: Key enablers for the success story in San Francisco

5.3. Key Policy Initiatives across Europe

Table 35 describes the incentives that have been used in various parts of the world to promote adoption of Electric Vehicles. Policies across nations are in categories like that of non-fiscal incentives, direct incentives and other incentives.

Table 35: Government support structure across European countries

Government Support	Country
EV Financial Support	In Denmark, EVs are exempted from vehicle registration taxes (up to 180% of the cost of vehicle) until 2016, partial exemption to continue till 2020. The country also does not impose annual car tax on EVs
	France provides up to 6300 Euros (approx. USD 7430) grant for EVs and an additional diesel car scrappage grant of up to 3700 Euros (approx. 5900 USD).
	Netherlands provides 5000 Euros (approx. USD 6000) subsidy for fully electric taxis
	In Norway, EVs face no purchase or import taxes, are exempted from 25% VAT and are exempt from road and ferry tolls
	In Sweden, exemption and 80% reduction from vehicle taxes to BEVs and PHEVs respectively are provided in Canton of Zurich
	UK provides federal grant up to 4500 Pounds (approx. USD 5800) at EV purchase and also exempts annual circulation tax.
EV Non-Financial Incentives	Denmark provides designated free parking to EV owners
	In France, high polluting vehicles are banned from city streets on weekdays
	Netherland has priority lanes for electric taxis and also provides them residential parking permit priority

	In Norway, EV owners are entitled to free municipal parking and free electricity for normal charging (3.6 kW)
	In UK, EVs get exemption from congestion charges and reduced parking costs in some boroughs
EVSE Support	French government provides tax credit equivalent to 30% of home chargers or subsidies for installation of residential or workplace chargers
	In Norway, public funding is provided for fast charging stations every 50 km on main roads
	In Sweden, a total of SEK 130 Million (approx. USD 15.37 Million) was spent in 2015 as financial support for development of charging infrastructure[132].
	In UK, a grant of GBP 500 (USD 650) and GBP 300 (USD 400) are provided to individuals and business respectively for each charging point installed. Also tax breaks can be claimed on investment in large EVSE deployments.
	In US, the state of Colorado grants up to 80% of cost of EVSE installations
EVSE Regulations and Permits Support	France recently made it necessary for new or renovated buildings to pre-install conduits (electrical wiring) for EVSE (ranging between 7 kW and 22 kW) for 50% to 75% of parking bays
	France, Spain and Portugal have also adopted property laws which simplify the approval procedures for EV owners to deploy EVSE infrastructure.
	UK has introduced mandatory charging point requirements for all new developments.[133]

5.4. Key Learning's

- As it can be seen from cases of China, San Francisco and various other parts of Europe, government intervention is extremely important for promoting use of electric vehicles. The primary reason for the same is that achieving cost parity with existing modes of transportation modes is difficult and the same if completely borne by the user/operator would not lead to successful adoption. Further, Electric Road Mass Transportation makes one of the best cases for use of electric vehicles for public transportation with local agencies under the state/central government owning the same and incentivizing the purchase and usage.
- Further, the government needs to provide both fiscal and non-fiscal incentives to promote usage of EVs. The fiscal incentives may come in the form of subsidies and VAT exemptions on purchase of EVs. The non-fiscal incentives include access to priority lanes, designated free parking, exemption from toll fees, etc.
- As China holds almost the entire Electric Bus stock of the world, important learnings from the Chinese success story can pave the way forward for the rest of the world. Large scale procurement of electric buses which are indigenously manufactured and use of domestically produced batteries help in boosting local manufacturing industry along with reducing the cost of vehicles. This can be a compelling argument for countries to adopt

[132] Assuming average of 2015 exchange rates for Swedish Krona, where 1 Swedish Krona = 8.46 USD.
[133] Based on data provided by annual publications by IEA outlook and ICCT

ERMT as it can further lead to generation of new jobs and growth of the economy through domestic consumption.

- Another important lesson from China has been the widespread investments in the EVSE (Charging Infrastructure). To ensure long-term sustainability of not just ERMT but electric vehicles in general, it is very necessary for the government to support in installation of an exhaustive and effective charging infrastructure. The government can either take the onus of setting this up on itself or can provide subsidies to individuals or groups willing to do it (which may include power utility companies or other players willing to enter the segment). Both methods have turned out to be productive as has been evident in the in previous section. While Chinese Government and municipalities have been setting up the EVSE primarily on their own, the UK government provides grants to those willing to set up EVSE. Setting up of initial EVSE can also trigger a virtuous cycle where EVSE availability makes users comfortable in buying EVs, thus, the adoption of EVs is led by infrastructure.
- The EV development across the countries have shown economy wide transactions among various players which include Government and Regulatory Agencies, EV manufacturers and suppliers comprising battery manufacturers, power & utilities companies and consumers. These stakeholders perform various tasks and have multiple interactions among themselves, which is leading to the development of new supply chain networks and is changing the energy value chains.

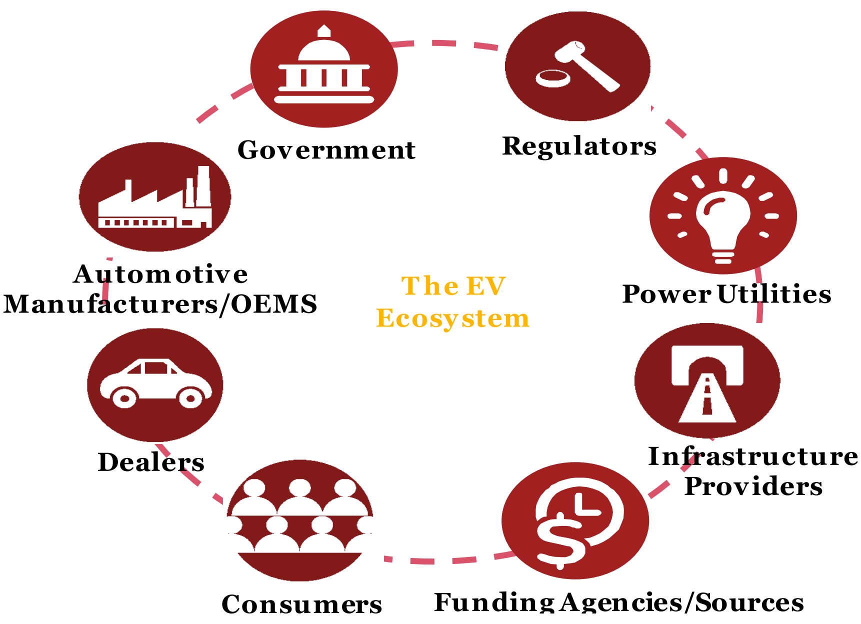


Figure 34: Various stakeholders in the e-vehicles industry

A key point to note is that a successful implementation and adoption would depend on how these players interact. Innovative business models are being developed around mutual benefits and collaboration of stakeholders.

6. Challenges and Opportunities

6.1. Challenges in deploying ERMT in the SAARC Region

6.1.1. Electricity Needs

To setup a sustainable infrastructure for ERMT, access to electricity is a prerequisite. One of the biggest challenges for the SAARC Member States is to provide electricity to the citizens of their respective nations. With many parts of the countries still having little to no access to electricity, supply to the charging stations for ERMT could stand as a challenge. Except for Bhutan and Maldives, no other SAARC Member States have being fully electrified, as represented in the table below. Also, apart from Bhutan, Sri Lanka, Maldives and Pakistan, all SAARC Member States are importers of electricity. Therefore, the increased electricity requirement for implementing ERMT may also impact their import bills.

Table 36: National electrification rates across SAARC Member States

Country	National Electrification (%), 2016[134]
Afghanistan	89.5 (2014)[135]
Bangladesh	62.0
Bhutan	100.0
India	81.1
Maldives	100.0
Nepal	76.3
Pakistan	72.5
Sri Lanka	98.6

In order to meet the power needs, SAARC countries are planning to invest heavily in their energy infrastructure in the upcoming years. Following are a few highlights of their upcoming energy generation targets:

Table 37: Upcoming Targets in Energy Generation for SAARC Countries

Country	Upcoming Targets in Energy Generation
Afghanistan	• Afghanistan has about 100 MW worth of renewable energy projects open for investments. The country requires about USD 326 million

[134] Energy Access Database, World Energy Outlook 2016

[135] Access to electricity (% of population), World Bank Open Data

	worth of investments in the sector[136].
Bangladesh	• Bangladesh plans to increase its total energy generation to 24 GW by 2021 and 39 GW by 2030. Of this, the 2.9 GW of Energy would be through renewable sources[137].
Bhutan	• Bhutan plans to increase its electricity generation from the current levels of 1.6 GW (2016) to 5 GW by 2020.
India	• India targets to increase energy production to 523 GW by 2021-22 and to 640 GW by 2026-27. • Targeted installation capacity of renewable energy is of 175 GW (by 2021-22) and 275 GW (by 2026-27)[138].
Maldives	• Maldives currently has 100% energy electrification and wants to attain carbon neutrality by 2020[139].
Nepal	• In 2016 climate action plan, Nepal targeted 12 GW of hydro and 2.1 GW of solar by 2030. • Nepal also aimed for 220 MW of additional bioenergy and 50 MW of additional micro-hydro by 2030[140].
Pakistan	• Pakistan is aiming to add 5.77 GW of electricity to its national grid by 2018[141].
Sri Lanka	• Sri Lanka has 100% Renewable Energy generation target of 34.3 GW (including 1.5 GW of large hydropower generation) by 2050. • Sri Lanka currently has 1.8 GW of Renewable Energy, which includes 1.3 GW of large hydro[142].

While SAARC nations have ambitious investment targets for electricity generation, most SAARC nations do not have investment policies for Electric Vehicles. While the investments in energy infrastructure are a must for the rapidly growing economies of SAARC, they can simultaneously invest in Electric Vehicles. This will not only help in cutting down their spending on oil import, the country's current account deficit could also be put to check. This will further allow SAARC governments to invest more in their energy infrastructure.

While there is no alternative to setting up the electricity generation and transmission network in the long run, there are a few methods through which SAARC nations can reduce their electricity requirement during ERMT implementation. One of the methods to reduce the challenges involved

[136] 'Invest In Energy Sector', article published on website of Invest in Afghanistan, an initiative of Afghanistan Investment Support Agency
[137] 'Future Plans and Targets (Renewable Energy)', article on website of Sustainable & Renewable Energy Development Authority
[138] National Electricity Plan, 2016, Central Electricity Authority
[139] Maldives Energy Policy & Strategy, 2016, Ministry of Environment and Energy, Republic of Maldives
[140] Nepal Renewable Energy Target, Climatescope 2017
[141] Pakistan to add 5,770 MW electricity by March-2018, published on website of Pakistan American Business Association
[142] 100% Electricity Generation through Renewable Energy by 2050, ADB, 2017

in setting up the excess electricity supply can be to plan their ERMT in such a way that most, if not all, of the charging for electric buses happens at night or non-peak hours. This additionally will be useful in sharing the load on the grid. Another method which could be of use is that of battery swapping, built around innovative business models, also attracting private participation. The process of battery swapping will also aid in shifting the load of charging to non-peak hours.

6.1.2. Road and Charging Infrastructure

Another major challenge for some SAARC Member States would be the lack of road infrastructure. Countries like Afghanistan, Bangladesh and Bhutan have very low road densities when compared to some of the developing and developed economies.

Table 38: Road density comparisons

SAARC Member States	Road Density (km/'000 km²)[143]	Selected Countries	Road Density (km/'000 km²), 2014[144]
Afghanistan	61 (2017)	Belgium	5,100
Bangladesh	144 (2016)	France	1,960
Bhutan	291 (2016)	Hungary	2,250
India	1,665 (2017)	Japan	1,080
Maldives	NA	Netherlands	4,120
Nepal	592 (2017)	Switzerland	1,810
Pakistan	332 (2017)	United Kingdom	1,740
Sri Lanka	476 (2017)	United States	730

The lack of road structure would hinder the usefulness and the economic viability of implementing ERMT. It is therefore necessary for governments of respective countries to invest in the road infrastructure as they plan to implement ERMT. Investments in road infrastructure will also help in increasing the overall connectivity and accessibility of the SAARC Member States.

Similarly, charging infrastructure across the SAARC Member States is non-existent with low penetration of electric vehicles, both in public and private sectors. Only Bhutan, India, Nepal and Sri Lanka have some presence across key cities to support the electric vehicles on road. Furthermore, the domestic chargers used by most EV owners cannot be used to power electric buses, as these would require higher capacity chargers. Further, implementation of trolley buses may require laying out of overhead lines which comes with its own challenges of ROW (Right Of Way) and higher cost of installation.

[143] Respective Countries' Statistical Yearbook, ADB Basic Statistics 2017
[144] Density of road in OECD countries

Obtaining Right Of Way permissions is among the biggest challenges for installation of overhead lines. These are generally associated with land acquisition, regulatory and environment clearances. Narrow corridors and multiple lines can create congestion around sub-stations. This makes future expansions difficult. Further, in densely populated towns and cities, getting permissions for new corridors can be extremely difficult. All these factors can lead to delay in implementation of infrastructure required for trolley bus.

6.1.3. High Initial Capital Outlay

Another major challenge in the implementation of the ERMT is the high initial capital outlay involved. Both the initial outlay and operational cost required have been assessed earlier in the report. Irrespective of the technology being used, related costs could act as a major deterrent for private players as well as the governments which are being clogged by widening fiscal and current account deficits.

Table 39: Fiscal and Current Account Deficits across SAARC Member States

Country	Fiscal Balance Surplus/(Deficit) as a % of GDP, 2016	Current Account Balance Surplus/(Deficit) as a % of GDP, 2016
Afghanistan	1.61	4.36
Bangladesh	-3.09	1.67
Bhutan	-3.01	-29.38
India	-3.50	-1.00
Maldives	-7.38	-17.71
Nepal	1.39	6.25
Pakistan	-4.56	-1.15
Sri Lanka	-5.64	-2.05

One of the methods to phase out these investments could be structuring the procurement plans in such a way that the same comprises of both plug-in hybrid buses and battery electric buses for selected cities/towns. This will allow for time and investment for setting up the related charging infrastructure that suits the convenience of the government and also support the initiatives required for raising awareness of benefits electric road mass transportation in a city. Though private companies can sometimes bear the cost of this expenditure, generally it has to be the government which bears a major portion of the costs. Slowing with public private participation in setup of charging infrastructure to operating a bus transit agency can be worked around as per the willingness of the central/state government.

While evaluating this choice, the countries should also assess the social cost of benefits that come with implementation of ERMT. Implementing ERMT will help countries tackle the pollution emissions inside the city and make them healthier, and thereby safer, for their citizens.

6.1.4. Political Instability

Development of a long-term and investment-heavy policy requires deep and continuous support from the governments that stretches over a long period of time. Unfortunately, some of the SAARC Member States have had historical precedents of unstable governments. In such a scenario, sustained efforts and investments that are required for implementation of such a policy would not be possible. As the initial investments in implementing ERMT are higher than those in expanding existing infrastructure, lack of a long-term vision may result in governments choosing the conventional bus transport over ERMT.

6.2. Enabling conditions for deployment of ERMT system in the SAARC Member States

6.2.1. Support from Government

Support from government has been constantly a major factor in the success stories of adoption of electric vehicles around the world. This support can come from the central level, as in case of China, or from regional or state level, as in case of state of California. This is mainly because of the lack of cost parity between electric vehicles and conventional vehicles, making electric vehicles less attractive for buyers. Through direct and indirect subsidies/incentives, the government can make such electric vehicles attractive for consumers. This support can come in various forms.

While direct incentives can be in the form of tax credits, state rebates or a bonus-malus systems; indirect incentives can range from subsidized loans to preferred parking spots or special-lane access. Apart from incentives towards purchase of vehicles, perhaps, more importantly, the governments also need to invest in the charging infrastructure. Whether a government decides to install an exhaustive network of high power DC charging stations or establish a battery swapping mechanism, intensive planning and capital would be required.

The government may consider the investment to reap the long-term benefits of a healthier environment. Also, oil-importing nations which have cheap access to electricity can look at it as a measure to curb down their fiscal deficit and their dependency on other nations in oil procurement. Table 40 gives information about consumption of oil by transport sector for various SAARC countries.

Table 40: Consumption of Oil[145] in Transportation Sector across SAARC Nations in 2015[146]

Country	Net Oil Consumption (MTOE)	Oil Consumption by Transport Sector (MTOE)	% Oil Consumption by Transportation Sector
Bangladesh	12.58	3.25	26%
India	203.3	84.2	41%
Nepal	1.15	0.75	65%

[145] Oil refers to Oil, Oil products and Natural Gas
[146] Information obtained from website of International Energy Agency. Information for Afghanistan, Bhutan and Maldives was not available.

Pakistan	33.18	13.85	42%
Sri Lanka	4.12	2.86	69%

6.2.2. Private sector investments

While the initial investments in ERMT infrastructure are generally initiated from the government, private sector could play a key role in ensuring smooth implementation and sustainability in the ERMT. Though in most cases, their role is generally as manufacturers of buses and batteries; in case of Japan, in 2014, a consortium of domestic vehicle manufacturers (Nissan, Toyota, Honda and Mitsubishi) together with the Development Bank of Japan, developed a mechanism to fund infrastructure and eventually charged owners of electric vehicles for usage of those stations. Such a method maybe useful for governments of countries which do not want to bear the full burden of implementation of ERMT. However, to attract private sector investments, the government has to ensure that there is existing traction of the market, have historical evidence of sustained investments in the domain and provide incentives making the sector attractive. In case of Japan, the government had started investing in electric vehicles since 1971[147].

To ensure clean energy is being used to power ERMT, it is also necessary to ensure that private companies, support government initiatives to invest in renewable energy. Traditional companies who have been in the business of oil exploration/generation of electricity from conventional sources have plans to move towards greener and cleaner fuels/sources of energy. In general, these companies have started increasing focus on developing a portfolio in Renewable Energy. Engie has been working towards low-carbon or zero-carbon energy generation through solar and wind power. Similarly, French state-owned utility EDF announced plans for a big push into solar energy that is likely to cost around 25 billion euros[148]. BP is going to invest $200m in Lightsource (a major in solar generation) over the next three years for a 43% stake in the business[149]. Shell too is investing in clean energy and is developing more efficient and cleaner mobility. Indian oil companies such as IOCL and HPCL have setup charging infrastructure for electric vehicles at their company-owned, company-operated fuel station. Hence, acknowledging the changing dynamics of the energy market and emerging trends in electric mobility major players have started moving or have plans to move towards cleaner sources of power.

6.2.3. Incentives/subsidy for manufacturing and R&D

As electric vehicle is an emerging technology, and is still struggling to obtain a decent share in sales, manufacturers can reasonably be expected to be hesitant towards investing in this technology. To boost the confidence of manufacturers, the government cans chose to provide subsidies and incentives to them. Manufacturing units also lead to creation of jobs and enhancement of demand

[147] Plug-in electric Vehicles: A Case study from seven markets, Institute of Transportation Studies, University of California, October 2014
[148] 'French utility EDF plans major push into solar power', Financial Times, Article Published on December 11, 2017
[149] 'Lightsource and BP join forces to drive growth in solar power development worldwide', BP Global Website, Article Published on December 15, 2017

for raw materials, thereby having multi-levelled impact on the growth of economy. The incentives can include direct subsidies on vehicles or manufacturing parts, tax credits or cheaper land prices. However, as discussed in the case study of China, an unmonitored method of granting subsidies may be vulnerable to exploitation. Thus, it is necessary that the government monitors the distribution of subsidies and regulates them to reflect improvement in technology and changes in demand.

6.2.4. Consumer Adoption

Acceptance of the new technology will be a key factor in determining success of electric buses. While the perceived level of safety of buses is important for passengers to use ERMT, features likes driving terrains and access to charging stations are important for adoption of ERMT. The following are important factors in determining the mindset of customers:

1. **Availability of Needed Vehicles:** Due to limited demand, currently, only few manufacturers of electric buses exist. The current range of electric buses, may not necessarily meet all the characteristics like capacity, range and ground clearance. As there are many choices available in the diesel bus segment, electric bus manufacturers will suffer a disadvantage unless they too bring in such options.
2. **Customization according to terrain:** As SAARC Member States have varying landscapes ranging from mountainous terrains to deserts, setting up charging infrastructure may be difficult in such different terrains. Therefore, to ensure that buses do not get stranded in middle of such terrains, either buses with longer range are procured or an extensive charging infrastructure in the routes are being provided. Customization of buses to suit the diverse terrains may also be required.
3. **Consumer Awareness:** Governments also need to focus on advertising the benefits of electric buses. While this might seem like an extra expenditure over an already expensive ERMT implementation, it will help convince the citizens of the need for investments in ERMT. This will help ensure sustained support for the same. Also, it can be a good way to dispel public anxiety related to safety or range issues of ERMT. Moreover, this sort of visibility will also indirectly encourage use of private EVs and thereby help form positive public opinion towards adoption of EVs.

Summarizing key findings by a SWOT Analysis of ERMT implementation

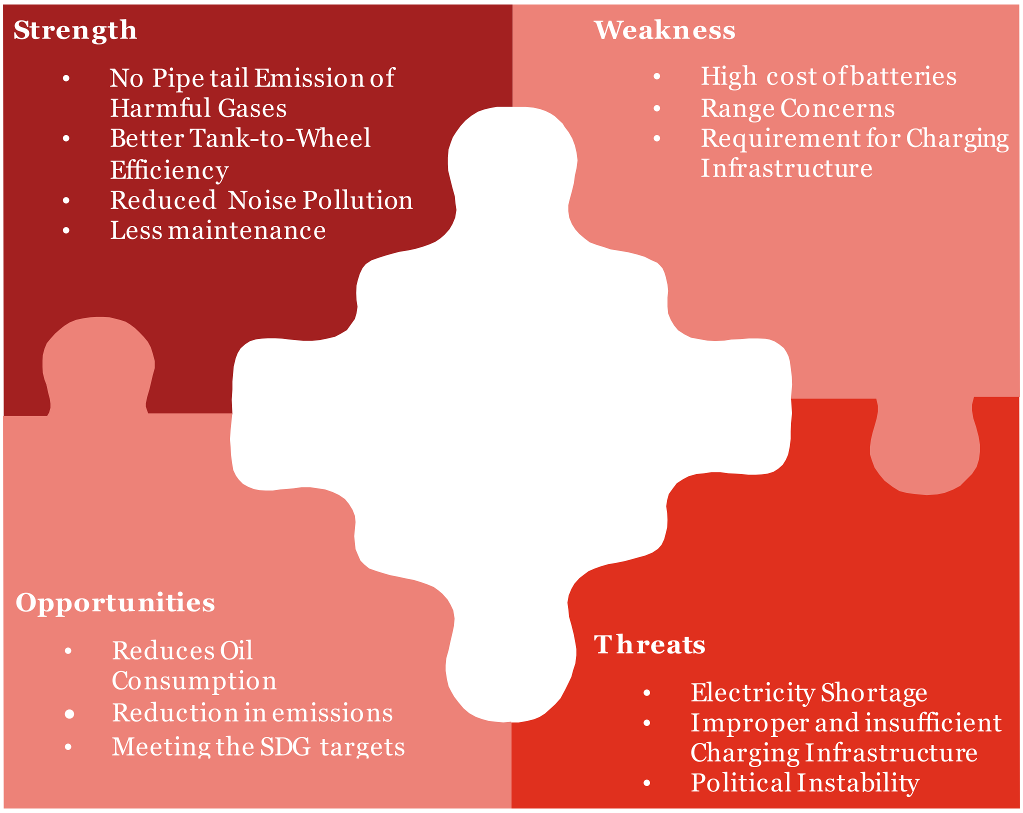


Figure 35: SWOT Analysis for ERMT Implementation

6.3. Preferable SAARC countries for deployment of ERMT

In order to arrive at preferable SAARC countries for deployment of ERMT, a scoring framework has been designed comprising of macro-economic factors, transportation & power sector profiles of each of the countries and initiatives/ steps currently being taken by the individual countries towards adoption of electric vehicles. Macro-economic factors (Weightage of 20%) represented by the current assessment of the country in terms of how the country is expected to grow, income levels of the citizens, urban population, current state of economics and the ease of doing business in the country forms the first level of assessment. Secondly, transportation and power sector profiles (Weightage of 25%, each) forms the crucial segment for ERMT implementation which can be developed only by amalgamation of the two sectors. Finally, the current initiatives in terms of EV Policy / e-vehicle implementation (Weightage of 30%) has been assessed to check whether there has been any traction in the recent past and analyze on to the intent of the government towards EV implementation as a whole. Each of the selected parameters, along with its respective weightages has been described in Table 41.

Table 41: Scoring Framework used for assessment

Segment	Score	Parameter	Rationale
Macro-Economic Profile	**20.00**		Equally spread over 8 parameters.
	2.50	GDP growth rate	Faster GDP growth rate translates to increased transportation requirements and addition of related infrastructure in terms of roads and vehicles.
	2.50	Per capita income	Higher per capita income represents increased demand for transportation and the capability to pay for increased tariffs, if any.
	2.50	Urban Population (% of total population)	Higher levels of urban population represent increased urban mobility needs which forms a case for ERMT in cities.
	2.50	Inflation	Lower inflation rates enable consumers and businesses to make long-term decisions, knowing the purchasing power of the money invested will hold the test of time. This forms a key in ERMT implementation which needs to have a long term horizon.
	2.50	Overall Fiscal Balance Surplus/(Deficit) (as a % of GDP)	Fiscal surplus represents effective management of government revenues and a sign of a healthy economy. Also, a surplus situation supports the government in investing in initiatives towards infrastructure development and allocation of required funds for ERMT.
	2.50	Current Account Balance-Surplus/(Deficit) as a % of GDP	Current Account surplus represents a healthy economy indicating the country being a net lender to the rest of the world.
	2.50	Ease of Doing Business	A better rank for a country indicates a conducive environment for a player (foreign/domestic) to conduct business, further attracting foreign entities to conduct business/invest in the country.
	2.50	Sovereign Credit Rating	
Transport Sector profile	**25.00**		Road and bus density has been given a higher weightage due to its relative importance for creating a business case for ERMT.
	5.00	Contribution to GDP	A higher contribution to the overall GDP of the country represents importance of the transportation sector, further reflecting government's intent to invest more into the same.
	5.00	Quality of roads	Signifies quality of road infrastructure present in the country.

Segment	Score	Parameter	Rationale
	7.50	Road Density	Road density (km of roads/ land area of the country) represents the connectivity for the citizens covering the entire nation.
	7.50	Bus Density	Bus density (number of buses/ population of the country) represents the amount of bus (public transportation) available for the citizens.
Power Sector Profile	**25.00**		Equally spread over the parameters of access to electricity, dynamics of electricity demand-supply/import, tariffs and generation from renewable sources.
	5.00	Contribution to GDP	A higher contribution to the overall GDP of the country represents importance of the power sector.
	5.00	National electrification Rate	Represents the % of population with access to electricity. A higher % reflects availability of electricity for other purposes like ERMT.
	2.50	Demand Supply Surplus/(Deficit)	Signifies whether a country is able to meet the electricity demands of its consumers (industrial, domestic, commercial, etc.). Surplus in electricity supply would not hinder operations of ERMT.
	2.50	Electricity imported (as a % of total supply)	Represents the true scenario of the country on how the electricity needs are being met and whether it is independent for the same.
	5.00	% electricity generated from Renewable Sources	Higher % of generation signifies cleaner mode of electricity generation and lower emissions related to the same. Electricity generated in this form along with ERMT implementation builds a stronger case for investment for emission reduction.
	5.00	Price of electricity	Lower power tariffs represent cheaper sources of power and a lower cost of operations for business. This would further reflect on to lower fuel/operations cost of ERMT.
EV related Policy/Initiatives	**30.00**		
	10.00	**Presence of EV policy/targets/plans for the same**	
	2.50	EV Policy	A set policy/plan for development of Electric Vehicles supports faster adoption of the same. It also represents the government's intentions towards early adoption of electric vehicles as a mode of transportation and its initiatives to support the same.
	2.50	Initiative	
	2.50	Target	
	2.50	Any subsidy plan	

Segment	Score	Parameter	Rationale
	10.00	**Presence of any e-buses/trolley buses/plans for procurement**	
	5.00	Presence of e-bus/trolley/hybrid bus/EV	Presence of electric buses/vehicles or plans to procure the same represents the intent to move towards cleaner modes of transportation and would further support future implementation of ERMT
	5.00	Any plans for procurement	
	5.00	**Presence of EV manufacturers/battery suppliers**	
	2.50	Local presence of manufacturers/battery suppliers	Local presence of manufacturers and battery supplier would jump start the implementation of ERMT as a key part of the value chain is present. If the country does not currently have the capabilities in form of manufacturing players, presence of set channels for import would support plans of ERMT implementation.
	2.50	Imports	
	5.00	**Penetration of charging infrastructure**	
	2.50	Presence of charging infrastructure	Existing charging infrastructure sets the base of the faster implementation of ERMT. However, upcoming charging stations and plans for the same would also support the cause in the future
	2.50	Plan to set charging infrastructure	
Total	**100.00**		

Each of the countries was individually scored on each of the parameters and the total scores were compared to arrive at three bands indicating prefer-ability of implementation of electric road mass transport among the SAARC Member States.

Table 42: Preferable countries for ERMT implementation

Band	Country
Band I - Most Preferable	India, Sri Lanka
Band II - Moderately Preferable	Bhutan, Nepal
Band III - Preferable	Afghanistan, Bangladesh, Maldives and Pakistan

Detailed data points and scoring has been provided in Appendix II.

7. Deployment Strategy for SAARC States

7.1. Potential National Targets

Implementation of the Electric Road Mass Transportation solutions have significant opportunities in terms of reduction in pollution levels, improvement in efficiencies and reduction of fuel consumption. However, these opportunities come with their own challenges of high initial capital expenditure and development of supporting infrastructure across all the SAARC Member States. Market potential of ERMT lies in procurement of new buses falling in either of the categories and phase-wise replacement of the current fleet of buses run by public or private entities.

However, doing so would require significant amount of investments from ideally from the government/municipal corporation/state run bus transit agencies; which may or may not have the funds readily available with them. Hence, a phase-wise implementation plan is being recommended. In order to promote faster adoption of electric road mass transportation across the countries, the onus should be on the central government to facilitate and incur the initial capital expenditure towards the assets.

To start with, each country has been assessed based on its current government expenditure in a year along with allocations towards the transportation sector. Further, the state of electrification across the country, electricity demand-supply scenario and prefer-ability assessment among the SAARC Member States (done in previous sections) has been analyzed. This has been used to arrive at short term targets of probable budgetary allocation towards the initial investment required for electric road mass transportation; which the SAARC Member States may aspire within the next 2-3 years. Using the probable budgetary allocation along with the total investment plan (as discussed in Section 7.2) involved with procurement of one battery electric buses, the market potential (in number of buses) has been derived for each of the SAARC Member States.

Table 43: Country wise Market Potential for SAARC Member States

Country	Existing Number of Buses	Expenditure on Transport Sector	Prefer-ability of ERMT Implementation	Probable Budgetary Allocation	Market Potential (Numbers)
Afghanistan	106,947	0.07%	Band III	0.25%	33
Bangladesh	158,517	10.12%	Band III	0.50%	272
Bhutan[150]	100	-	Band II	1.00%	13

[150] The expenditure on transport sector is not available.

India	1,527,396	5.29%	Band I	2.50%	27,144
Maldives	140	5.33%	Band III	0.50%	14
Nepal	57,374	11.03%	Band II	1.00%	150
Pakistan	228,588	0.30%	Band III	0.25%	219
Sri Lanka	52,203	10.69%	Band I	2.50%	750

Note: The market potential for ERMT has been evaluated based on cost assumptions for battery electric buses. As discussed in Section 6.1.3, the government can structure the procurement plans by incorporating a plan to combine hybrid buses with battery electric buses. The same would increase the number of buses which can be procured and would completely depend on proportions in which the procurement is being done.

For the market potential assessment, budgetary allocation to ERMT implementation in India and Sri Lanka has been capped at 2.5% considering the current traction from the governments of both the countries, procurement plans set by various transport authorities and significant investments in the transport sector along with initiatives on urban development and emission reduction. Bhutan and Nepal, assessed in the Band-II of the preferable countries for ERMT implementation also have high fiscal expenditure in the transport and electricity sector along with initiatives rolled out for adoption of electric vehicles in the country.

Among the countries assessed in Band III of the preferable countries for ERMT implementation, Afghanistan and Pakistan, although being large countries in terms of land, population and buses catering to the citizens; have very less investments in the transportation sector. In case of Afghanistan, over 70% of the fiscal expenditure has been towards upliftment of the social sector. Further, Pakistan also has plans of investing 68% of FY 2017-18 expenditure in General Public Service and only 0.33% in the construction and transport sector. However, with more than three lakh buses in both the countries, there would be an immense potential in reduction of fuel costs and emissions. To cater to the same, 0.25% of the total budgetary allocation would lead to a market potential of 33 and 219 electric buses respectively in Afghanistan and Pakistan. This can be planned in a phase-wise manner, starting with pilot projects in major metropolitan cities with support of other Ministries of Transportation, Urban Development, Energy and Environment Protection.

Though Bangladesh does not have any procurement plans as of date for purchase of electric buses, the total market size of over 1.58 lakhs buses and an investment of 10.12% in the transportation sector makes it lucrative for ERMT implementation. To derive the same, a budgetary allocation of 0.5% has been assessed resulting into a market potential of 272 electric buses. In case of Maldives, only 188 of the 1,190 islands (land area of ~ 224 sq. km) are habitable, and the population is concentrated in few of the larger islands with 39% of the population residing in the capital, Malé. The country, almost entirely is dependent on fossil fuel imports (20% of its GDP) to meet its energy needs for electricity generation and transportation. Further, reduction of economic, social and environmental implications of high fossil fuel dependence is a top priority of the Maldives

Government and the government is currently working towards increasing the use of renewables as a means to achieve energy security. Hence, initiation of ERMT implementation with procurement of electric buses charged through electricity generated from renewable sources would add on to the government's agenda of independence from fossil fuels. This can be tested on a pilot basis in the capital city of Malé and later on extended as per the results and learnings from the initiative.

7.2. Investment Plan

As discussed in the above sections, the implementation of ERMT would require investments in the following areas:

- **Capital expenditure for procurement of electric buses:** The cost of battery electric buses would depend on whether a country imports such buses or manufactures them indigenously as is the case with India. The cost of importing battery electric buses will depend on countries from which they are being procured. Battery electric buses procured from North American and Europe costs higher when compared to the counter parts from India and China which cost around USD 350,000 -400,000 and USD 400,000-500,000 respectively. Trolley buses on the other hand would require an investment of USD 250,000. With advent of battery standardization and proposals to ensure manufacturers produce buses/ vehicles having a battery of specific design, business models revolving around battery swapping could be developed. Manufacturers would produce the electric buses without batteries and the user would rent out the battery to get it swapped at the battery swapping stations after usage, with charged batteries. This could significantly drive down the cost of procurement as battery costs are approximately 50% of the total cost of the vehicle.
- **Investment to setup related infrastructure with respect to the technology used**: To support the ERMT implementation, infrastructure requirement in the form of charging stations for battery electric buses and overhead lines for trolley buses are a pre-requisite. The cost of charging stations would vary as per the specifications (AC or DC Charger) and power output which determines the time taken to completely charge an electric bus. The cost for charging stations, which have about 50 kW capacity can be around USD 27,000 - USD 33,000. Such a DC charger (rapid charger) will allow the electric buses considered in the above case to be charged in approximately 6 hours.
- **Operational costs:** This comprises salaries of employees, repair and maintenance costs (for buses as well as the supporting infrastructure) and administrative expenses; all of which would be incurred yearly.

Table 44: Overview of costs to be incurred in implementation of electric buses

Parameter	Cost	Rationale
Cost of Electric Bus	USD 450,000	Considering imports from China at an average cost
Investment towards charging infrastructure	USD 30,000	Considering average cost of 50 kW

		capacity DC Charger (rapid charger)
Operational Cost	USD 45,000	Lifetime cost of operations and maintenance with an assumption of useful life of 10 years
Total Investment Required	**USD 525,000**	

Based on the above derived market potential and costs required towards setup of electric road mass transportation in a country, investment plan to meet the market potential in the next 2-3 years have been outlined in Table 45.

Table 45: Country wise Investment Plan to meet the market potential

Country	ERMT Implementation Cost (USD Million)
Afghanistan	17.1
Bangladesh	143.1
Bhutan	6.7
India	14,250.5
Maldives	7.3
Nepal	79.9
Pakistan	115.0
Sri Lanka	393.8

7.2.1. Source of Funds

Building new and advance transportation solutions always come with financial challenges of funding the same. Uncertainties in terms of technological assessment and selection, followed by risk of lower adoption tend to add on to the difficulties in arranging funds for implementation. In case of ERMT implementation, the quantum of funds required by each of the Member States to attain probable short term targets and full potential is immense. Chances of complete funding by the individual governments are also minimal with all nations running into budgetary fiscal deficits. Hence, there is a need to look for other sources of funds, details of which have been discussed below.

- **Loans/ Grants from Multilateral Agencies**: One of the most notable funding vehicle for gaining access to grants/ concessional loans for critical issues is through Multilateral Agencies. It is generally considered as a more non-political form of aid encouraging international cooperation. SAARC Member States could reach out to such agencies requesting support for implementation of ERMT through funding of various initiatives covering pilot projects and setting up of necessary infrastructure. Agencies like Asian Development Bank (ADB) have set investments towards programmes for financing pilot projects to demonstrate, deploy, or transfer low-carbon technologies (ADB – Clean Technology Fund). Under the Clean Technology Fund (CTF), the Philippine government had proposed investment for energy efficient transport through introduction of electric vehicles. The plan was approved with ADB providing grant of USD 5 million, a concessional loan of USD 100 million under CTF and an additional loan of USD 300 million[151]. These agencies have set processes for evaluation of proposed projects which includes reviewing technical and financial feasibility of the project along with its adherence to the agency's overall strategy. After proper due-diligence, negotiations and approvals, the project gets a financial closure which is then monitored continuously by the agency for effective execution.

- **Private Sector Investments through Public Private Partnerships (PPPs)**: Collaboration of public and private sectors is a must for truly building a sustainable transport infrastructure with both parties working towards innovation, risk and return sharing for the financing brought in by the partners. It is to be noted that private sector involvement should be looked at from a perspective to not only access required funds, but to also gather technical and execution expertise. To facilitate Public Private Partnerships, the following commonly used structures can be considered: Build/Rehabilitate-Operate-Transfer (B/ROT) and Build/Rehabilitate-Transfer-Operate (B/RTO). The first case allows the private player to own and operate the infrastructure before transferring to the public sector entity. In the second case, ownership of the asset is first transferred to the public sector entity post construction, after which it is operated by the private sector entity for a defined period of time under a lease/concession agreement.
- **Leveraging the SAARC Development Fund (SDF):** In April 2010, heads of all eight SAARC Member States established SDF with an aim of promoting welfare of people, improvement of quality of life and acceleration of economic growth, social progress and poverty alleviation in region. SDF has three primary windows for funding projects - social, economic and infrastructure. Apart from these, it also provides funding to Social Enterprise Development Program and Micro, Small and Medium Enterprises. Of these options, Infrastructure Window will be best suited for funding ERMT projects as this window covers both energy and transportation.

[151] Philippines: Market Transformation through Introduction of Energy-Efficient Electric Vehicles Project, ADB

Social Window	Economic Window	Infrastructure Window
• Poverty alleviation • Social development focusing on education & health • Human resources development • Support to venerable/disadvantaged segments of the society • Funding needs of communities, micro-enterprises and rural infrastructure development.	• Trade • Agriculture and allied value additions • Industry/Manufacturing • Micro Irrigation • Any other sectors as approved by the Board	• ***Energy*** • ***Power*** • ***Transportation*** • Telecommunications • Environment • Tourism • Other infrastructure areas

Figure 36: SDF Funding Windows

SDF considers projects (equity 25%, loan 75%) with project cost ranging between USD 2 million and USD 20 million. The maximum contribution from SDF is equal to 75% of the total project cost and loan period is generally for 7 Years, including 2 years of grace period.

- **Alternative Methods of financing**: The Central Government of various SAARC Member States may look at levying additional taxes/ duties like that of a clean energy tax or an environmental tax which would be applied on entities operating on fossil fuels. These could include charging vehicles plying on petrol or diesel, power plants running on conventional energy sources, etc. The fund generated through this could be used to fund ERMT implementation. Also, innovative concepts like that of Green Bond Financing can be considered to attract investors looking to put proceeds into green projects such as renewable energy or initiatives to reduce carbon emissions.

7.3. Institutional Arrangement

The adoption of the electric road mass transportation can be broadly divided into four phases: Planning, Investment, Execution and Monitoring.

1. Planning

- Understand the current transportation model and key issues to be addressed
- Identify key policies which need to be developed to shape the electric vehicles market
- Broad Areas which could be covered: Industry structure, Stakeholder management, Operating Model, Identification of Targets (Short term and Long term), Investment Plan, Need for subsidies/incentives for early adoptions
- Development of nationalized as well as city level plans

2. Investment

- Phase wise plan for incurring the investments
- Identification of source of funds – Investment from the Government, Support from multi-lateral agencies, Private sector involvement.

3. Execution

- Procurement and implementation plan to meet the desired goals
- Risk Management and Quality Assurance

4. Monitoring

- Creation of project controls and reporting
- Improvements and initiatives to cater to delays

Figure 37: Key phases of ERMT implementation

In order to successfully implement these four phases, institutional arrangements can be devised into two frameworks: **Centralized and Decentralized Implementation**.

7.3.1. Centralized Implementation

Centralized implementation implies that the Central Government of the country takes concentrated efforts with focus across all the phases of Planning, Investment, Execution and Monitoring. In the planning phase, the Central Government would be responsible for developing the overall policy for the nation covering probable targets to achieve, phase-wise implementation plans and support/guidelines for various stakeholders. Further, for assessment of implementations at city-level, the Central Government should seek support from the local transportation authorities in order to understand and cater to the local needs. The Central Government would be supported by various ministries like that of Finance, Transport, Energy, Urban Development, Industrial Development and Environment Protection. A schematic diagram of the centralized implementation has been given below.

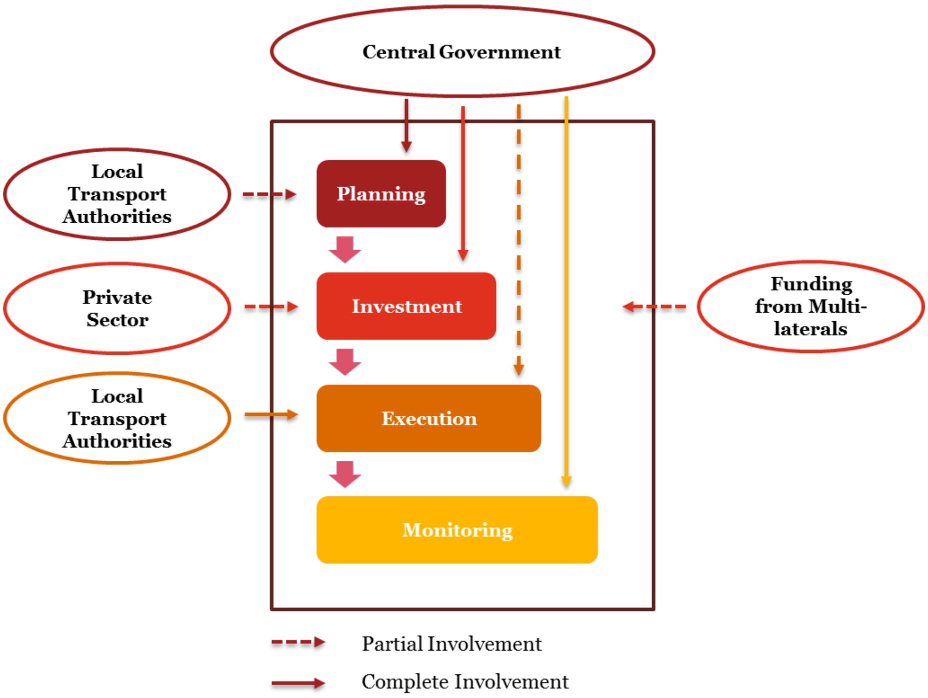


Figure 38: Framework for Centralized implementation

Further, investments for the complete programme would be led by the Central Government along with funds/grants received from various Multi-lateral agencies and investments from private sector. As ERMT implementation would be primarily built around addressing transportation requirements of various cities, the local transport authorities would lead the execution, along with the Central Government driving various initiatives with partial involvement. However, the monitoring of each of the initiatives will be kept under the Central Government for ensuring effective and timely execution.

Such institutional arrangement is best suited for smaller countries among the SAARC Member States including Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka. As can be seen from the current plans of Bhutan, Nepal and Sri Lanka, the Central Governments of the respective countries have initiated either implementation of electric buses in metropolitan cities (Sri Lanka) or have taken steps for early electric vehicles adoption (Bhutan and Nepal). Bangladesh and Maldives can also initiate similar implementation strategies, with the respective governments leading the initiatives with support from local transport authorities, investment/participation of private sector and necessary funding from multi-lateral agencies.

7.3.2. De-Centralized Implementation

In a de-centralized implementation arrangement, the Central Government primarily leads the planning and investment phases whereas the State/Provincial Government looks after complete execution and monitoring of the initiatives. The central government, however, monitors the overall implementation status to ensure identified targets are been met and necessary support is extended to remove bottlenecks, if any. The primary intent for de-centralized implementation is to ensure reach across the country covering large and diverse areas where drive from State Governments would be necessary for effective adoption by the consumers and to ensure execution in a localized and effective manner. A schematic diagram of the de-centralized implementation has been given below.

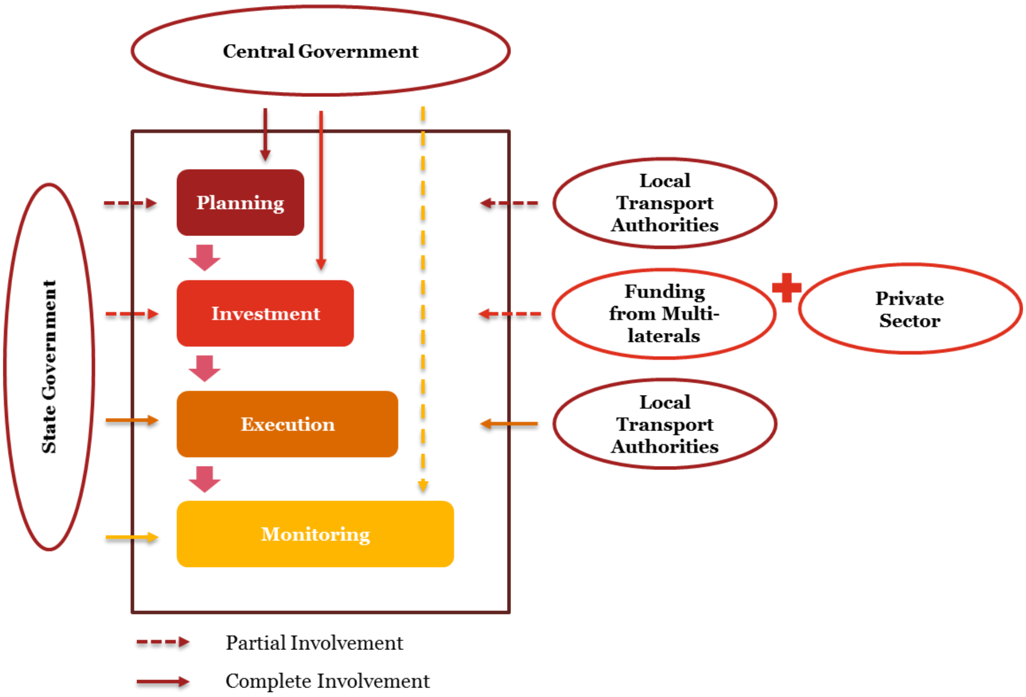


Figure 39: Framework for De- Centralized implementation

As can be seen in the above diagram, the State Government and Local Transportation Authorities will be supporting the Central Government in regional/city level plans which would add-on to achieving the National targets defined by the Central Government. Majority of investments would be expected to be from the Central Government with State Governments partly funding the same. An example of such a structure can be that of Central Government providing subsidies to manufacturers for production of electric buses, along with the State Government supporting the industry by ensuring that attractive lending rates are being extended for setup of production units.

Such institutional setup is ideal for larger countries among the SAARC Member States like Afghanistan, India and Pakistan, all of which have larger diverse area to be catered to and have independent State Governments for managing respective states/provinces. This structure would assist the countries in faster adoption of ERMT where multiple initiatives are being executed by the State Governments across the country. However, it is to be ensured that technical capabilities of each of the region is developed to ensure quality and timely deliverables. Similar structures, already exist in India, with transportation agencies procuring and implementing electric buses on various routes across cities. They are seeking support from the Central Governments under the FAME Scheme and are also looking for avenues of partnership with private entities. Government of India is further coming up with a nation-wide policy that should further fast track the adoption process.

7.4. Commercial Plan

With limited exceptions like that of Honk Kong Metro Transit Authority, most transit authorities around the world run in losses and are generally compensated by the government. This is primarily because of inherent inefficiencies caused by additional buses routes being run to ensure last mile connectivity, high operational frequency on bus routes for passenger convenience, low fares to ensure affordability among masses and project uncertainty arising due to longer time taken for completion. Though it is difficult to completely eradicate all these sources of inefficiencies from the system, there are approaches through which the same could be minimized during implementation of ERMT.

7.4.1. Choosing the right city for implementation

The most important consideration for financially viable ERMT implementation would be to identify the correct city/region through assessment and feasibility studies. Key parameters which could be used to determine the same include ratio of passenger using public transport to those using private transport, the total population, the average distance covered by a passenger using public transport and the average seat occupancy of the buses. Emphasis on other factors like improvement in passenger convenience, operational efficiency and adherence to safety standards should also be evaluated by electric bus operating agencies looking for sustainable urban transport solutions.

Additionally, factors like average per capita income, current bus fares and even environmental awareness need to be studied by bus transit agencies to identify the probability of incremental pricing of bus fares that the passengers will be willing to pay in order to generate maximum possible revenue through operations.

7.4.2. Choosing the most profitable routes

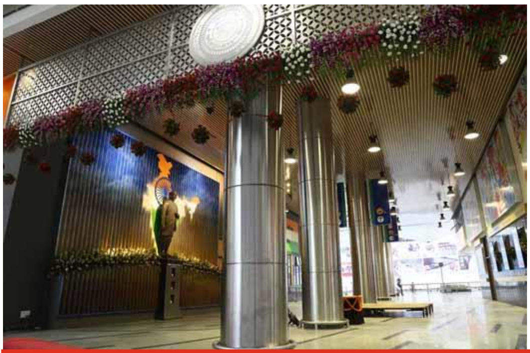
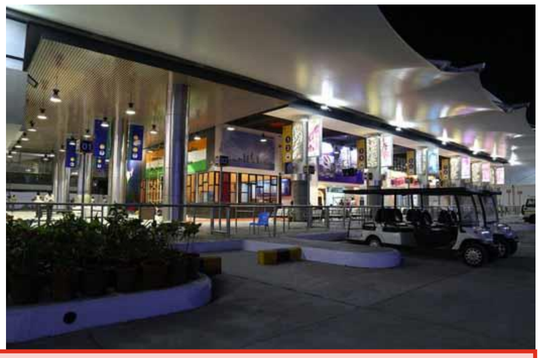
Selection of routes for implementation of ERMT in a designated city would be a crucial factor and the respective planning agency needs to consider possible routes which can promise the highest Fare Box Recovery Ratio. Fare Box Recovery Ratio is the fraction of operating expenses which are met by fares paid by passengers. Therefore, selection of routes for ERMT should be either based on assessment of fares on the existing routes, or through extensive studies of possible passenger traffic along proposed routes. Given the high initial capital outlay, it is essential that the selected routes generate maximum traffic, thereby generating maximum revenue. At the same time, selection of routes where charging infrastructure can be installed is also necessary. As six out of the eight SAARC Member States still do not have complete electrification in the country, it must be made sure that the routes selected have charging stations in distances within the operating range of the electric buses.

7.4.3. Land Value Capture

Along with the ticketing revenue received, transit authorities should also explore avenues for alternative sources of income. The most common method for the same is the land value capture mechanism. This method can especially be used to fund new connection routes for bus transportation agencies. In this approach, typically a transport authority will work with the State/ Central Government, plan a new bus route, estimate costs and eventually identify potential sites along the bus route. The transit authority will then purchase lease of those sites for a long period, typically about 50 years, from the government. The land will be used for property development near the bus depots. Land is purchased at a premium pre-commercialization rate of the area. Private developers bear all development costs along with the risks associated with construction and development. This also ensures that the transit authorities are safeguarded against unforeseen circumstances. Initially the transit authorities can keep the premium charges low to encourage participation of developers in such schemes. The transit authorities can also allow them to keep a higher share of profits, or complete profits, that are generated through selling of the residential and commercial units on the land developed.

SAARC Member States may modify this arrangement based on the legal, political and regulatory frameworks of their respective nations. Also, transit authorities will need to decide the profit sharing mechanism with the developers. In case of Honk Kong Metro Transit Authority, one of the widely recognized implementer of a successful Land Value Capture Mechanism; after the development, the transit authority received a share of all the residential units sold before deadline, and then acquired the remaining ones for selling or leasing them out. Commercialization risk for the same was under taken by the developers and it helped in reduction of financial risk for the leveraged transit authority. For commercial units, the transit authority may either lease out the property directly with developers or keep part of the assets for long-term income.

Another method to generate higher revenue from the ERMTs, is to focus on bus depot oriented commercialization of the land available. This can be done through shops, restaurants, parking spots and, if possible, resting locations like hotels. These will be very useful for passengers who want to stay near the bus depots, either due to frequency of their travel or because of the time interval between connecting buses. The transit authorities or the bus depot owners can either charge a percentage of the total revenue from these shops, or an annual/monthly rent, or lease fees, or a combination of all three. Advertising on depots and buses, both inside and outside, is another method for generating additional revenue.

Geeta Mandir Bus Depot in Gujarat, India was one of the first bus depots in Gujarat built on a PPP model with a focus on the commercialization aspect of bus terminals.

Figure 40: Images of Geeta Mandir Bus Depot in Gujarat, India.

7.4.4. Associated Social Benefits

A combination of these approaches will help increase the efficiency and returns of financial investments made on ERMT. Additionally, the implementation will have its social benefits too. Pipe tail emissions by conventional buses lead to air pollution, global warming and also have harmful implications for human lungs, which in turn could be reduced by implementation of ERMT. Also, the reduced noise pollution will compound the benefits of reduced emissions. Noise pollution can lead to issues ranging from cardiovascular issues to sleeping disorders. The reduction in pipe-tail emissions caused by the ERMT ensures a healthier lifestyle for the citizens and will potentially reduce their medical expenses. This will further support the Central/ State governments to sustain a lower growth rate in their health care and medical expenditure for their citizens. Therefore, while considering the initial capital outlay and operating expenses for ERMT, the social benefits should also be considered. They have far reaching benefits than that may or may not be quantified in monetary terms. Healthier citizens are always a more-efficient workforce helping in increase of overall productivity of the nation.

7.5. Technical Capacity Building

7.5.1. Charging Infrastructure

Except for a few charging stations in Bhutan, India, Nepal and Sri Lanka, the charging infrastructure is almost non-existent in the SAARC region. As analyzed earlier, installation of charging infrastructure will require additional capital expenditure over and above the outlay towards procurement of buses. SAARC Member States may choose to reduce this investment by choosing lower wattage chargers, which will take more time to charge. However, it will be better for longer run, if they decide to invest in DC Level 2 chargers allowing the buses to charge quickly and be ready for operations.

An extensive and well laid out charging infrastructure will not only help in implementation of ERMT but would also encourage private consumption of electric vehicles. As charging infrastructure installation is costly and a long term-investment, SAARC Member States need to plan their installations strategically. Instead of equally spreading the charging stations, nations should first install the charging infrastructure at routes/places which experience heavy traffic. However, the charging infrastructure shouldn't be placed along the roads, instead special diversions should ideally be created for them. This will ensure that charging stations don't create bottlenecks in the heavy traffic zones. China plans to have a network of 800,000 charging stations for 5 million electric vehicles by 2020[152], i.e. one Electric Charging station for every 6.25 electric vehicles. This can be a benchmarking standard for SAARC Member States as the target for the number of charging stations they wish to install in a phase wise manner. This benchmarking standard is however based on the total number of EVs and not just electric buses. Eventually, as the adoption of electric vehicles increases, the charging infrastructure can be spread out to medium and low traffic zones, as and when feasible.

While planning the layout and number of charging infrastructure for electric buses, factors like total number of buses, average route length of buses, range of buses and the traffic density along the routes should also be considered. The charging stations can be installed at bus depots so that buses can charge themselves during the non-operational hours. This would also help in reducing the time taken for land selection, getting clearances and appropriate approvals from various authorities and also providing an additional source of generating revenue by allowing access to private electric vehicle owners. However, for those routes where the distance between the depots is more than the range of electric buses, the charging infrastructure may also be installed on diversions created along route paths. Also, with standardization of batteries being discussed and planned in countries like India, Battery Swapping Stations can also be installed at the charging stations where one could swap the used batteries with charged ones to ensure continued operations.

7.5.2. Research and Development

Innovation is necessary to ensure sustainability of any technology. As import of technology is a costly affair, investments in domestic research institutes in a focused manner can help nations become self-reliable in terms of technology. **SAARC Member States can form a common pool of funds focused on funding research in electric vehicles**. Institutes could be established primarily for research on EVs or the fund could be used towards existing Centers of Excellence among SAARC Member States. These centers of excellence can either be the research and development units of automobile manufacturers or research institutes with advanced testing facilities. These investments will not only result in limited, or no, expenditure on import of technology but will also help the countries develop technological advancements that can be exported, bringing wealth and prestige for the SAARC region.

Research and development initiatives should also be focused at developing benchmarking standards. These standards will help in establishing best practices across the spectrum of processes involved in ERMT implementation in particular, and EV in general. From

[152] China to build more charging points for electric vehicles, The State Council, The People's Republic of China, Article Published on 9 February 2017

safety standards for batteries to wattage outputs expected from charging stations, clear specifications should be defined for each SAARC Member States. In making these standards, global standards such as UN Recommendations on Transport of Dangerous Goods, Manual of Tests and Criteria, Part III, Section 38.3, J2464[153] and J2929[154] of Society of Automotive Engineers and IEC 62281[155] of International Electro technical Commission can be referred. Setting up of such standards and adherence to the same will also help increase public trust and acceptability towards these electric vehicles. Further, SAARC Member States should also work towards a common set of standards to increase the possibility of exchange of technology, transfer of knowledge, as well as of physical goods.

7.5.3. Manufacturing

Indigenous manufacturing is very essential for SAARC Member States to keep the cost of ERMT low. **SAARC nations should consider coming together for an OEM agreement for electric vehicle manufacturing. Under such an agreement, every nation may take the responsibility of manufacturing certain components as per their capability and resource availability**. For example, Afghanistan which has large deposits of lithium can either setup its own manufacturing plant or export to another SAARC Member State having capabilities for manufacturing of Lithium Ion batteries. This will help in upward integration of supply chain for manufacturing electric buses, hence, driving down the overall costs. These batteries can then be shipped to other SAARC nations, with no import and export duties getting applied as per the common agreement. The batteries which are manufactured this way, will be way cheaper than the ones imported. Further, overall cost of manufacturing of electric buses could reduce on the basis of economies of scales being achieved from centralized production entities.

Such an arrangement will also accelerate the industrial activities across countries along with employment generation opportunities. For smaller nations, where economies of scale might be difficult to achieve, given the limited number of domestic numbers, this will serve as a good incentive for setting up manufacturing units as the manufacturers would be able to cater to a larger potential across SAARC Member States and also open up for exports to foreign markets at competitive rates. SAARC Member States can again setup a common pool of funds to fund setting up of such manufacturing facilities or can decide to provide direct and indirect subsidies to private entities interested in the same which may include easier land acquisition process, subsidized interest rates for loans and reduced tax obligations.

7.5.4. Regulatory Body

As technology of electric vehicles is still under-going an evolutionary phase, it is of utmost importance to ensure that exhaustive safety standards are set for vehicles. This will ensure that

[153] Standard for Electric and Hybrid Electric Vehicle Rechargeable Energy Storage Systems (RESS), Safety and Abuse Testing
[154] Standard for Electric and Hybrid Vehicle Propulsion Battery System Safety Standard and their Lithium-based Rechargeable Cells
[155] Standard related to safety of Primary and Secondary Lithium cells and batteries during transportation

manufacturers do not end up compromising on the safety of passengers. Apart from the safety issues in conventional vehicles, electric vehicles have additional safety issues related to batteries and use of charging stations. Therefore, regulatory authorities need to frame standards focused on electric vehicles and the charging of its batteries.

7.5.4.1. Safety Standards for Electric Batteries

Electric batteries are vulnerable to electric, mechanical, and other types of damages during operation, storage and transfer. Various organizations including United Nations, Underwriters Laboratories, Institute of Electrical and Electronics Engineers, National Electrical Manufacturers Association, Society of Automotive Engineers, International Electro technical Commission, Japanese Standards Association and Battery Safety Organization have proposed various testing methodologies to ensure that these battery are safe under rigorous conditions. A list of various such test is given below. SAARC Member States may choose to establish their own testing standards similar to these tests, modified to accommodate local temperature variations, road conditions and usage patterns.

Table 46: List of tests for ensuring safety standards of electric batteries

Test Category	Test Name[156]	Description
Electrical Tests	External Short Circuit Test	Determines the ability of cells to withstand a maximum current flow condition without causing an explosion or catching fire.
	Abnormal Charging Test	Determines whether the battery can withstand an over-charging current rate without catching fire.
	Forced Discharge Test	Determines the ability to not explode under an imbalanced series connected pack, which is eventually short-circuited.
Mechanical Test	Crush Test	Determines the ability to withstand specified crushing force between two plates, without catching fire.
	Impact Test	Determines the ability to withstand impact applied to a cylindrical steel rod placed across battery, without catching fire.
	Shock Test	Determines the ability to bear specified average and peak acceleration without explosion, ignition, leakage or venting.
	Vibration Test	Determines the ability to bear a simple harmonic mention at specified amplitude without explosion leakage or venting.
Environmental Test	Heating Test (Not required under IEC 62281, UN 38.3)	Evaluates cell's ability to withstand specified application of an elevated temperature without explosion or ignition.
	Temperature Cycling Test	Determines ability to survive at temperature above and below room temperature for a specified number of cycles without explosion or leakage.
	Low Pressure Altitude Test	Determines the ability to withstand exposure to less than standard atmospheric pressure without explosion, ignition, venting or leakage.
Other Specialized	Projectile (fire) Test	Determines the ability to survive flame from test burner, while position within a specified enclosure composed of wire mesh and

[156] Safety Issues for Lithium Ion Batteries by Underwriters Laboratories

Test Category	Test Name[156]	Description
Test		structural support without explosion.
	Continuous Low Rate Charging Test	Determines the ability of fully charged cells to survive at a long-term uninterrupted specified charge rate without leak.
	Mold Stress Test	Determines ability of plastic-encased batteries to survive without leakage at specified elevated temperature for specified time.
	Insulation Resistance Test	Measures resistance between each battery terminal and accessible metal parts of battery pack, which should be above specified values.
	Reverse Charge Test	Determines a discharged cell sample's ability to not ignite or explode under specified charging current in reverse polarity

7.5.4.2. Safety Standards for charging infrastructure

Charging infrastructure is one of the most perilous elements involved in the usage of ERMT implementation. Therefore, it has its own set of benchmarking protocols. Though many nations have their own protocols, their foundation is always based on the following regulations. While IEC 61851-1 is common for all types of charging stations, IEC 61851-23 and 61851-24 are for DC chargers and AIS 138 – Part I are especially for AC charging systems.

Table 47: Safety standards for charging infrastructure

Regulation	Implication
IEC 61851-1	Electric vehicle conductive charging system - Part 1: General Requirements
IEC 61851-23	Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station
IEC 61851-24	Electric vehicle conductive charging system - Part 24: Digital communication between a DC EV charging station and an electric vehicle for control of DC charging
AIS 138-Part I	Electric vehicle conductive AC charging system

Apart from the safety features under these protocols, special charging protocols also need to be established on peripheries including basic insulation, cable assembly, exposed conductive parts, plugs and outlet sockets.

The most essential part is classification of chargers as Type – I and Type – II. Under this kind of nomenclature, chargers are categorized in a manner that allows estimation of charging time. A Type-I charger would typically take 6-8 hours to charge a battery while a Type-II charger will only need 1.5-2 hours for charging. The final time take, of course, depends on the actual size of the battery and the chargers. SAARC Member States need to classify the charging infrastructure available based on the range of output wattages. A common set of standards across SAARC nations will provide more opportunities of import and export of components and equipment across the region as the same technology will not be re-categorized under different regulations of countries.

7.5.5. Deployment

Deployment of ERMT will be the most critical and challenging part of implementation. Countries will face issues ranging from financial challenges for sustainable operations to attracting and retaining private entities. SAARC Member States should consider establishing an independent ministry for implementation of electric transportation solutions, which may also be structured within the existing transport ministry, so that all the issues related to ERMT can be handled on priority. The governments can otherwise consider putting specific responsibilities to existing departments of transportation, energy, urban development, and environment.

The deployment will also depend on the division of power as per the political and legal frameworks of the country. For smaller nations, in terms of size and population, the central government can take the responsibility of implementing the ERMT. For nations with larger populations and a more de-centralized federal structure of government, the responsibility of implementation can be owned by the state government, and perhaps even the local municipal agencies. In either case, governments, whether central or local, will have to be the driving force in ensuring smooth deployment of ERMT.

Power Utilities too will play a critical role in successful deployment. The utilities will be primarily responsible for laying the supporting infrastructure required for the charging stations. In a more active role, they can even partially or completely fund the charging infrastructure.

While supporting the deployment through subsidies and other fiscal or non-fiscal incentives, government bodies of SAARC Member States will need to ensure that the utilization of funds is done in a transparent, effective and sustainable manner. This will require continuous monitoring of funds and expenditure made by both government and non-government bodies involved in the implementation.

7.5.5.1. Retro-fitment of existing buses

As adoption of ERMT spreads across cities, the countries would also need to look at replacing the current fleet of buses with their electric-variants in a phase wise manner. Ideally, the government should look to develop a policy towards retro-fitment of the existing buses. The following key areas should be addressed:

- Technical assessment of the current inventory to identify key parts which needs to be replaced/modified
- Clear parameters such parts to be replaced should be defined
- Assign manufacturers to develop the required technology and manufacture such kits
- Set up of authorized installers through service stations/camps to retrofit the existing buses
- Provision for financial incentives like subsidies to owners to encourage retro-fitment of their inventory.
- Disposal Policy for the damaged/scrapped parts

A typical plan to current the current inventory of diesel buses to hybrid/battery electric/trolley buses has been outlined in Figure 41.

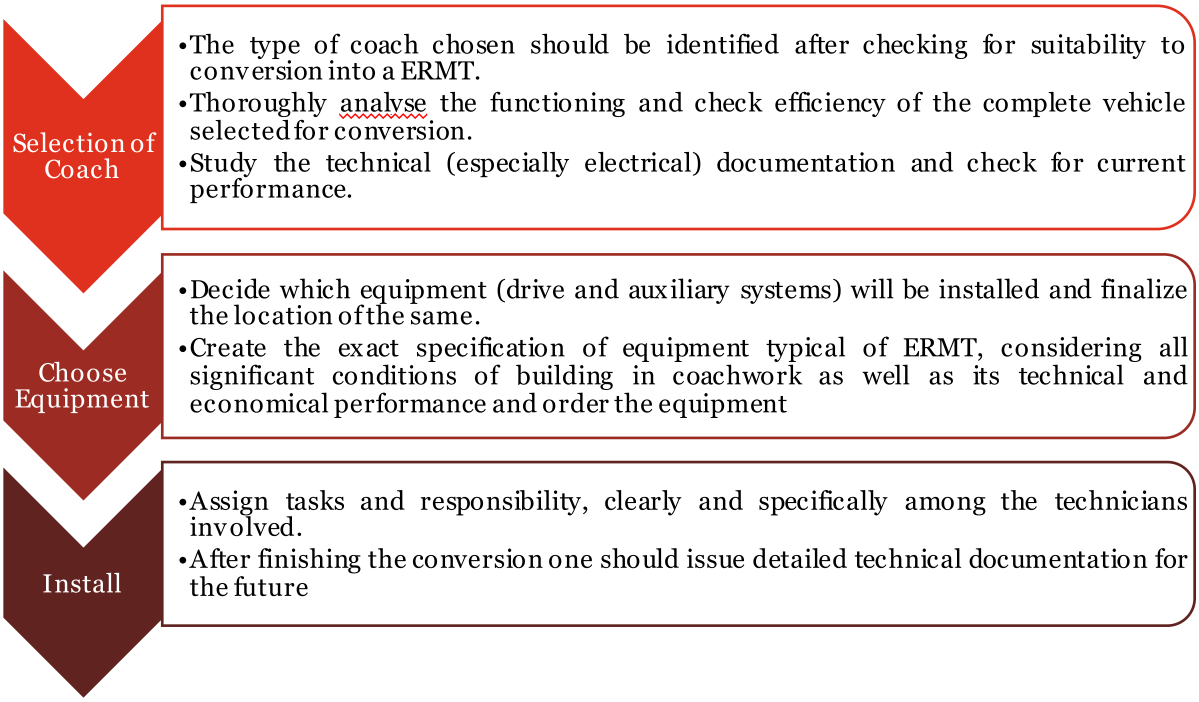


Figure 41: Typical steps involved in conversion of diesel buses to ERMT

7.6. Awareness Generation

Creating awareness about ERMT among the various stakeholders is vital to its success. Consumers, Power Utilities, Manufacturers and Other Entities need to be made aware about ERMT and its benefits.

7.6.1. Consumers

Making consumers aware is important in order to ensure that the public opinion about government spending on the high initial expenditure for EMRT remains favorable. Government should hold awareness campaigns through online mediums and public advertisements highlighting the benefits of reduced emissions on the health of their citizens and promote more use of public transportation facilities. A list of general activities which can be used for promotions have been listed below:

- Organizing launch events in cities
- Regular road shows highlighting benefits
- Advisement through newspapers, radio, television and online platforms

The government should also focus on making school and college students aware about the environmental benefits through educational institutions. This can be done through various instruments ranging from textbooks to awareness events, like Electric Vehicle Day s. This can be along the lines of traffic rule awareness campaigns which are regularly organized in various educational institutes. If the public opinion about ERMT is favorable, the government can also consider raising ticket fares for ERMT without facing much disagreement from the public.

7.6.2. Support to Industry (Power Utilities and Vehicle Manufacturers)

Power Utilities play a highly important role in implementation of ERMT and ensuring its sustainability. The governments will need to create awareness among utilities about ERMT and the potential growth in electricity consumptions, and thereby the revenues, that ERMT will bring for them. As utilities are responsible for electricity management, they can implement various techniques that will ensure better grid management. For example, they can implement a tariff structure which allows maximum usage of charging infrastructure in non-peak hours which will be beneficial for customers with lower cost and help in grid stabilization. The governments can organize seminars and discussion forums with utilities on discussion of such benefits and development of policies and plans for increased participation and easier implementations.

As discussed earlier, indigenous manufacturing will play a key role in keeping the costs of ERMT down. If possible, the government should form a consortium of manufacturers and discuss the potential benefits of ERMT and methods for effective implementation along with increase in competition. The government can also provide manufacturers with a credit system, as discussed in case of China, which makes them eligible for prioritized loans and better subsidies on good performance. The government should provide manufacturers with grants on research and development, to promote development of common sharable technology that is suited to needs of the manufacturing industry.

The government should also try and seek interest and investment of other industries segments. These industries can bring major investments which can help accelerate the implementation of EMRT. SAARC Member States can hold joint summits where key private entities across industries would be invited and told about the plans of the Government and further look forward for support from these entities in implementation of ERMT.

7.6.3. Association of Interested Industry Participants

The government should support the formation of an association of segment leaders across the market, who are interested in investing in ERMT. Ideally such an association should have a core functional body which comprises of representatives of the industry, the government and even representatives of civil society. Such an association will provide a platform for a two way communication between the government and the industry. This will also allow the government to spread its message and make the interested organizations aware about the incentives, fiscal or non-fiscal, offered by the government. At the same time, it will also allow the government to receive feedback about the drawbacks in the existing schemes/policies and be informed about the hurdles in implementing ERMT for necessary actions. This end-to-end process will facilitate smooth and effective interaction with the industry and help speed up the implementation of ERMT.

Table 48 gives an overview of the existing associations related to EVs in SAARC Member States. Among the SAARC nations, currently only India, Nepal and Sri Lanka have established organizations promoting usage of electric vehicles.

Table 48: Associations present in SAARC Member States for promoting electric vehicles

Country	EV Association	Industry Representation	Civil Society Representation	Major Functions
India	Society of Manufacturers of Electric Vehicles (SMEV)	Yes	No	• Support policy framework on EVs to be part of town planning infrastructure. • Represent EVs in center/state bodies for benefits and rationalization of rules. • Assist manufacturers in implementing government policies for optimum benefits. • Persuade nodal agencies for faster implementation of pilot projects. • Spread awareness of Electric Vehicles. • Help in evolution of implementable ARAI standards. • Catalyze bulk purchase of EVs in Government departments and offices.
Nepal	Electric Vehicles Association Nepal (EVAN)	Yes	Yes	• Meetings with government authorities and other concerned bodies to discuss the various obstacles faced by both two-wheeler and four-wheeler EVs in the country • Representations made to the government for interests of EV manufacturers and Charging Station Owners
Sri Lanka	Electric Vehicle Club Sri Lanka	No	Yes	• Promote and facilitate the use of Electric Vehicles and Vehicles using Alternative Energy Sources. • Create deeper awareness and enhanced knowledge among the society by arranging public forums and platforms for EV users • Promote, educate and engage in dialogue between the users of Electric Vehicles, the Government Authorities and Private Sector Organizations.

Moreover, these associations can also help the government keep a track of effective usage of government subsidies. This will ensure that the private entities do not misuse the funds provided by the government, as it had been in the case with China, and at the same time help government in deciding a distribution of funds in a manner aligned with the needs and demands of the industry. The organization will also help keep a track of best practices and policies related to Electric Vehicles around the world and suggest methods for their adaption in the local context of SAARC Member States. Participation of civil society members, preferably EV owners or frequent users of ERMT, in the association will ensure that the government and manufacturers can get direct consumer feedback. At the same time, these members can be excellent ambassadors for promotion of use of electric vehicles.

8. Conclusion and Recommendations

- Global warming, leading to climate change, is one of the biggest global threats today. In an attempt to tackle this, all SAARC Member States have taken up INDC commitments at the Paris Agreement at the twenty-first session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). While Afghanistan, Bangladesh, India, Maldives, Pakistan and Sri Lanka plan to reduce their GHG emissions, Bhutan plans to remain carbon neutral and Nepal wants to reduce dependency on fossil fuels by 60%. Electric Road Mass Transportation provides an opportunity in developing mobility infrastructure which would reduce emissions, support in decreasing air and noise pollution along with improving operational efficiency vis-à-vis traditional ICEs.
- The three economically viable technologies for implementing ERMT include plug-in hybrid buses, battery electric buses and trolley buses. Trolley buses need an infrastructure of overhead wires, while plug-in hybrid electric and battery electric buses need a network of charging stations. Plug-in hybrid buses have an option of operating on conventional fuels and hence are not completely dependent on the charging infrastructure. Each of these technologies have better well-to-wheel efficiency, lower operational costs and reduced emissions when compared with buses running on diesel. However, the range of battery electric buses are a concern for their operations, which determines the frequency of charging at the stations. Though with technological advancement in battery development, the range of battery electric buses have reached ~250 - 300 km of seamless operation after a complete charge.
- The challenges for ERMT implementation include high initial capital outlay, meeting the electricity requirements for ERMT and installation of charging infrastructure or overhead lines for operations. **Support from government, investments from private sector and sustained funding to boost and support manufacturing and R&D efforts will play a key enabling role in implementation of ERMT.**
- As evident from cases of China and San Francisco, the initial investments in deployment of electric buses would have to be made by the Central/ State Government. These investments could be incurred towards procurement of buses and installation of charging stations. Also, for long term benefits of development of the industry, investments in research and development supporting reduction in cost of technology should be targeted.
- The Central Government across the SAARC Member States should **develop a comprehensive policy covering the following key areas**.
    - Develop the automotive industry for manufacturing electric vehicles and buses
    - Support manufacturing units by providing direct subsidy, access to cheaper source of funds and reduction of tax obligations

- Provide a network of charging stations for seamless operations of electric vehicles/buses
- Design standards for battery manufacturing covering safety aspects of the same
- Decide concreate steps in promotion of R&D
- Finalize time bound targets to be achieved
- Design structures for execution and monitoring of the programme
- Provision of direct subsidy/non-financial incentives to procurement authorities/customers
- Promote Public-Private-Partnerships to facilitate investments in the sector along with gaining the technical and operation effectiveness in implementation of ERMT like setup of charging infrastructures.

A well-defined and focused approach of government will increase the confidence of private entities and help in attracting more attention.

- **SAARC Member States should explore both fiscal and non-fiscal benefits while incentivizing ERMT in particular, and EV in general.** The fiscal incentives could include exemption from vehicles registration charges, diesel vehicle scrappage grants, subsidies, waiving of purchase and import taxes, exemption from road and ferry tolls and waiving of annual vehicle taxes. Non-fiscal incentives generally include designated free parking spaces, banning of high polluting vehicles, access to priority lanes and free access to charging stations. With advent of ERMT implementation, direct subsidy either to the manufacturers or the procurers would be ideal, followed by phasing out of the same with plans to promote efficient vehicles (which have longer operating range or take lesser time to charge) or development of an electric vehicle credits systems (e.g. New Energy Vehicle (NEV) credit system in China). The incentives provided should also be extended to support installation of charging infrastructure.
- **Private sector participation is extremely necessary for the success of ERMT**. They can especially play a key role in development of charging stations and commercialization of the operations. A consortium of manufacturers or power utilities can take the onus of setting charging infrastructure and asking users to pay a membership fees/ pay for use, as was done by the Nippon Charge Service in Japan. A key point to note is that a successful implementation and adoption would depend on how various stakeholders (Government, Transport Authorities, Regulators, Vehicle Manufacturers, Power Utilities, Infrastructure Providers, and Funding Agencies) interact and innovative business models are developed around mutual benefits and collaboration of stakeholders.
- **SAARC Member States should mutually agree upon joint investments into development of electric vehicles and form an association to share technology and provide support in implementation of ERMT along with faster adoption of EVs across the nations.** The association developed could further drive the following key areas which would benefit all the participating nations:

- Free flow of components/vehicles without attracting any taxes and duties
  - Harness benefits of centralized manufacturing which could drive down overall costs of the vehicles by benefiting from economies of scales achieved during production.
  - Leverage on easy availability of capital with support of investors willing to finance projects/initiatives across nations.
  - Formation of a common pool for funding R&D efforts
  - Exchange of technical capabilities along with access to manpower for implementation and training resources across other nations which might not have similar capabilities.

  The ERMT Council could also keep a check on the working, maintenance, daily routine schedules of the ERMT network across nations and support the manufacturing units in administrative work like getting necessary approvals in the respective countries. They can work in coordination with various State and Central government and support in their endeavors of successful and faster adoption of ERMT.

- For a completely successful adoption, SAARC Member States will have to focus on ensuring customer awareness, eventually leading to customer adoption. This will have to be done through targeted advertisement campaigns eventually leading to word-of-mouth promotions, which would result in citizens adopting efficient and environment friendly public modes of transport.

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Appendices

A.1. Appendix I - List of Bus Models manufactured by key players across the globe

Manufacturer	Model	Key Features
BYD	K9	• Driver range - 250 km. Powered with Lithium Iron Phosphate (LiFePO4) batteries • Total power capacity - 324 kW • Includes intelligent key systems for starting the car with a single button and has an ABS and anti-slip regulation system that ensures the safety and comfort of passengers
	12 m Overseas	• Low entry Battery Electric Vehicles with a total passenger capacity of 95 m. and weighs around 19,000 kg • Top speed of 80 kmph and the range of the vehicle is 300 km
	Mini Bus	• A low/entry/low floor vehicle with a length of 8.7 m • Top speed of 70 kmph and the range of the bus is 200 km
	10.8 m Variants	• Low entry BEV with length varying between 9.6-11.5 m • The maximum passenger capacity among models is 90, corresponding to a weight of 19,000 kg • Maximum speed of 80 kmph and the range is 340 km
	Double Decker	• Double Decker bus with length generally between 10.2-12m • Total passenger capacity for the 12 m. variant is 95 and it weighs about 20,000 kg • The maximum speed is 70 kmph
EBUS	EBUS22	• Electric Bus equipped with 130 kWh battery and running on Lithium Iron Phosphate (LiFePO4) battery technology • It gets 200 km. range from an overnight charge
	40 foot Composite Ebus	• Lightweight composite body electric bus with 6000 pound lighter body leading to saving of up to 20% more fuel
	CNG micro-turbine	• Hybrid electric bus with zero emission • Powered by CNG producing up to 65 kW of electricity that keeps the battery charged
Proterra	Proterra Catalyst	• Comes in two models, a 35-foot and a 40-foot battery electric bus. • Both of these are equipped with fast-charging technology and extended range which gives a fuel economy of 1.7 kWh/mile, speed of 104 kmph. • Both the 35 ft. and 40ft. models and both models use a single standard and proven components.

	FDG6113EVG	• The bus has a top speed of 80 km. per hour and manufacturers claim of a stable performance, zero emission, low noise, and a fashionable arc outline.
Wuzhoulong	FDG6751EVG	• This electric bus is designed for city use and is 7m long with a capacity of 10-30 passengers and no space for luggage cabin.
	FDG6801EVG	• The bus has a lattice-type frame design, making it lightweight. Further, the frame design helps in absorbing the tumbling and crashing energy, ensuring the safety of the passengers.
	Perun HP	• 12 m BEV with a total capacity of 82 passengers • Top speed of 70 kmph, range of ~160 km and weighs ~18,600 kg
Skoda	26 Tr	• 12 m Trolleybus with a vehicle passenger capacity of 85 • Top speed of the vehicle is 70 kmph and it has a fuel economy of 1.5 kWh/km • The bus weighs around 18,000 kg
	27 Tr	• 18 m trolleybus with a total passenger capacity of 125 • Top speed of ~70 kmph and the bus has a fuel economy rate of 2.4 kWh/km • The gross vehicle weight is about 29,000 kg
	Urbino 12 Electric	• 12 m BEV with a total passenger capacity of 90 • Top speed of ~80 kmph and a fuel economy rate of 0.9 kWh/km. • The gross vehicle weight is about 19,000 kg
Solaris	Trollino 12	• 12 m trolleybus with a total passenger capacity of 83 • Top speed is ~70 kmph and gross vehicle weight is about 29,000 kg
	Trollino 18,75	• 18.75 m trolleybus with a total passenger capacity of 139 and top speed is about 70 kmph • The gross vehicle weight is about 30,000 kg.
TATA	Ultra-Electric	• 9 m electric bus with a passenger capacity of 12 • Top speed of 80 kmph and a range of 150 km • The gross vehicle weight is about 10,200 kg
	Starbus Hybrid	• 12m diesel hybrid bus with a total passenger capacity of 60 • The bus has a top speed of 80 kmph, range of 300 km and the gross vehicle weight is about 16,200 kg.
Volvo	7900 Electric Hybrid	• 12 m PHEV and which can accommodate 71-98 passengers depending on seating specifications • Top speed of 70 kmph and the bus can weigh between 12,100-12,900 kg

	7900 Electric	• 12 m PHEV and which can accommodate 80-105 passengers • Top speed of 80 kmph the bus can weigh between 11,400-12,000 kg.
Ashok Leyland	Circuit	• BEV with a passenger capacity of 35-65. • Top speeds of 80 kmph and can travel up to 120 km with a single charge
	Versa EV	• 11 m bus with a seating capacity of 44 • Top speed of 95 kmph and the top torque is 600 Nm • Maximum output of 200 HP @ 500 rpm
Yutong	ICE 12 fully Electric Bus	• 12.3 m bus with a passenger capacity of 59 and driving range of 200 km • Battery volume is of 295 kWh
	E12 Fully Electric	• 12 m bus with a passenger capacity of 92 • Driving range - 220 km • Battery volume of 295 kWh
	H12 Hybrid City Bus	• 12 m bus with a passenger capacity of 92 • Runs on super capacitance as electric storage device • Average fuel consumption is of 10 km/l
Nanjing Golden Dragon	E Bus	• 12 m bus with a passenger capacity of 24 • Operates on ultra-capacitor lithium battery • Maximum speed of 69 kmph and a range of 30km
Hunan CRRC Times	TEG6110EV	• 11 m bus with a passenger capacity of up to 47 • Top speed of 100 kmph and a peak power of 180 kW • 186 kWh battery and a range of 335 km
	TEG6106BEV02	• 6 m electric bus with a seating capacity of 14 • 51.6 kWh battery capacity and a range of 251 km
New Flyer	Xcelsior Electric	• Models of 35 foot, 40 foot and 60 foot, with passenger seating capacity varying from 32 to 61 • Manufactured batteries that range from 100 kWh - 480 kWh.

A.2. Appendix II - Data Sheet and Scoring of Preferable Countries for ERMT Implementation

It is to be noted that the below compiled data is as on September 2017.

Data Sheet:

Segment	Score	Parameter	Unit	Year	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Macro-Economic Profile	20.0											
	2.5	GDP growth rate	%	2016	2.00	7.11	6.44	7.11	3.40	0.77	4.71	4.38
	2.5	Per capital income	USD	2016	580.00	1330.00	2510.00	1680.00	7430.00	730.00	1510.00	3780.00
	2.5	Urban Population (% of total population)	%	2016	27.00	35.00	39.00	33.00	47.00	19.00	39.00	18.00
	2.5	Inflation	%	2016	4.50	5.92	3.28	4.70	0.50	9.92	2.86	3.97
	2.5	Overall Fiscal Balance Surplus/(Deficit) (as a % of GDP)	%	2016	1.61	-3.09	-3.01	-3.50	-7.38	1.39	-4.56	-5.64
	2.5	Current Account Balance-Surplus/(Deficit) as a % of GDP	%	2016	4.36	1.67	-29.38	-1.00	-17.71	6.25	-1.15	-2.05
	2.5	Ease of Doing Business	DTF Score	2016	38.1	40.84	65.37	55.27	53.94	58.88	51.77	58.79
	2.5	Sovereign Credit Rating	Moody's Rating	2017	Not Rated	Ba3	Not Rated	Baa3	B2	Not Rated	B3	B1
Transport Sector profile	25.0											
	5.0	Contribution to GDP	%		18.11	8.76	9.00	6.97	5.96	8.11	11.92	12.09
	5.0	Quality of roads	Score	2016	Not Rated	2.90	3.80	4.40	Not Rated	2.80	3.80	4.70
	7.5	Road Density	km/'000 km2		61.05	144.43	291.11	1664.65	NA	592.18	332.12	476.48
	7.5	Bus Density	No./'000 people		3.87	0.99	0.00012	1.19	0.32	2.00	1.19	2.46
Power Sector Profile	25.0											
	5.0	Contribution to GDP	%		0.08	1.50	14.34	2.58	0.87	1.16	1.76	1.05
	5.0	National electrification Rate	%		89.50	62.00	100.00	81.12	100.00	76.30	72.50	98.60
	2.5	Demand Supply Surplus/Deficit	%		91.04	15.22	276.62	-0.70	0.00	-16.46	21.23	10.66
	2.5	Electricity imported	%		80.35	7.32	0.00	0.45	0.00	34.76	0.00	0.00
	5.0	% installed capacity from RE Sources	%		86.09	1.99	99.50	16.52	0.00	99.90	29.60	32.80
	5.0	Price of electricity	US cents per kWh	2016	16.80	9.30	5.70	16.00	27.30	10.40	19.00	20.10
EV related policy	30.0											
	10.0	Presence of EV policy/targets/plans for the same										
	2.5	EV Policy			No	No	No	No	No	No	No	No
	2.5	Initiative			Partial	No	Yes	Yes	Yes	Yes	No	Yes
	2.5	Target			No	No	No	Yes	No	Yes	No	Yes
	2.5	Any subsidy plan			No	Partial	Yes	Yes	No	Yes	Partial	Yes
	10.0	Presence of any e-buses/trolley buses/plans for procurement										
	5.0	Presence of e-bus/trolley/hybrid bus/EV			No	Partial	Yes	Yes	No	Yes	No	Yes
	5.0	Any plans for procurement			No	Partial	No	Yes	No	Yes	Partial	Yes
	5.0	Presence of EV manufacturers/battery suppliers										
	2.5	Local presence of manufacturers/battery suppliers			No	No	No	Yes	No	No	No	No
	2.5	Imports			No	Yes	Yes	Yes	No	Yes	No	Yes
	5.0	Penetration of charging infrastructure										
	2.5	Presence of charging infrastructure			No	No	Yes	Yes	No	Yes	No	Yes
	2.5	Plan to set charging infrastructure			No	No	Yes	Yes	No	Yes	No	Yes
Total	**100.0**											

Scoring

Segment	Score	Parameter	Unit	Year	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
Macro-Economic Profile	20.0				8.75	12	11	13.5	12	8.75	10.5	10.75
	2.5	GDP growth rate	%	2016	1	2.5	2	2.5	1.5	0.5	1.5	1.5
	2.5	Per capital income	USD	2016	0.5	1	1.5	1	2.5	0.5	1	2
	2.5	Urban Population (% of total population)	%	2016	1	2	2	1.5	2.5	0.25	2	0.25
	2.5	Inflation	%	2016	1.5	1	1.5	1.5	2.5	0.5	2	1.5
	2.5	Overall Fiscal Balance Surplus/(Deficit) (as a % of GDP)	%	2016	2.5	1.5	1.5	1.5	0.5	2.5	1	1
	2.5	Current Account Balance-Surplus/(Deficit) as a % of GDP	%	2016	2	1.5	0	1	0	2.5	1	1
	2.5	Ease of Doing Business	DTF Score	2016	0.25	0.5	2.5	2	1.5	2	1.5	2
	2.5	Sovereign Credit Rating	Moody's Rating	2017	0	2	0	2.5	1	0	0.5	1.5
Transport Sector profile	25.0				14	9	12	18	2.5	13.5	15	19.5
	5.0	Contribution to GDP	%		5	2	3	2	1	2	3	4
	5.0	Quality of roads	Score	2016	0	1	3	4	0	1	3	5
	7.5	Road Density	km/ '000 km2		1.5	3	4.5	7.5	0	6	4.5	4.5
	7.5	Bus Density	No./ '000 people		7.5	3	1.5	4.5	1.5	4.5	4.5	6
Power Sector Profile	25.0				13.5	11.5	25	14.5	10.5	12	14.5	15.5
	5.0	Contribution to GDP	%		0	2	5	3	0.5	1	2	1
	5.0	National electrification Rate	%		3	0	5	2	5	1	0.5	4
	2.5	Demand Supply Surplus/Deficit	%		2.5	2	2.5	1	1.5	0.5	2.5	2
	2.5	Electricity imported	%		0	1.5	2.5	2.5	2.5	0.5	2.5	2.5
	5.0	% installed capacity from RE Sources	%		5	1	5	3	0	5	4	4
	5.0	Price of electricity	US cents per kWh	2016	3	5	5	3	1	4	3	2
EV related policy	30.0				1.25	8.75	17.5	27.5	2.5	25	3.75	25
	10.0	Presence of EV policy/targets/plans for the same			1.25	1.25	5	7.5	2.5	7.5	1.25	7.5
	2.5	EV Policy			0	0	0	0	0	0	0	0
	2.5	Initiative			1.25	0	2.5	2.5	2.5	2.5	0	2.5
	2.5	Target			0	0	0	2.5	0	2.5	0	2.5
	2.5	Any subsidy plan			0	1.25	2.5	2.5	0	2.5	1.25	2.5
	10.0	Presence of any e-buses/trolley buses/plans for procurement			0	5	5	10	0	10	2.5	10
	5.0	Presence of e-bus/trolley/hybrid bus/EV			0	2.5	5	5	0	5	0	5
	5.0	Any plans for procurement			0	2.5	0	5	0	5	2.5	5
	5.0	Presence of EV manufacturers/battery suppliers			0	2.5	2.5	5	0	2.5	0	2.5
	2.5	Local presence of manufacturers/battery suppliers			0	0	0	2.5	0	0	0	0
	2.5	Imports			0	2.5	2.5	2.5	0	2.5	0	2.5
	5.0	Penetration of charging infrastructure			0	0	5	5	0	5	0	5
	2.5	Presence of charging infrastructure			0	0	2.5	2.5	0	2.5	0	2.5
	2.5	Plan to set charging infrastructure			0	0	2.5	2.5	0	2.5	0	2.5
Total	100.0				37.5	41.25	65.5	73.5	27.5	59.25	43.75	70.75

A.2. Appendix III - Latest major undertakings by prospective EV Giants

Company	Latest Happenings[157]
Tata	On December 06 2017, Tata rolled out its first batch of Tigor EV from Gujarat (India) factory.
	As on December 01, 2017, Tata has supplied 15 electric buses to Mumbai Metropolitan Region Development Authority. TATA is still in the process of further developing its Fuel Cell Technology for Buses.
	In September 2017, EESL awarded a coveted USD 174 million order in September to Tata Motors Ltd to supply 10,000 electric cars.
	In August 2017, Tata Power installed its first EV charging station in Vikhroli, Mumbai.
	In June 2017, Tata and Chandigarh Transport Undertaking conducted a 15-day trial for its 9 m electric bus (TATA Ultra Electric), with a seating capacity of 31 passengers.
Mahindra and Mahindra	In November 2017, Ford Motor and Mahindra & Mahindra could create their own electric car line in the country to help battle pollution, chairman Anand Mahindra said
	In September 2017, Mahindra & Mahindra received contract for 150 electric sedans by EESL.
	In May 2017, Ola launched a taxi fleet service comprising completely of EV in Nagpur. The pilot project has 200 electric vehicles, including 100 of Mahindra's new e20 plus.
Suzuki	In November 2017, Japanese automakers Suzuki Motor and Toyota Motor finalized an agreement to manufacture and sell electric vehicles in India by 2020.
Ashok Leyland	In July 2017, Ashok Leyland announced the formation of a strategic alliance with SUN Mobility for supply of batteries.
	In October 2016, Ashok Leyland unveiled the Country's first Circuit electric bus designed and engineered entirely in India.
Tesla	On December 7 2017, Anheuser-Busch placed an order of 40 Tesla semi-trucks.
	In September 2017, Tesla had reached out to Indian Government for entry through single brand retail route.
BYD	In December 2017, a fleet of 10 pure electric buses manufactured by BYD started operating on the Japanese island of Okinawa
	In November 2017, the first two 100% electric buses in the history of Santiago City's public transport began operating. They were both manufactured by BYD
	In October 2017, BYD Coach and Bus unveiled North America's largest electric bus factory with a build-up capacity of 1500 electric buses annually.
	In September 2017, BYD joined Global Effort to Bring 'Soot-Free' Buses to 20 Megacities, committing to make it easier for major cities around the world to purchase its eco-friendly zero-emissions pure electric buses beginning in 2018
	In September 2017, BYD announced in will supply 170 MW to Utility Scale Projects and Gears Up to Launch its Residential Storage System, the B-Box HV in U.S.
	In April 2017, BYD opened Hungary electric bus factory, targeting 400 a year capacity.

[157] These have been compiled from news articles in Livemint, Hindu, Hindustan Times, Economic Times, the Verge, Inc42, and websites of Tata Motors, Tata Power, BYD and Ashok Leyland