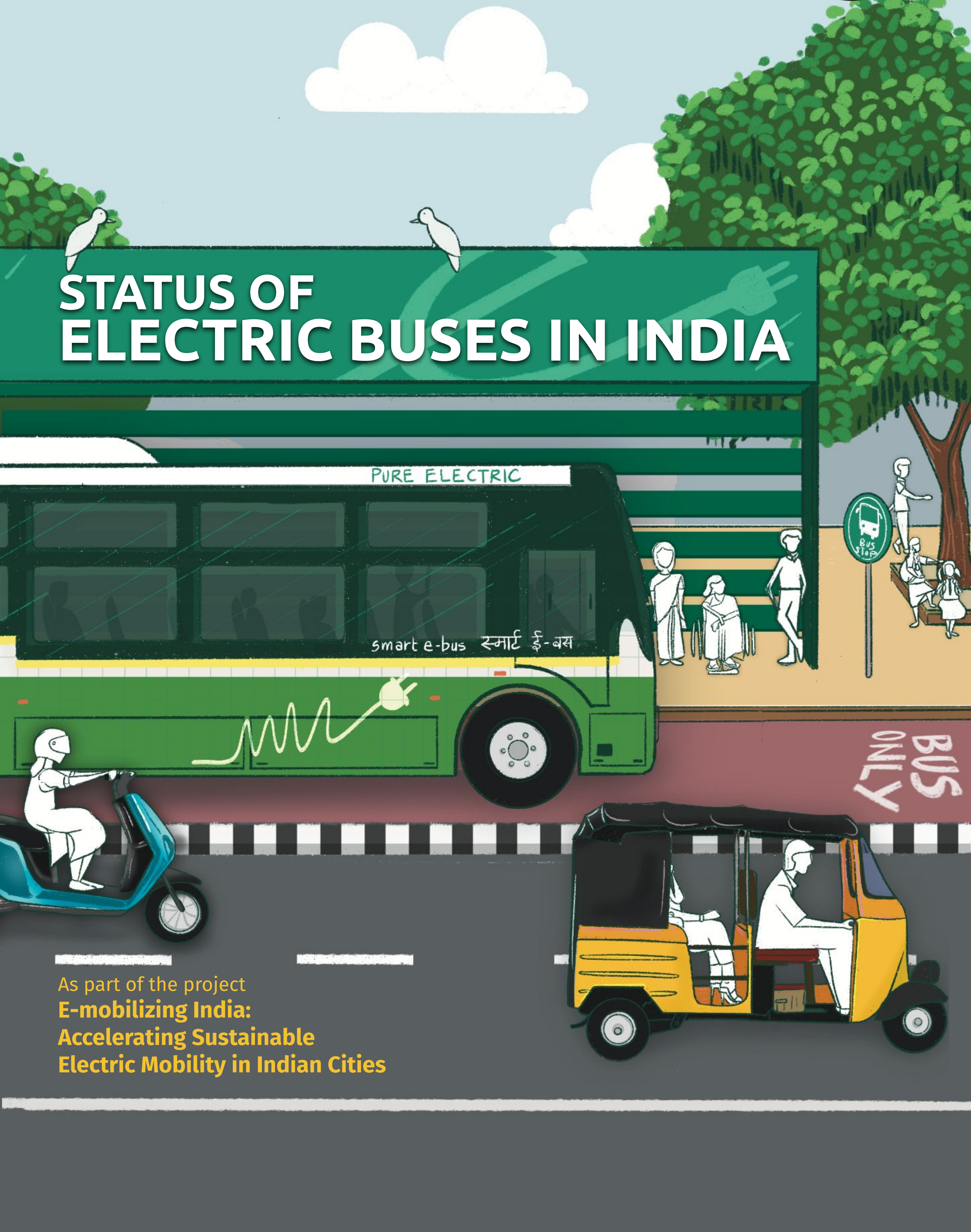
STATUS OF ELECTRIC BUSES IN INDIA



As part of the project
E-mobilizing India: Accelerating Sustainable Electric Mobility in Indian Cities

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Prepared by

The Institute for Transportation & Development Policy (ITDP) is a global non-for-profit organisation that works with cities worldwide to promote transport solutions that reduce traffic congestion, air pollution, and greenhouse emissions while improving urban liveability and economic opportunity. ITDP is represented in India by ITDP Pvt Ltd and works with governments, multilateral agencies, and civil society to make visible, on-the-ground improvements by providing technical expertise, policy solutions, research publications, and training programmes.

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Preface

In the last decade, the private vehicle ownership has been on the rise, while the ridership of public transport in many Indian cities has been reducing, leading to an increased number of vehicles, and overall traffic along with their various negative externalities like congestion, air and noise pollution, anxiety, etc. These problems can be solved by encouraging people to use public transportation, which has the potential to efficiently carry a large number of people on the road. However, very few cities have formal public transport system. Even among the cities with public buses, none of them have more than 60 buses per lakh of population in accordance with the benchmark prescribed by Ministry of Housing and Urban Affairs (MoHUA) for Level of Service A. This indicates an urgent need to augment the bus fleet.

To combat the problems of pollution and lack of buses, fleet augmentation using the electric buses as presented itself as an ideal solution as ebuses have zero tailpipe emission and 30-40% less overall emissions1. To accelerate the process of adaptation of electric vehicles, the Department of Heavy Industries launched Faster Adoption and Manufacturing of Electric Vehicles India (FAME India). Under the FAME scheme, the State Transport Undertakings (STUs) or City Transport Undertakings (CTUs) are given subsidies for the procurement of electric buses for the public use as well as to put up the supporting charging infrastructure. Benefitting from the scheme, many cities have already started the electric bus operations.

This report aims to provide the status of the e-buses across cities and discuss their experience. E-buses have been adapted before India in some countries, hence, this report also discusses the global experience. Since e-bus is a new and emerging technology, it is important to understand various aspects of e-bus, battery and charging technology as well as the charging strategy, which are covered comprehensively in this report.

1. *Zero Emission Vehicles (ZEVs): Towards a Policy Framework. NITI Aayog. (2018)*

Contents

Source - Time

01

Public Urban Buses in India

1.1 Introduction

In urban India, almost 50% of people walk and cycle to work[2], followed by public transport, two-wheelers, cars, and autos. Just five per cent take cars. Public transport in Indian cities varies across geographies, but bus transportation is constant in most large urban centres.

While metropolitan cities such as Delhi, Mumbai, Chennai, etc. have multiple modes like city buses, commuter rail, and metro rail; smaller towns such as Ranchi, Gwalior, etc. rely mainly on IPT rather than buses. In large cities like Hyderabad, Bengaluru, and Chennai, buses cater to more than 70% of public transport trips[2].

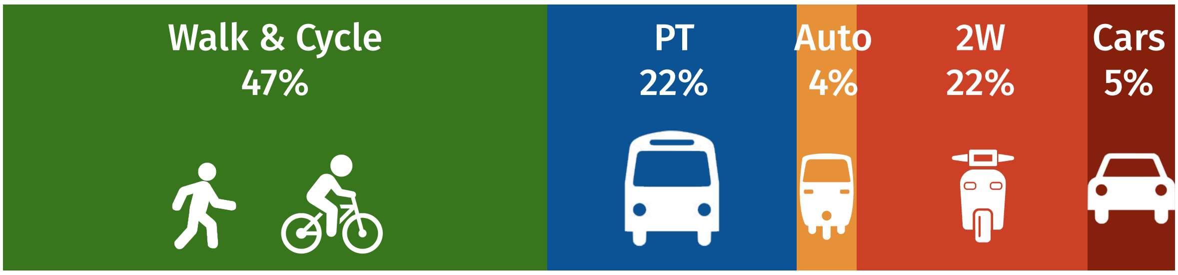

Figure 1: Mode Share in Urban India (Source: Census, 2011)

Bus services in Delhi and Bengaluru recorded close to 44 lakh and 36 lakh trips per day respectively in 2019-20[2] (before COVID-19). At first glance, the ridership stats of some cities might seem rosy, but a year-to-year comparison lays bare the problem that's brewing beneath the surface. In the past few years, declining ridership has been a cause for great concern for city bus operators. Mumbai's BEST has been witnessing a steep drop in ridership—from 39 lakh a day in 2012 to 28 lakh in 2019. With multiple waves of Covid-19, there has been a further decline in bus transport ridership across all the cities.

The COVID-19 pandemic has prompted governments and authorities around the world to impose restrictions on transport and mobility at an unprecedented scale and magnitude. Physical distancing has a significant impact on mobility behaviour and preferences. Many people have switched to a transport mode that reduces the risk of infection. Because of this, since the pandemic began, several cities have noticed a decline in bus ridership.

2. *Census of India, 2011*
3. *Statista.com and Times of India*

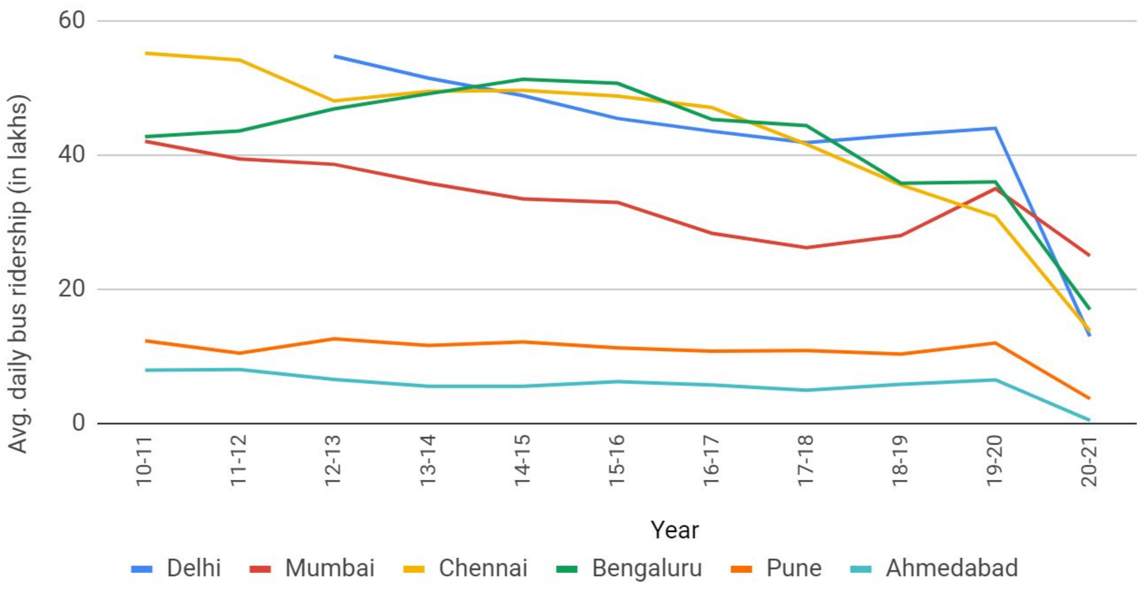

Figure 2: Declining ridership in city bus systems (Source: CIRT and newspaper articles)

There are nearly as many daily trips made on buses in Chennai as there are in Bengaluru. However, the fleet sizes are a sharp contrast in these two cities. Bangalore runs around 6300 buses as compared to 3800 by Chennai. The number of buses in other cities hasn't increased proportionately with the rise in population—resulting in overcrowding and reduced level of service. Chennai's Metropolitan Transport Corporation (MTC) carries over 1.9 times more passengers per bus per day (1197) than Bangalore's BMTC (623)[4] which is an indicator of overcrowding in buses.

1.2 Existing Scenario and Need for Electric Buses

According to the service-level benchmarks[5] laid out by MoHUA for urban transport, cities should have at least 60 buses per lakh population to achieve Level of service (LOS) 1. Most mega-cities are at LOS 3 with 20-40 buses per lakh population- resulting in a reduced level of service, except for Bangalore which is at LOS 2 (40-60 buses per lakh population) and almost able to reach LOS 1. Hence, there exists an immediate need to augment the fleet in most cities.

A large number of buses in India have internal combustion engines. Many cities tried to introduce CNG buses but suffered from a shortage in supply of CNG. The introduction of buses with stringent emission norms has also been slow given the bad financial health of many transport undertakings.

4. *CIRT (2021). State Road Transport Undertakings Profile and Performance 2018-19*
5. *http://www.utbenchmark.in*

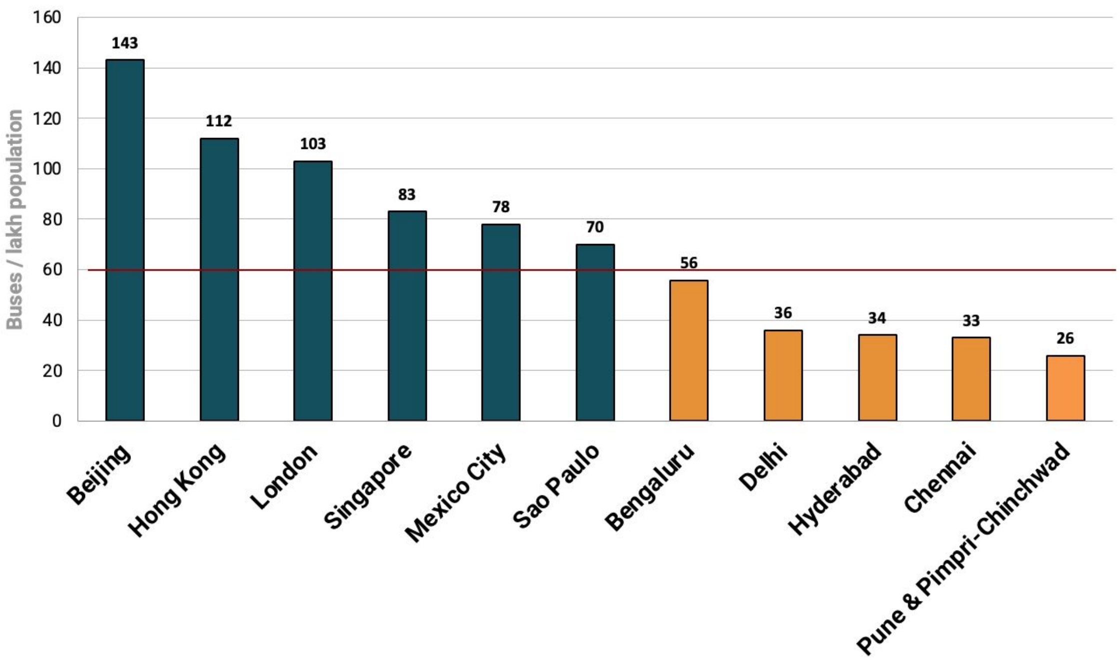

Figure 3: Buses per lakh population in 2021-22

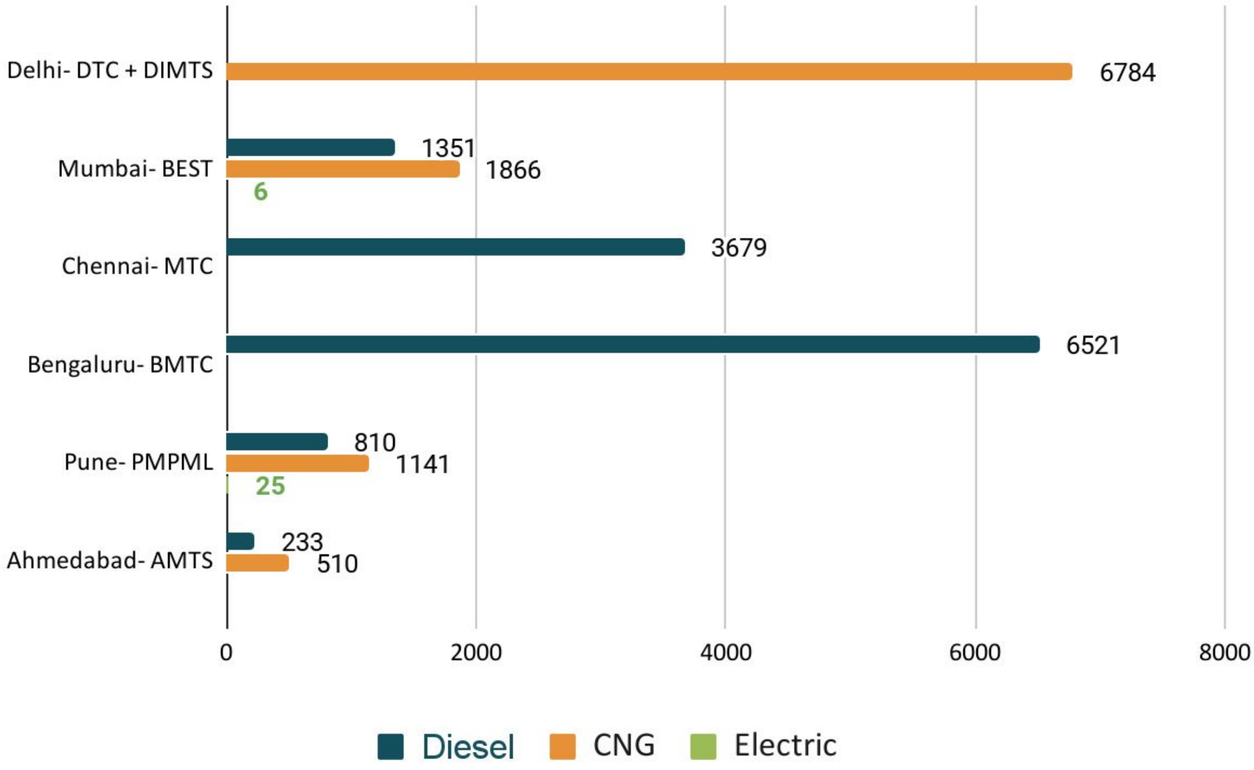

Figure 4: Buses by fuel type in 2018-19 (Source: CIRT)

In 1998, the Supreme Court of India issued a directive to replace or convert all transport vehicles (buses, three-wheelers and taxis) to CNG in Delhi by April 2001. In addition, the court specified 70 CNG refuelling stations, and financial incentives for the conversion of vehicle fleets be made available. This was a result of a Public Interest Litigation filed by environmental activists concerned with the quality of air in Delhi.

The switch to CNG showed significant results, at least initially. A study[6] by the Washington DC-based Resources for the Future said the conversion of buses from diesel to CNG has helped to reduce PM10, CO, and SO2 concentrations in the city. Along with the conversion of public transport vehicles to CNG, many cities and states in India, including Delhi, worked towards reducing emissions by mandating low levels of sulphur in diesel, along with stringent emission norms. In 2016, the Government of India issued a gazette notification[7] mandating BS-VI emission norms (equivalent to Euro VI norms) from April 2020 across India.

Meanwhile, emissions from motor vehicles continue to affect air quality. Adding to the misery, personal motor vehicle ownership is on the rise in many Indian cities. According to a study by the International Council on Clean Transportation (ICCT)[8], compared with other countries, India ranked second after China in the number of deaths attributable to transportation emissions in 2015. The study estimated 74,000 premature deaths due to transportation emissions in India. This represents a 28% increase in annual transportation-attributable deaths in the country compared with 2010.

The National Electric Mobility Mission Plan (NEMMP)[9] lists achieving National Fuel Security as one of its main objectives. India is one of the biggest importers of crude oil. The NEMMP envisioned the sale of 6-7 millions units, which can help in achieving liquid fuel savings of 2.2 – 2.5 million tonnes in 2020. This will result in a substantial lowering of vehicular emissions and a decrease in carbon dioxide emissions up to 1.5% in 2020 as compared to a status quo scenario. Greater emphasis on the electrification of public transport will undoubtedly have a positive impact on the reduction of emissions and reliance on fossil fuels.

The Government of India deregulated the pricing of petrol in 2010 and diesel in 2014. This allowed oil marketing companies to determine the price of these products, and revise them every fortnight. Since 2017, prices for petrol and diesel are revised daily. As a result, the cost of diesel has increased manifoldly. Urban public bus service providers spent an average of ₹17.77 ($0.23) per km on fuel in 2018-19[10] with an increase of ~14% over the previous year. As fuel prices are expected to grow, transport undertakings should reconsider their spending on fossil fuels, and utilize alternate sources of energy like electricity.

6. *https://media.rff.org/archive/files/sharepoint/WorkImages/Download/RFF-DP-07-06.pdf*
7. *http://egazette.nic.in/WriteReadData/2016/171776.pdf*
8. *Health Impacts of Air Pollution from Transportation Sources in Delhi, ICCT. (2019)*
9. *https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf*
10. *CIRT (2020). State Road Transport Undertakings Profile and Performance 2017-18*

Source - Sustainable Bus

02

Introduction to Electric Buses

2 Introduction to Electric Buses

Road-based transport contributes about 87% of the total transport emissions[11] which includes carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and pollutants such as carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOCS), Sulphur dioxide (SO_2), PM and oxides of nitrate (NOx)[12]. On-road diesel vehicles were responsible for nearly half of the health impacts of air pollution from vehicles worldwide in 2015, and two-thirds of impacts in India[13].

Studies suggests that the most vulnerable population, including children, the elderly are exposed to higher levels of pollution[14]. Cities well serviced by public transport tend to have lower per capita emissions improving air quality and overall public health[15].

Indian cities have been witnessing a constant deterioration in air quality. To make the situation worse, the number of cars and two-wheelers have been continuously increasing over the years. As a way out of this gridlock, electric buses can play a significant role, as they offer several benefits over conventional diesel buses in terms of reduction in local pollution, noise, and fuel cost. However, despite the many positive benefits related to electric bus technology, certain challenges remain. Most State Transport Undertakings (STUs) — the agencies responsible for public bus operations in India, lack the technical knowledge to procure, deploy, and manage their e-bus fleet optimally.

This report aims to evaluate the existing electric bus technologies in India and their performance through the pilots undertaken by STUs across the country.

11. *Sharma, S., et al. "India-California Air Pollution Mitigation Program (ICAMP)." (2013).*
12. *Task Force on National Greenhouse Gas Inventories of the Intergovernmental Panel on Climate Change (IPCC), 2006*
13. *A global snapshot of the air pollution-related health impacts of transportation sector emissions in 2010 and 2015, ICCT*
14. *Holgate ST. 'Every breath we take: the lifelong impact of air pollution - a call for action. Clin Med (Lond). 2017;17(1):8-12. doi:10.7861/clinmedicine.17-1-8; The toxic school run, UNICEF, 2018; Air pollution and child health: prescribing clean air, WHO, 2018*
15. *CSE – Urban Commute (Reference only if necessary)*

2.1 Electric Bus Technology

2.1.1 Engine technology

Electric buses are powered by the energy stored in rechargeable batteries rather than fossil fuels. Instead of internal combustion engines, they are propelled by electric motors — hence have fewer moving parts than a conventional bus. This helps in reducing the cost of maintenance and maintaining the structural integrity of the bus for more years. Electric buses also have regenerative braking that charges the battery on braking and hence helps in increasing the range of the buses.

2.1.2 Battery

Most electric buses across the world use advanced Lithium-Ion batteries as they can handle high voltage, and have a good cycle life. Most buses in India have batteries with capacities ranging between 200-300 kWh. A 12m bus with a 300 kWh battery is rated to operate up to 250 km per charge with air conditioning turned on. This allows transit agencies to run electric buses on schedules similar to their diesel counterparts. However, it's not all rosy in the electrification segment.

The cost of an electric bus lies in its battery. Big battery packs increase the cost of the bus significantly. Even with a steady decline in the price over the last few years, lithium-ion batteries cost ₹11,000 - ₹15,000 ($150 - $200) per kWh[16]. As of 2019, a 12m electric bus in India with a 300 KwH battery costs around ₹2.5 crores ($320k) as compared to ₹55 lakhs ($70k) for a diesel counterpart.

Having big battery packs also increases the weight of the bus — reducing its efficiency and eating up precious space for onboard use. To reduce the procurement cost and increase passenger capacity, many bus manufacturers have devised innovative ways to deliver electric buses with small battery packs, opportunity charging and battery swapping. Buses with opportunity charging — a system that permits batteries to be charged several times during the work cycle; tend to have battery packs with a capacity of 50-200 kWh.

16. *Zero Emission Vehicles (ZEVs): Towards a Policy Framework. NITI Aayog. (2018)*

2.1.3 Battery Technology

Batteries have been the major energy source for EVs for a long time. Different battery technologies have been invented and adopted for different uses. The most important criteria are to have high energy density and high power density. High specific energy is required from a source to provide a long driving range whereas high specific power helps to increase the acceleration.

Batteries used in EVs consist of several electrochemical cells that are coupled in parallel and in series to form a battery with a specific voltage and capacity. Batteries age over time as a result of multiple charging and discharging cycles. The aging of a battery causes a higher internal resistance and a loss of storage capacity. A battery is deemed not suitable for EV/bus application if the remaining storage capacity is 80 % of the initial capacity typically by the eighth year[17].

2.1.4 Battery Chemistry

Three battery chemistries are dominant in e-buses - lithium titanium oxide (LTO), lithium nickel manganese cobalt oxide (NMC) and lithium iron phosphate (LFP) are the most common cell types encountered in E-buses.

- LTO permits the highest charging power of all technologies, however, owing to its comparatively low energy density, it has the lowest capacity. LTO is only applicable in opportunity-charging systems. These have been widely used in the USA.
- NMC enables the largest capacity as well as high charging power and therefore lends itself both to AC and DC. These have been widely used in Europe.
- LFP has a lower C-rate for charging and requires typically bigger batteries for a long driving range. These have been widely used in China, South East Asia etc.

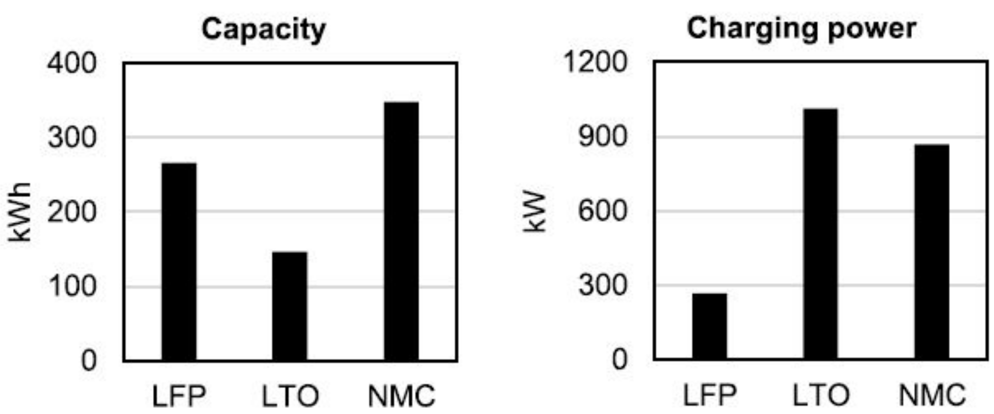

Figure 5: Capacity and Charging Power of different battery chemistry[18]

17. *Battery Capacity Needed to Power Electric Vehicles in India from 2020 to 2035, ICCT, 2021*
18. *Göhlich, Dietmar & Fay, Tu-Anh & Jefferies, Dominic & Lauth, Enrico & Kunith, Alexander & Zhang, Xudong. (2018). Design of urban E-bus systems. Design Science. 4. 10.1017/dsj.2018.10.*

2.1.5 Types of batteries

Lead-acid batteries

Lead-acid batteries have been in use since the mid-nineteenth century. They use lead electrodes and sulphuric acid to create a flow of electrical energy to the device.

Advantages	1. Long service life. 2. Cheap to produce. 3. Low long-term self-discharge 4. Capable of a high discharge rate
Limitations	1. Unsafe as they produce dangerous gases when in use 2. Overcharging can lead to explosion or fire hazards. 3. They have a lower energy density[19] 4. Their service life shortens when used with full discharge / deep discharge cycles 5. Reserve battery has to be maintained, which reduces the effective capacity. 6. Not environmentally friendly due to lead and acid contents 7. Transportation of batteries is a challenging task due to the possibility of acid spillage.

19. *Energy density of a battery determines how much energy the battery can store. The energy density is usually expressed in terms of weight (Watt-Hour/Kg) or volume (Watt-Hour/liter)*

Nickel metal hydride batteries

This battery technology uses a Nickel-hydroxide cathode and anode made up of hydrogen-absorbing alloys. Potassium-hydroxide is used as an electrolyte. This battery technology uses a Nickel-hydroxide cathode and anode made up of hydrogen-absorbing alloys.

Advantages	1. Considered to be safer than lead-acid batteries. 2. Higher energy density than lead-acid batteries 3. Possibility of deep discharge is possible. 4. Long shelf life 5. Higher number of life cycles as compared to lead-acid batteries
Limitations	1. They display a memory effect[20] 2. High long-term self-discharge rate 3. Overcharging can damage the battery 4. Lower cell voltage than Lithium-ion batteries 5. Lower service life, deep discharges reduce the service life. 6. NiMH batteries contain relatively toxic materials.

20. *Memory effect is the reduction of battery capacity due to consistent recharge events without complete discharge of the battery.*

Lithium-ion batteries:

These batteries are best suited for electric buses. The anode is made of graphite, and the cathode is typically made from one of these materials:

-Li-Iron-Phosphate (MFP)
-Li-Metal-Polymer (LMP)
-Lithium Nickel Manganese Cobalt Oxide (NMC)
-Lithium Titanate Oxide (LTO)

Advantages	1. Better energy density than other batteries 2. Safer than other batteries 3. A battery management system (BMS) that controls the rate of charge and discharge to optimise the battery efficiency and avoid overheating and overcharging 4. No memory effect, hence low maintenance 5. Relatively lower self-discharge (less than 50% of the NiMH battery) 6. Capable of providing high power output.
Limitations	1. Comparatively expensive to produce as technology is still developing 2. Li-ion batteries have not resolved recycling and disposal problems. 3. These batteries age even when unused.

2.2 Charging Technology

2.2.1 Conductive Charging

Electricity transfer through conduction requires direct contact between the two surfaces. Hence, conductive charging is done primarily through plugs that are required to be connected to an electric vehicle. Depot charging and opportunity charging are the two most commonly-used strategies for charging electric buses using conductive chargers.

- **Depot Charging:** As the name suggests, depot charging requires buses to be parked in the depot to be charged during their off time. This could be done either at night or day depending on the operations plan and prevailing electricity tariffs.

  Plug-in charging is the most commonly used technology for depot charging. There are usually two main parts - a Power Control System (PCS) and a charging dispenser. Depending on its size and capacity, a PCS can service up to ten charging dispensers. In turn, each charging dispenser can charge up to two buses.

- **Opportunity charging** allows the buses to be charged quickly with the help of superchargers, enabling them to charge at the end of a route, between shifts or intermediate stops. This method of flash charging is a comparatively new technology and has been instrumental in reducing charging time and battery load on buses. Flash charging infrastructure provides a burst of electric current to the battery, which increases the charging rate. As conventional chargers have a lower rated voltage, they do not impose a burden on the grid. But flash charging draws a very high voltage in a short time frame which puts a heavy load on the grid.

  Pantographs are generally used for opportunity charging. They are usually attached to poles at the passenger bus stops. A pantograph descends and connects to the roof of the bus and recharges the battery. In some cases, the pantographs are on the roof of the bus, and they rise to connect to the pole. In case of opportunity charging, they are used at the route end bus stops, where it can take several minutes to charge the battery. Whereas in flash charging, they are used at the selected intermediate bus stops. The minimum voltage associated with pantograph systems is 415 V.

  A smaller battery can reduce the load on the electric bus. The battery can be charged overnight at the depot and supplemented by top-ups using opportunity charging at route ends or some selected passenger stops.

2.2.2 Inductive Charging

Induction is the process of transfer of energy from one surface to the other without direct contact. In electric vehicles, it is the process of charging wirelessly. The minimum output voltage for inductive charging is 415 V.

Inductive charging requires minimal space for the charger, but an ancillary infrastructure is needed. The cost of such equipment is high; hence it has not been adopted in India so far.

2.2.3 Battery Swapping

Battery swapping involves the replacement of a depleted battery inside a bus with a charged battery. Such a mechanism overcomes a significant disadvantage of high in-depot time during charging of plug-in battery buses. Because of the reduced in-depot time, it is comparable to diesel/CNG bus refuelling time. This advantage, however, comes at the cost of a reduced range because the batteries need to be smaller and lighter for the convenience of swapping.

Battery swapping is automated using robotic arms which is an additional infrastructure over and above the battery chargers. This extra cost makes it less attractive for adoption. Ahmedabad is the only Indian city to have piloted buses with battery swapping.

2.2.4 Regenerative braking

Regenerative braking is the process by which energy produced during braking can be used to recharge the batteries inside electric buses. In a conventional braking system, brakes operate using brake pads which produce friction with the brake rotors to slow the vehicle down. The friction produces heat; hence there is a loss of energy.

An electric motor drives the bus forward. In a regenerative braking system, the electric motor starts running backwards to slow the vehicle. It acts as an electricity generator while in reverse mode. The electricity thus produced is either routed to charge the battery or stored in capacitors to accelerate the vehicle when needed. Braking using electric motors has its limitations, and therefore conventional braking systems are also provided in most vehicles.

2.3 Charging Strategies

Many cities use more than one system of charging. Relying on depot charging alone requires larger batteries, but provides freedom of operation. Larger batteries increase deadweight on the bus and thus reduce passenger capacity. They need slow chargers (typically 40 kW); hence ancillary equipment like transformers, etc. are not required.

A combination of both depot charging and opportunity charging can help increase the operating range of buses significantly by providing a trade-off between range and dead weight.

Opportunity charging during layovers using fast chargers (150 kW) can provide a top-up to match the ICE bus operating schedules. The third layer of opportunity charging using flash chargers at intermediate passenger stops can provide the much-needed top-up and help in reducing the size (and load) of the battery. A smaller battery would also reduce the cost of the overall bus as the battery forms a major chunk of the cost of the bus.

Source - Autofutures.tv

03

Electric Bus Experience Around the World

3.1 Introduction

There are almost 600,000 e-buses on the road globally, representing 39% of new sales and 16% of the global fleet. China accounted for the vast majority of all e-bus sales in 2020, with over 74,000 units sold and continues to account for 98% of the global e-bus fleet[21].

This share is projected to decrease as Chinese city bus fleets start to saturate and adoption picks up in Europe, USA, South East Asia, India and South America. It is expected that the number of e-buses is going to triple by 2025 from the existing total of 5,000 in these geographies. This section, examines the electric bus markets in China, Europe, and North America to understand the dynamics of a growing electric bus market in India.

China

China's battery-electric buses totalled 324,231 in 2019, accounting for around a half of the bus fleet—becoming the mainstreamed bus technology. With more than 16,000 electric buses in service, Shenzhen—a Chinese megacity—transitioned to a fleet of 100% electric buses in less than ten years. This was possible because of a strong market for electric buses. World's biggest electric bus manufacturers like BYD, Yutong, and Foton are all based in China.

Unlike other markets, Chinese Original Equipment Manufacturers (OEMs) benefit from easy access to the latest battery technology. In fact, BYD, which is now expanding across the world, started off making batteries for mobile phones in the 90s.

Chinese OEMs have ventured into the manufacturing of double-decker and articulated buses, increasing the options for operators. BYD unveiled a fully electric double articulated bus. This allows Bus Rapid Transit systems across the world to provide a more efficient, reliable service. Owing to the size of the market and expertise gained in China, OEMs are now expanding to Africa, Europe, and South Asia as well.

21. *https://about.bnef.com/electric-vehicle-outlook/*

Source - Singularity HUb

Source - sustainable-bus.

Europe

Volvo, Solaris and VDL have been at the forefront of developing hybrid and electric buses in Europe. Most OEMs in Europe are offering buses with options of both opportunity charging and depot charging. Additionally, Chinese manufacturers like Yutong, and BYD have been working closely with ADL — an OEM in the UK, to deliver their products. BYD, in partnership with ADL, has recently delivered a fleet of fully electric double-decker buses in London.

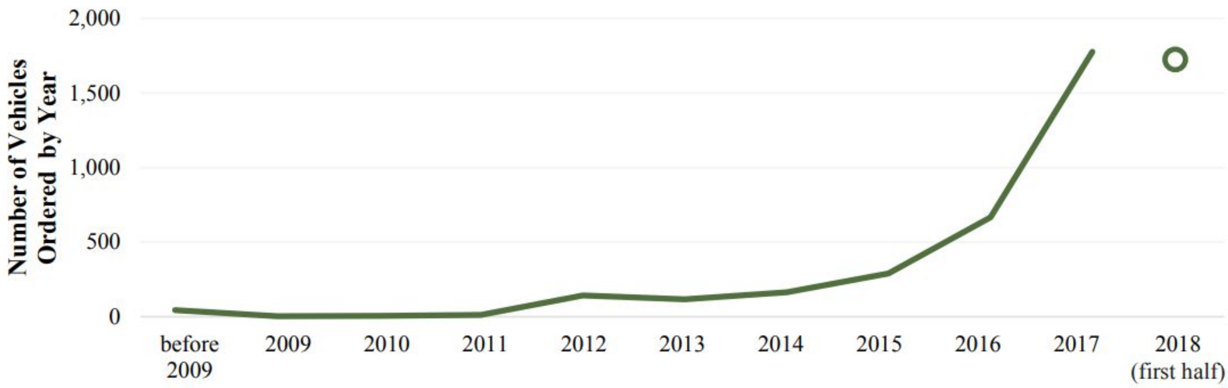

Figure 6: Electric bus orders in Europe, 2009 to 2018[22]

According to a recent publication from Interactive Research[23], BYD and ADL are market leaders in electric buses across Europe. The publication also states many cities are moving away from the option of opportunity charging in favour of overnight charging at depots mainly because BYD offers buses with only overnight charging at depots.

Swiss company ABB has also introduced Trolleybus Optimisation Système Alimentation (TOSA)[24], a flash charge technology that enables buses to be charged quickly. The system uses a combination of three chargers - overnight slow charging at the depot (45 kW chargers), occasional fast charging at the terminals (400 kW chargers) and intermediate flash charging (600 kW) at select passenger stops.

Flash charging is capable of adding two to three kWh of energy to the battery in just 15-20 seconds. The batteries also receive regenerative charging during operation.

22. *Compiled by UITP using data provided by Stefan Baguette, ADL Market Analyst and Product Manager.*
23. *https://www.sustainable-bus.com/news/650-electric-buses-delivered-in-europe-leader-vdl/*
24. *ABB power products (2016). Taking Charge. Flash-charging is just a ticket for clean transportation.*

TOSA - a full large capacity urban battery-electric bus system; uses a battery pack between the grid and the bus charger to cushion the impact on the grid when the power is drawn for charging. Inherently, battery packs in buses are directly connected to the grid which charges using a charger of lower power capacity. When a bus connects to the flash charger, the energy is drawn out of the battery pack to charge the bus.

With more OEMs entering the market and cities drawing up plans to electrify the buses, the market is only expected to grow.

Source - sustainable-bus. Milan

North America

The electric bus market in the United States has expanded dramatically since 2014. There were a total of 650 fully electric battery-driven buses in service across the country in 2020. Major cities in the US are committed to go all-electric by 2045[25].

Often referred to as the "Tesla of Buses" by automobile enthusiasts, Proterra - an American startup has been making waves by delivering electric buses and coaches capable of ranges unheard of before. With light bodies and efficient batteries, their buses can run up to 500 km on a single charge. Many cities like New York and Washington DC have used federal funds to induct these buses into their fleets to improve their level of service significantly.

New flyer, one of North America's biggest bus makers, has also delivered high-quality electric buses, now in use in cities across the US and Canada. Like all other markets, BYD too has had a significant impact on the electric bus market in North America. BYD is supplying 18m articulated buses for Bus Rapid Transit networks in cities like Indianapolis and Albuquerque. Early deployers of electric buses, however, have experienced a set of technological and economic hurdles that will need to be overcome in future to bring electric buses to scale quickly and deliver the promised benefits for public health and the environment.

Source - sustainable-bus, New York

25. *Electric Buses in America: Lessons from Cities Pioneering Clean Transportation, 2019. US Pirg Education Fund, Environment America Research and Policy Center and Frontier Group*

3.2 Financing of Electric Buses Across the Globe

Electric buses are gradually expanding all over the world. Achieving a better understanding of the financial mechanisms that enabled this growth is essential to keep the momentum going. Currently, the costs of procuring e-buses are twice to thrice of their ICE counterparts with the battery accounting for 50-60% of the total cost. Given the high capital investment, robust financial mechanisms are required to promote widespread adoption.

According to a study by Transport and Environment in 2018, the total cost of ownership that includes external costs on health and climate (based on inputs from CE Delft), showed that electric buses are cheaper than their diesel equivalent. An overnight electric bus costs ₹88.45/km ($1.14/km), an opportunity charging bus costs ₹87.61/km ($1.13/km), while a diesel bus costs ₹94.35/km ($1.21/km)[26]. If environmental and climate costs are removed, then e-buses are still slightly more expensive than diesel buses. If subsidies are provided on procurement, then the electric bus market can become quite lucrative for many cities across the globe.

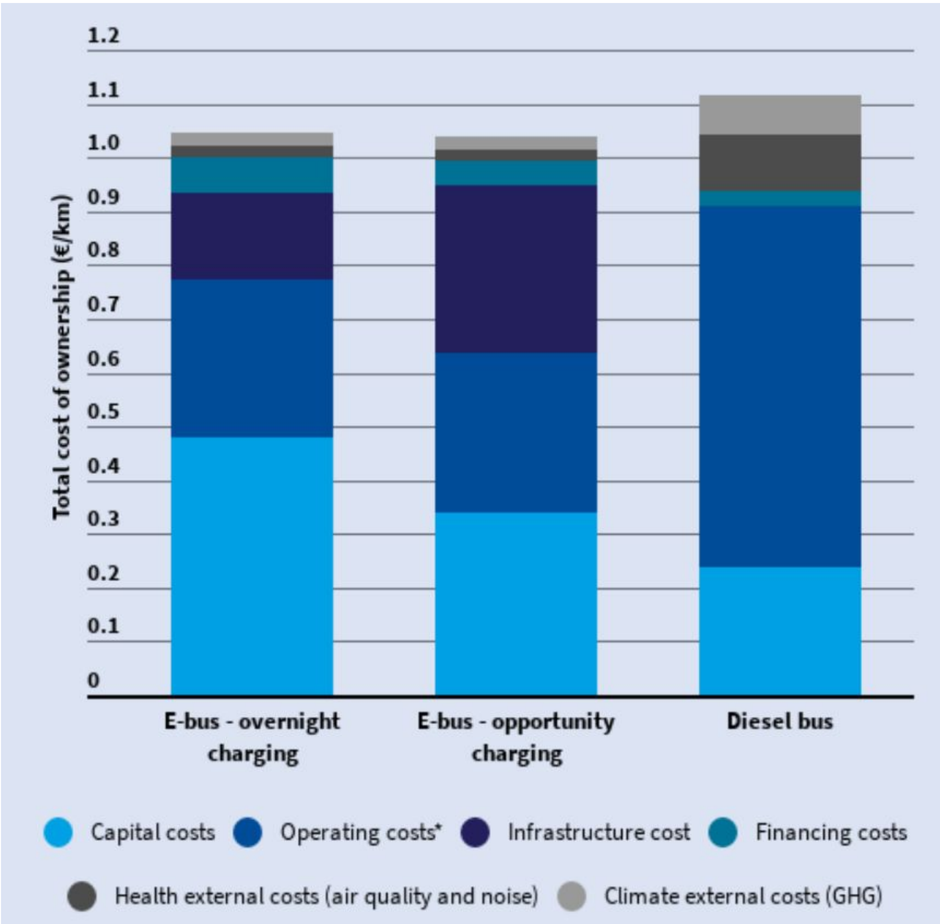

Figure 7: 8-year Total Cost of Ownership in 2018 in Europe[27]

26. *Cost converted from Euro to Rupee at an exchange rate of ₹84.24 as of May 2020*
27. *Electric buses arriving on time: Marketplace, economic, technology, environmental and policy perspectives for fully electric buses in the EU, 2018. Transport and Environment*

Case study : Electric buses in China

Similar to India, the electric bus market in China has been driven by subsidies from the city, provincial, and the national government. For example, in Shenzhen, subsidies from both provincial and national governments combined were ₹1 Crore ($128k) per bus in 2016. Cost per bus was ₹ 60-80 lakh ($77k-103k) after subsidy, based on the length of the bus. Aim of the governments is to bring down the cost of an electric bus to that of their diesel counterparts.

According to a study conducted by the World Bank and the Global Environment Facility, the lifecycle cost of e-buses in Shenzhen as of 2016 (including procurement, energy and maintenance costs over eight years) is ₹2.92 crores ($375k), slightly higher than the diesel bus' lifetime cost of ₹2.66 crores ($342k). However, over the years, the subsidies have been reduced. The sale of electric buses peaked in 2017 when there was an announcement to withdraw subsidies starting in 2018.

According to a report by Interact Analysis[28], the growth rate of electric bus sales has stayed negative for four consecutive months beginning June 2018. However, the market for electric buses in China is expected to stabilise and not crash thanks to clean air mandates in many cities. The market has already shown signs of recovery with orders at the end of the year. Cities have responded to the reduction in subsidies by taking buses/batteries on lease from OEMs. This has reduced the burden of high upfront costs and allowed cities to deliver climate mandates.

Case study : Electric buses in Europe

In many cities in Europe, electric buses are procured up-front from existing public budgets. Even where private operators purchase buses, public investment incentives are provided to reduce the up-front cost. In Germany, for example, the European Union Commission approved an increase of 300 million euros in Germany's state aid for the purchase of electric buses and charging infrastructure under state aid law.

The total state funding for this now amounts to 650 million euros (~₹5,300 crores)[29]. The German government subsidies up to 80% of the additional costs in the purchase of an electric bus compared to a diesel counterpart.

28. *https://www.sustainable-bus.com/news/chinese-electric-bus-market-is-still-growing-but-the-subsides-switched/*
29. *https://www.electrive.com/2020/01/31/eu-commission-approves-electric-bus-funding-for-germany/*

Case study : Electric buses in USA

USA offers several federal, regional, and state grants and incentive programs to support the expansion of electric buses. In 2018, the ‘Low or No Emissions Grant’ program awarded grants to over 50 state and local governments, totalling $84.5 million (equivalent to ₹590 crores).

The annual grant was solely for the purchase of electric buses and charging equipment. Additionally, in 2017, 141 school districts across the country received rebates from the program totalling $8.78 million (~₹68 crores). This program has been used extensively to transition buses from diesel to diesel-electric hybrids across the country[30].

Source - PV Magazine USA

30. *Paying for Electric Buses: Financing Tools for Cities and Agencies to Ditch Diesel, 2018. U.S. PIRG Education Fund*


Source - Deccan Herald

04

Operationalising Electric Buses in India

4.1 Introduction

As of January 2022, there are more than 1,000 electric buses in service across various cities in India. Additionally, the Department of Heavy Industries (DHI) has sanctioned 5,595 e-buses to 64 STUs/public bus service providers. This chapter looks at the story of electric buses in India till now.

The Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme introduced in 2015 gave subsidies to support state transport corporation in purchasing e-buses. The price of e-buses varies anywhere between 2-3 times of their diesel counterparts. Since several state corporations were already facing funding challenges and did not have budgets to make direct purchases, the scheme had a slow uptake.

In addition, transit agencies lacked technical crew to maintain and operate the electric buses. As a response, the second phase of FAME encouraged a 'Gross Cost Contract' (GCC) of procuring e-buses as per which, instead of outright purchases, state transport corporations simply paid original equipment manufacturers or e-bus operators a per km cost for operations and maintenance. This model removes the risk involved associated with new technologies from the STUs and puts the onus of operating and maintaining e-buses on the private player. Since then, of the 5,595 e- buses already sanctioned under FAME II, more than 1000 e-buses are on the road.

4.2 E-bus Market in India

In India various OEMs have just begun to ramp up their production and R&D facilities making the most of government schemes to promote electric mobility. In Ahmedabad, Ashok Leyland had partnered with Sun Mobility to pilot battery swapping on the BRT corridor in 2019, allowing buses to have smaller batteries that can be changed at the end of the route. However as of early 2022, all the original 50 battery swapping buses have been converted to operate with plug-in charging owing to several issues. Ashok Leyland is currently operating 125 buses (including the original battery swap buses which were later converted to plug-in charging mode) along BRT corridors and airport express line. In total, 170 e-buses are plying along the BRT corridor in Ahmedabad. The remaining buses are operated by AJL and use plug-in chargers.

There is a high court ruling to replace the diesel buses with CNG buses or e-buses in 8 cities in Gujarat including Ahmedabad. There are 1,000 buses in Ahmedabad that are operated by AMTS and it has been decided to replace these with e-buses. Currently a plan to procure 150 additional e-buses is already underway.

At the same time, TATA was developing electric buses on its Starbus platform. The OEM has supplied more than 200 e-buses to various cities including Lucknow, Srinagar, and Kolkata under FAME-I. It has also bagged a contract to supply 300 electric buses to Ahmedabad Janmarg Ltd under FAME-II[31]. KPIT, a technology firm based out of Pune was among the first to create retrofitting kits to convert diesel buses to electric. The company is now working with Eicher to make efficient and affordable electric buses. A small fleet of their buses are already in service in the suburbs of Kolkata.

Various Chinese and European OEMs have partnered with Indian companies to deliver electric buses. These OEMs bring with them the experience of successfully operating fleets of electric buses across the world. BYD - a Chinese firm has partnered with Olectra to supply its highly successful K7 and K9 coaches in India. Olectra-BYD has set up manufacturing plants in Tamil Nadu and Telangana where they build battery packs and buses. Olectra had supplied the first fleet of e-buses in India to Himachal Pradesh. It is currently operating over 600 e-buses in India and has orders of more than 1500 e-buses from various STUs.

Foton, a Chinese OEM is working with its Indian partner PMI to deliver high-quality 12-meter buses with plug-in charging. It has participated in the most tenders floated across the country under FAME-II and is planning to set up a manufacturing facility in Pune. Meanwhile, Solaris, a European OEM, has partnered with JBM to deliver India's first bus with opportunity charging. Their bus - ECOLIFE can run up to 200km on a single charge. Delhi Transport Corporation has recently tested one of its buses successfully. JBM Solaris set up a manufacturing facility in Uttar Pradesh, prepared for the ever growing electric bus market in India.

4.3 Financing of Buses in India

One of the significant barriers preventing the uptake of electric buses is their high upfront cost. Batteries alone account for 50% of the cost of an electric bus. With the government of India reducing import duties on Lithium-ion cells and encouraging manufacture of battery packs in India, the cost of electric buses is set to come down. The trend has been similar internationally as well, with battery costs coming down from ₹50,000/kWh ($1100/kWh) in 2010 to ₹10,000/kWh ($137/kWh) in 2020[32].

31. *https://www.financialexpress.com/auto/car-news/tata-motors-bags-order-for-300-electric-buses-to-be-deployed-at-ahmedabads-brts-corridor/1726825/*
32. *.https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/*

For most State Transport Undertakings (STUs), farebox is the only source of revenue. It is evident from reports published by MoRTH that there is a significant difference in earnings and expenditure with most STUs running in losses. While STUs must be held accountable to reduce the gap between revenue and expenditure, state and city governments must chip in with enough financial aid to help STUs invest in better buses.

4.3.1 FAME-I

One of the stated objectives of FAME scheme was to "provide affordable and environmental friendly public and private transportation/vehicular mobility options for the masses". However, as the performance of the initial phase of the scheme shows, the focus was very much on boosting consumer demand, industry development and sales. In fact, until mid 2017, the FAME scheme did not include an incentive structure for fully Electric buses, it was included in the FAME-I scheme only after mid 2017.

Source - financial express

Case study : Electric buses in Himachal Pradesh

Following directions issued by the National Green Tribunal (NGT), Himachal Pradesh Road Transport Corporation (HRTC) proposed to operate electric buses from Manali to Rohtang. At that time, no OEM in India was manufacturing fully electric buses that could navigate the harsh terrain in Manali.

HRTC worked closely with DHI and industry partners like Association of State Road Transport Undertaking (ASRTU), Central Institute of Road Transport (CIRT) and Society of Indian Automobile Manufacturers (SIAM) to prepare and issue an RFP to procure 25 electric buses in May 2016.

Only Ashok Leyland and Goldstone (now Olectra) bid to supply buses after going through a tendering process. Following this, both OEMs conducted trial runs of their buses in December 2016. While BYD buses managed to reach Rohtang from Manali on a single charge, Ashok Leyland buses were not successful in doing so. BYD won the order after negotiating to reduce the price per bus to 1.9 crores ($244k).

It is important to note that DHI took up this project as a pilot in the absence of guidelines to fund electric buses. The RFP too, included clauses for Annual Maintenance Cost (AMC) and a trial run given the technology had not been tested. The centre and state shared 75% and 25% equity respectively to finance these electric buses.

On September 23, 2017, India's first fleet of 25 electric buses was launched in Manali. These 9m non-ac buses can run up to 230 km in a single charge that could take about 4 hours to fill up the battery.

Buoyed by the success, Himachal Pradesh government introduced 50 more electric buses at Shimla in February 2019[33]. These buses received subsidy under FAME-I. PMI Foton, a Chinese company has supplied 30 seater buses capable of a 150 km range. Foton claims batteries can be charged in 30 minutes using fast chargers installed at various bus depots and terminals.

33. *https://swachhindia.ndtv.com/queen-of-hills-gets-fifty-electric-buses-himachal-pradesh-flags-off-its-third-electric-vehicle-project-31278/*

Growing interest from both public and private bus operators led to a belated push for the inclusion of public transport under the FAME-I scheme. DHI issued an Expression of Interest (EoI) in October 2017 – after the scheme was extended – for the rollout of shared, multimodal transport, consisting of modes such as buses, three-wheelers and even cars.

The rollout planned to cover a minimum of 5 cities with a population above one million, with a grant of up to ₹105 crores ($1.35m) per city. DHI received 47 proposals from 44 cities spread across 21 states. However, most proposals, especially from metropolitan cities, included only buses. The selection committee in DHI limited the number of buses to 40 per city with an additional fund of ₹4 crores ($514k) for setting up charging infrastructure. Following the evaluation, a list of 11 cities was published and guidelines issued for procurement.

DHI had initially sanctioned 40 buses each for Delhi, Mumbai, Kolkata, Bengaluru, Hyderabad, Ahmedabad, Jaipur, Lucknow and Indore, while hilly cities of Guwahati and Jammu were sanctioned 15 buses each. However, with Delhi opting out of the scheme, its quota was allocated to Bengaluru. With a total outlay of ₹ 895 Crores ($115m), these 11 cities were sanctioned subsidies for 390 e-buses.

DHI benchmarked the prices of electric buses after analysing the rates received by various STUs. According to a notification published by DHI[34] in 2018, the indicative benchmark price for a 12m AC bus with 320 kWh battery is ₹1.75 cr ($225k), and a 9m non AC bus with 125 kWH battery costs Rs ₹75 lakhs ($96k). It is important to note that these are indicative prices and they can change based on the conditions in Request for Proposal (RfP).

In the first phase of FAME scheme, DHI offered demand incentive at 60% of purchase cost or ₹1 crore ($128k), whichever is less, for buses that achieved 35% localisation and 60% of purchase cost or ₹85 lakhs ($109k), whichever is less, for buses that achieved 15% localization.

Deployment of electric buses in India started through the Fame-I scheme. Several pilots were initiated across different cities. These pilots varied between 15-40 buses across 12 cities in India. Most of the buses deployed were 9m buses.

34. *https://dhi.nic.in/writereaddata/UploadFile/Benchmark%20price%20for%20Electric%20Buses636662995963975616.pdf*

DHI allowed cities to choose the method of procurement from two options, outright purchase or through GCC. For outright purchase, DHI provided 60% subsidy, and the rest was to be borne by the State governments or STUs. Under GCC, the buses would be operated and maintained by the supplier at a fixed cost per km. Operators would receive a subsidy of up to 60% of the cost of Electric Bus over three years in installments of 20% each.

Five cities (Bangalore, Mumbai, Hyderabad, Ahmedabad, and Jaipur) invited bids under GCC, and the rest (Indore, Lucknow, Kolkata, Jammu and Guwahati) went ahead with the outright purchase of buses.

Tender conditions across cities were utterly different, leading to a considerable variation in price for both GCC and outright purchase models. While some cities asked for 9m buses, others chose a mix of 12m standard size buses and 9m buses in AC and non-AC variants.

A vast difference was also noticed in terms of the range requirements (assured km per day) for cities. Kolkata, for example, had one of the lowest requirements at 150km/day while Hyderabad asked for 225 km/day. The tender documents also revealed that some cities pushed the cost of electricity onto the GCC operators while others chose to pay for it themselves.

The rollout of buses has been slow in many states due to a variety of reasons. Tenders have been cancelled in Bangalore, Mumbai, Ahmedabad, and Jaipur while buses have been pressed into service in the rest. It is important to note that cities that chose to get buses under GCC have cancelled tenders due to varied reasons.

In Bangalore, news reports suggested the state government preferred outright purchase of buses whereas, in Mumbai, BEST cancelled tenders after receiving better rates from a new bidder. Bombay High Court quashed termination of contract notice for 40 midi-buses issued by BEST, after the operator- Olectra BYD appealed to the court[35].

Though few of the originally eligible cities did not succeed in securing buses with subsidy, Table 1 summarizes the cities where buses were deployed using subsidy under FAME-I.

35. *https://indiankanoon.org/doc/130079118/*

Table 1: Deployment of Electric Buses under FAME I[36]

S.no.	City	Number of Buses	Size
1	Guwahati	15	9m
2	Jammu	40	9m
3	Manali	25	9m
4	Navi Mumbai	30	9m
5	Lucknow	40	9m
6	Indore	40	9m
7	Hyderabad	40	12m
8	Mumbai	65	9m & 12m
9	Shimla	50	9m
10	Kolkata	80	9m & 12m
Total		**425**	

Source - DHI, GoI

This kind of deployment across multiple cities helped in getting a better understanding of electric buses in India. The dominant business model under the Fame-I scheme was outright purchase with subsidies from Government of India. However, the buses were very expensive compared to diesel buses and hence transit agencies were not in favor of deploying electric buses.

Case study : Electric buses in Hyderabad

Telangana State Road Transport Corporation (TSRTC) participated in the EoI issued by DHI and was shortlisted to receive demand incentive for 40 buses along with ten other cities as explained already.

TSRTC chose to procure buses under GCC, given the high up-front cost and lack of technical know-how on maintenance. Also, TSRTC operates a fleet of 3800 city buses in Hyderabad, and about 500 of these buses are hired in a crude form of GCC. This experience allowed TSRTC to choose GCC over the outright purchase.

36. *https://pqars.nic.in/annex/252/AU89.pdf*

After a quick tendering process, TSRTC received bids from TATA, Olectra BYD, and Mytrah NN4 energy. Bids varied between ₹40 ($0.51) and ₹60 ($0.77) per km for both 9m, 12m buses[37] and Olectra BYD bid the least for both models. TSRTC negotiated with Olectra BYD and agreed to pay ₹33/km ($0.42/km). At this juncture, it is essential to note that DHI had benchmarked the price of a 12m bus at ₹1.69 crore ($217k)) and these buses were eligible to receive an incentive of ₹ 1 crore($128k) a piece. Perhaps this helped Olectra BYD reduce the asking price per km to ₹33/km ($0.42/km) from ₹40/km ($0.51/km).

TSRTC received the first lot of buses in January 2019 following which it started extensive trials of the buses on proposed routes. As per initial plans, buses were to operate on four different routes starting from different parts of the city leading to the airport. TSRTC chose the airport routes to minimize cost and maximise earnings, given these routes have no conductors and the fare is higher than regular city buses. Trials were successful with about 90 drivers receiving extensive training on the routes, buses, and charging infrastructure.

To minimize dead kilometres, two depots were chosen. Each depot has ten charging stations capable of charging 20 buses overnight. These buses are equipped with 324 kWh batteries that can deliver 250 km range on a single charge. However, TSRTC is using the fleet extensively with vehicle utilization varying between 350 km-450 km per day.

While buses are charged at depots overnight between 12 am, and 4 am, the additional range is achieved by giving the buses a quick top-up between schedules in the afternoon. TSRTC is spending ₹7/km ($0.09/km) on electricity bringing the cost of operation to ₹40/km ($0.51/km).

Since their launch in March 2020, electric buses have seen a steady rise in ridership, earning about ₹40/km ($0.51/km) most days.

Source - swachhindia.ndtv.com

37. *https://india.uitp.org/news/electric-buses-procurement-indian-cities-got-the-viable-rates*

Case study : Electric buses in Kolkata

As compared to other metropolitan cities, Kolkata records the highest amount of PM and NOX emissions per 1,00,000 vehicles, despite having lesser number of on-road vehicles. This is primarily due to operations of older vehicles in the citys[38]. In Kolkata, 33% of PM emissions from the transport sector are owed to buses, and 50% of NOX emissions stem from transport. The Government of West Bengal has adopted multiple measures to catalyze electric mobility in the city and the state – especially as Kolkata's air quality has been found to deteriorate to "poor" levels during the winter season.

One such measure is 100% electrification of bus-based public transport by 2030, led by West Bengal Transport Corporation (WBTC). WBTC operates 1,553 diesel buses on 348 routes, of which ~40% are long-distance routes (greater than or equal to 20 km).

In February 2019, WBTC procured 80 electric buses under Phase – I of the FAME scheme, thereby electrifying nearly 5% of its bus fleet. The fleet included 40 9m e-buses and 40 12m e-buses from Tata Motors Limited. These buses were deployed along 12 routes. However, full passenger loading was found to decrease the range of an electric bus by nearly 30%, from 130 km to 100 km per charge, which is significantly higher than estimated (~8%). The total development cost of charging infrastructure for 9 DCFCs, with each charger costing ₹14.86 lacs($19k) and 61 DCSCs, with each charger costing ₹9.02 lacs($12k) has been around ₹12 Crores ($ 1.5 million), including civil and electrical works.

Operating costs of electric buses (₹22/km or $0.28/km) being one-third those of diesel buses, were a major factor in driving their adoption forward, in addition to the purchase cost subsidy offered under FAME-I. When the declining costs of lithium-ion batteries in the global market are factored in, electric buses become even more financially attractive, especially as the cost of battery replacement is also reduced.

WBTC preferred the electric buses outright during its first procurement, as it aimed to leverage its existing public transport operations infrastructure, manpower and experience. In Kolkata, electric buses were being charged irrespective of load demand variations through the day. Hence, WBTC anticipates that city-level peak power requirement might surge if a large fraction of its fleet is converted to electric. To mitigate the same, it aims to explore smart charging opportunities and support the implementation of time-of-day or time-of-use tariff schemes.

38. *TERI. 2020 Successful Operation of Electric Bus Fleet – "A Case Study of Kolkata"*

4.3.3 FAME-II

Government of India approved Phase-II of FAME India Scheme, for three years commencing from 1st April 2019 with total budgetary support of ₹ 10,000 Crore ($1.3 billions). Unlike phase one of the scheme, the main focus of this phase is the electrification of public & shared transportation. The incentives are only being offered for e-bus procurement on GCC basis.

The quantum of incentive is being decided based on the battery capacity at ₹20,000 ($250) per kWh of battery capacity. The maximum ex-factory price of the e-buses has been capped at ₹2 Crores ($257k), and the maximum incentive has been fixed at 40% of the ex-factory price or ₹50 lacs ($64k), whichever is lower. Through this scheme, DHI intends to support a maximum of 7,090 e-buses, with a total outlay of about ₹3,500 Crores ($450 millions).

In June 2019, DHI issued an Expression of Interest (EoI)[39] inviting proposals from State Transport Undertakings, and Municipal Corporations interested in the deployment of electric buses for public transport in different cities under GCC model. The incentives offered for e-buses were also explicitly stated in this EoI, and the maximum incentive was increased to ₹55 lakh ($71k). DHI intended to support five of the seven cities with a population of more than four million according to census 2011, 20 million-plus cities, 20 smart cities and ten cities from states with special category status (states with geographical disadvantage, large tribal population etc.).

Table 2: Selection criteria for electric buses (Source: DHI)

Category of City	Minimum no. of buses	Total no. of target Cities	No. of cities to be selected	No. of buses planned to be sanctioned
Four Million plus cities	300	8	5	1500
One Million plus cities	100	45	20	2000
Cities in states with special category status	50	20	10	500
Other cities	50	50	20	1000
Total	500	123	55	5000

As specified in the EoI, cities need to guarantee that each bus will run for at least five lakh km during its contract period. Cities also need to inform the number of buses they intend to deploy at the time of submitting the proposal. The EoI allows STU/City to mix the bidding for the specified number of intra-city operations and a certain number of inter-city operations for a better price on a GCC basis.

39. *https://dhi.nic.in/writereaddata/UploadFile/Final%20EOI%2004%20June%202019%20Published.pdf*

Selection criteria encourage cities and states to formulate progressive policies to drive the adoption of EVs. Some of the most important criteria for selection are- separate EV policy for the state and waiver of registration charges/road tax for EVs.

While the EoI states incentives are calculated based on the capacity of the battery, demand incentive for buses has seen a significant drop from phase one of the scheme. For example, while the buses received a subsidy of up to ₹1 crore ($128k) in phase one, the maximum demand incentive available from DHI under phase two has been capped at ₹55 lakhs ($71k) per bus. The EoI also capped the incentive according to the size of the bus:

- Standard Bus (length > 10 m to 12 m): ₹55 Lakhs ($71k)
- Midi Bus (length > 8 m to 10 m): ₹45 Lakhs ($58k)
- Mini Bus (length > 6 m to 8 m): ₹35 Lakhs ($45k)

In 2019, Government of India amended the FAME scheme and mandated bus agencies to adopt the Gross Cost Contract (GCC) model for procuring e-buses, making it easier to procure electric buses without the burden of capital expenditure. Since states like Gujarat and Maharashtra were already experienced in this model, they have been able to deploy more electric buses when compared to other states.

The procedure followed was that bids were invited for deploying a defined number of electric buses by transit agencies. Pre-bid meetings were held with interested parties (Original Equipment Manufacturer OEMs/operators) to clarify any questions related to the Request for Proposal (RfP) document.

A consortium of operators and OEMs meeting the criteria listed by transit agencies submit both the technical and financial bids. The technical bid is evaluated by a committee set up by the transit authority followed by financial bids. The lowest bidder is selected and is invited for holding discussions for further negotiation. Following this financial closure is achieved and the contract awarded.

In some cases, the technical bids are evaluated, and shortlisted bidders are required to deploy an electric bus for a month (prototype) before the financial bids are evaluated. Successful deployment of an electric bus does not guarantee that the contract would be awarded.

Bidders who are not able to successfully complete or participate in the trial run automatically get disqualified for the next round. Following this, financial bids are evaluated, and rest of the process is same as discussed in the earlier section.

The EoI received a tremendous response with 86 proposals from 26 States/UTs for the deployment of 14,988 e-buses. After evaluation of these proposals as per EoI, the Government sanctioned 5095 electric buses to 64 Cities / State Transport Corporations for intra-city operation; 400 electric buses for inter-city operation and 100 e-buses for last-mile connectivity to Delhi Metro Rail Corporation (DMRC)[40]. DHI considered Maharashtra for the highest number of e-buses (725), followed by Uttar Pradesh (600), Gujarat (550) and Tamil Nadu (525). Other states were considered for a sanction of less than 500 electric buses.

DHI had given a deadline of March 2020 for the cities/STUs which had to be followed to be eligible for the incentive. Many cities complied and started the tendering process on time. Many electric-bus suppliers however quoted significantly higher prices[41] than during FAME-I scheme as shown below.

Table 3: Tender rates for procurement, operation and maintenance of electric buses under FAME II

Type of bus	Lowest bid received	Highest bid received	Median
9m AC	₹54.82 ($0.283)	₹75.00 ($0.964)	₹64.06 ($0.823)
12m AC	₹53.70 ($0.690)	₹90.90 ($1.168)	₹74.95 ($0.963)

Source - Rediff

40. https://dhi.nic.in/writereaddata/UploadFile/Press%20Release%20Final.pdf
41 https://www.electrive.com/2020/01/31/eu-commission-approves-electric-bus-funding-for-germany/

Table 4: List of buses deployed/supply order issued/extension to issue supply order given under FAME-II Scheme as on December, 2021[42]

S.No.	City / SRTU	Fleet Size
1	Ahmedabad	90
2	BEST Mumbai	314
3	Bangalore	600
4	Chandigarh	91
5	Delhi	325
6	Navi Mumbai	200
7	Other UP Cities	105
8	Patna	25
9	Rajkot	116
10	Silvassa	10
11	Surat	199
12	Tirupati	200
13	Uttarakhand	10
14	Gujarat SRTC	150
15	Kadamba SRTU (Goa)	230
16	Karnataka SRTC	50
17	Maharashtra SRTC	200
18	North Western Karnataka SRTC	50
	Total	**2965**

However, the process of bus procurement was delayed due to COVID-19 pandemic and other reasons, and many cities might were able to utilize FAME-II assistance, as a whole. DHI, therefore, decided to reallocate the subsidy for 2,000 electric buses through a fresh EoI[43]. They have also extended the second phase of FAME-II until 31st March 2024 to give more opportunity to cities to utilize the subsidies.

Additionally, Convergence Energy Services Ltd (CESL), an arm of state owned Energy Efficiency Services Ltd was tasked to aggregate the demand of the 9 cities with more than 4 million population, for the remaining demand under the scheme on OPEX basis. CESL had rolled out a tender for 5,450 buses worth ₹5,500 crores ($706 millions) to seek bids for the e-bus operation in 5 cities. Tata Motors has emerged as the lowest bidder across all five operational categories. Because of the mass tender, the bid received were of less than ₹50/km ($0.64/km) for 12m buses.

42. *Year-End- Review of Ministry of Heavy Industries – 2021.https://pib.gov.in/PressReleasePage.aspx?PRID=1784161*
43. *https://auto.economictimes.indiatimes.com/news/commercial-vehicle/mhcv/subsidy-for-2000-e-buses-to-be-reallocated-centre-to-invite-bids-next-month/73508634*

Table 5: Per km rates quoted by lowest bidder Tata Motors

Bus Type	Cost / km
12m Low floor AC	₹47.49 ($0.610)
12m Low floor Non-AC	₹43.49 ($0.559)
12m Standard AC	₹44.99 ($0.578)
9m Standard AC	₹41.45 ($0.533)
9m Standard Non-AC	₹39.21 ($0.504)

Case study: Bengaluru

Bengaluru Metropolitan Transport Corporation (BMTC) has attempted to induct electric buses into its fleet for the past five years. It was the first city in the country to pilot electric buses operations in 2016.

BMTC has floated eight electric bus tenders till date, of which six were unsuccessful, owing to either presence of a single bidder or high quotes from bidders, both stemming from risk perceptions. It floated five tenders for procurement of 300 units of standard size (12m) electric buses and three tenders for procurement of 90 units of midi size (9m) electric buses, with successful tendering happening only in 2021.

In August 2021, BMTC procured 90, 9m electric buses from JBM Group at the rate of ₹51/km ($0.655/km) through the GCC model, with subsidies provided under the scope of the Smart Cities Mission by Bengaluru Smart City Limited.

In November 2021, BMTC awarded a procurement contract of 300 12m electric buses to Ashok Leyland at the rate of ₹48.95/km ($0.629/km) , with subsidies from Phase – II of the FAME scheme and Government of Karnataka.

For electrifying bus routes, the depot identification process must consider the power infrastructure surrounding it. The best strategy is to select depots as close as possible to electrical substations (which have power capacity available to support requisite level of electric bus charging). This is important as the cost of drawing an 11 kV line extends up to ₹1 crore/km ($128,000/km) for the state transit agency. Here, a fine balance between locating close to substations and being closer to route terminals must be struck.

Certain clauses in electric bus tenders, such as 12-year concession periods in place of 10-year concession periods, and staggered release of subsidy bank guarantee, can play a role in limiting procurement costs. It is important to clarify the tender as far as possible and limit unnecessary risks for bidders - in order to get lower quotes and increase the bankability of the project. It is important to maximize bid participation by intensive pre-bid meetings with multiple bidders, understanding bidders' perspectives, relaxing high battery capacity and driving range requirements, allowing for opportunity charging during off-peak hours of operation among others.

Case study: Delhi

The focus on electric buses emerged as part of a larger conversation to limit transport sector emissions in the national capital. The Delhi Electric Vehicle Policy (launched in 2020) specified for the transit agencies in Delhi to procure 1,000 electric buses by the end of 2020. In 2021, the Delhi Transport Corporation (DTC) procured 300 electric buses under Phase – II of the FAME scheme. The details of the buses, which are supplied by two manufacturers and set to be delivered in the first quarter of 2022, are 100 buses from Tata Motors Limited at the rate of ₹72.20/km ($0.93/km) and 200 buses from JBM group at the rate of rate of ₹68.58/km ($0.88/km).

In Delhi, provision of power of the order needed for electric bus operations (>4 MVA) is proving to be a challenging task. Hence, the transit agencies in Delhi have prioritized their depots for commencing electric bus operation in coming years, based on the timelines communicated to them by relevant power distribution companies - for provision of a required level of power connection (if possible).

An analysis of Delhi's routes indicated to the Delhi Transport Corporation (DTC) that it is not feasible to deploy electric buses in the same way as conventional fuel buses. This could result in requirement of additional fleet or downtime for charging. Hence, DTC is contemplating on carrying out a system-wide route analysis, the pertinent results of which can feature in the tenders as tentative information to bidders for electric bus deployment. The same may help bidders to be more precise in quoting their rates, and help DTC avoid any operational and performance-related challenges.

As per DTC's understanding, the rest times' provisions in the Motor Transport Workers Act can be used to create top-up charging events for electric buses, which may reduce the charging requirements for electric buses at depots, thereby supporting operational feasibility.

Case study: Mumbai

Between 2005 and 2017, the share of public transport in all passenger trips made inside the Mumbai Metropolitan Region declined from 78% to 65%[44]. This trend is accompanied by a twofold rise in private vehicle trips in the same period.

The decline in share of public transport is credited to two main reasons: extensive development of road links and low-capacity transit in Mumbai, as per the Comprehensive Transport Study (2008), and; incapacitated public transport, with Brihanmumbai Electric Supply and Transport (BEST) having only 3,500 buses. As part of its fleet electrification and augmentation plans, BEST has added 386 electric buses by the end of 2021.

BEST has so for procured and deployed 386 electric buses under Phase – II of the FAME scheme. These buses include buses from Tata Motors Limited at the rate of ₹74/km ($0.95/km) and from JBM group at the rate of rate of ₹83/km ($1.07/km).

Mumbai has traditionally operated buses wherein they do not return to depots during operating hours, and staff change occurs at the terminals. However, as electric buses (in some cases) necessitate depot visits due to opportunity charging needs – BEST is forced to change its operation style.

Lack of land space for depots and terminals is a challenge for expansion of buses in Mumbai. BEST had to procure specially designed compact distribution transformers which occupies 75% less area.

In 2021, BEST announced that it will be procuring additional 2,100 e-buses. Furthermore, in Jan 2022, BEST announced that it will be procuring 900 double decker e-buses to its fleet.

44. *https://www.adb.org/sites/default/files/publication/710081/mumbai-metro-transforming-transport.pdf*

4.3.2 Beyond FAME

Outside FAME-I and II EoI, many cities and state governments have shown interest in procuring electric buses. Interestingly, many have chosen to procure these buses under GCC model. Kerala State Road Transport Corporation (KSRTC) procured ten 9m buses via GCC and operated them during the Sabarimala festive season. Now, the transport utility is successfully operating the same buses on popular intercity routes.

Pune's public transport operator, PMPML procured 25 9m and 125 12m buses via Smart Cities Mission. Other states too have issued RFPs for buses ranging from 10-500. However, the most important of them all is Delhi. With 10,00 buses, Delhi is set to have the world's biggest electric bus fleet outside China. DIMTS, the SPV that manages Cluster bus scheme in Delhi has already initiated the process to procure 375 12m AC electric buses.

Case study : Electric buses in Pune

Pune Mahanagar Parivahan Mahamandal Limited (PMPML) operates over 2,200 buses[45] across Pune and Pimpri Chinchwad both in mixed traffic and BRTS. To improve passenger service, PMPML is operating 150 electric buses in BRT corridors. It is operating 25 9m e-buses and 125 12m e-buses. The transport utility wanted to test the technology first and issued an RFP for 25 9m AC buses. PMPML was expecting a range of 225 km in a single charge. Conforming to UBS-II, auto transmission and air suspension were included in the technical specs.

Owing to the availability of ample space for parking and setting up charging stations, Bhekrai Nagar and Nigdi depots were chosen to house electric buses. To minimise dead kilometres, routes originating/terminating from these depots were chosen. Inner-city routes were given preference over their suburban counterparts. Only Olectra-BYD offered to supply buses and PMPML went ahead with their bid after receiving reasonable rates.

PMPML is paying ₹40.32/km ($0.52/km) for 9m bus and ₹58.5/km ($0.75/km) for 12m bus with 1% increase every 2 years. The contract tenure is 10 years which is subject to an extension of 2 years after evaluating the performance. The cost of electricity is being borne by PMPML. The rate of electricity is ₹4.5 ($0.06) per unit at night and ₹ 7.78 ($0.10) per unit during the day.

45. *PMPML statistical report (February 2020)*

Because this procurement was done outside the FAME scheme, PMC and PCMC - municipal corporations of Pune and Pimpri Chinchwad decided to provide an upfront subsidy of ₹50 lakhs ($64k) per bus themselves. The fare on electric buses is similar to regular buses and have seen tremendous success from the day of launch in February 2019.

Source - Twitter, Hemant AutoclickZ

Case study: Electric buses in Tamil Nadu

The Tamil Nadu Transport Department believed that the subsidy under FAME-I is not sufficient to catalyze a transition to electric buses, and would instead lead to higher operating costs of ₹20/km ($0.26/km) for the transit agencies compared to the current diesel buses operations in spite of the subsidy. Hence, the Government of Tamil Nadu did not proceed with procuring electric buses, despite 525 electric buses being sanctioned under FAME-II by the central government for different transit agencies in the state.

Tamil Nadu is now exploring financial assistance from sources other than the FAME scheme. The state plans to procure an additional 500 electric buses under the first phase of a loan agreement with KfW, the German development bank. Overall, the state envisions deploying 2000 electric buses across the state with assistance from KfW in phases.

05

Way Forward

The subsidies under the FAME scheme primarily drive electric bus procurement in India. The scheme has accelerated electric bus adoption across the country and integrated GCC model among the STUs.

At this juncture, it is important to repeat that most city bus systems don't recover the cost of operations. Public bus transport in India is characterized with lower Earnings Per Kilometer (EPKM) than the Costs Per Kilometer (CPKM) in a vast majority of cases. Urban public bus service operators in India reported a total loss of over ₹63,185 crores ($8.1 billions) in 2018-19[46]. The state and central government contributions for them stood at ₹32,490 crore ($4.2 billions) in the year 2018-19.

This makes financing institutions wary about funding e-bus procurement which is anyway currently a costly proposition. Any prospective lender, currently contemplating entry strategies for the e-bus ecosystem, is cautious of the technological nascency of e-buses, credit unworthiness of the STUs, the resulting lack of payment securities in place, and the escrow mechanism within the GCC model.

A major reason for financial lenders' discomfort regarding e-bus procurement by STUs in India is the escrow mechanism within the GCC model. Although escrow account-based payment mechanism is intended to secure the payment, the operator and the lender find that they effectively do not have any control over the escrow account; rather, the control lies solely with the STU.

The only asset in possession of the lender (within the concession period) would be the depreciating assets such as e-buses and their chargers. Escrow accounts should be tripartite with the lender, operator and STU. It is recommended to provide two- or three-month payment guarantees to lenders and operators to increase the project's bankability. This will provide payment securities to operator thus reducing the cost of financing for electric bus projects.

As more cities are procuring e-buses on the GCC model now, it is important to identify a sustainable source of funding to keep the service up and running. While viability gap funding from the government is useful, states and cities should consider setting up urban transport funds. It will not only help sustain operations of electric buses but also help cities maintain high-quality service.

46. *https://www.adb.org/sites/default/files/publication/710081/mumbai-metro-transforming-transport.pdf*

Metro rail corporations seek loans from development banks like JICA, KfW, ADB etc. Tamil Nadu has used loans from such development banks to improve and expand their bus operations, and other STUs must also consider this method of financing.

Additionally, STUs should make effort to understand the tender clauses from the bidders' perspectives and make amendments to allow flexibility in configurational requirements to maximize the pool of participants. Moreover, the STUs should share more data on fleet operations with the bidders to enable proper planning and effective service level agreements.

Opportunity charging and depot charging should be well planned. A major advantage of opportunity charging is to avoid the requirement for large-size batteries, thereby lowering the procurement cost. Further, careful depot planning with the objective to reduce dead kilometers and to set up upstream electrical infrastructure close to nearest High Tension supply line can help bring down per kilometer cost of operation.

Demand aggregation model can be explored to take advantage of economy of scale. CESL has initiated a grand challenge to procure e-buses at a large scale and distribute them to STUs. However, for such models to be more effective, CESL should be a part of the tripartite agreement along with the operators and STUs. Furthermore, financing alternatives should be explored to secure timely payments and thus, lower the cost of financing.

The incentives being provided by the government has created a good environment for the electric bus industry in the country to flourish in the coming time. As the market grows the cost of manufacturing will also come down, and so will the procurement cost. With financing looking relatively strong for e-buses in the future, it's now important for public transport undertakings to equip themselves technically to deploy and utilise the upcoming e-bus fleets efficiently and effectively.

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