IIT KANPUR

ELECTRIC VEHICLES IN COMMERCIAL TRANSPORTATION

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Abstract

As electric vehicles share strong linkage with multiple sustainable development goals. India is aiming to achieve 30% electric vehicle (EV) share by 2030 under the EV@30 Campaign.The global climate agenda established under the Paris Agreement to reduce carbon emissions in order to limit global warming is driving this push for electric vehicles. India's "Panchamrit" advocacy of five elements for climate change at the COP26 in Glasgow is a commitment to the same.

The paper begins with an in-depth discussion of the measures implemented by the Government of India as a result of researching EV trends, as evidenced by the increase in EV sales and public awareness in India. This report also describes the overall evolution of the EV and its market over the last few years.

In order to achieve the desired change, we must address a few major challenges, such as price, drive range, battery life of the Li-ion batteries used, safety, and so on. To solve these issues we propose state of the art solutions like inductive charging system, MultiStage charging schemes to ensure longer battery life, IoT integrated grid, etc which are proven to be very useful in our case.

We cited some ground-breaking case studies to back up our claims. One of the most relevant examples being the case of Shenzhen, China(with population density similar to India) where all commercial vehicles are electric.

At the same time, India has launched a number of new initiatives in this field, such as the case of Kolkata. However, emphasis should be placed on assisting other states to follow suit.

Introduction

Electric vehicles are destined to become lifelines in the automobile as well as the energy industry across the globe. This is majorly propelled by the powerful purpose of creating a greener, safer and sustainable planet. Over 194 countries participated in the historical Paris climate agreement enforced in 2016 and pledged to limit the average increase in global temperature to less than 2 degree celsius in this century. The USA, China and India combined together account for a staggering 50% of the world's GreenHouse Gases (GHGs) emissions. The transport sector of these major economies form the bulk of the emission of GHGs. The USA and China have already promoted the replacement of fossil fuel powered vehicles by e-vehicles and as of 2016 have the highest stock of e-vehicles in the world; however, India is lagging behind its counterparts. Out of the 20 most polluted cities in the world, 15 cities are in India. India has pledged to cut down its share of GHGs emissions significantly in order limit the average increase in global temperature. As a result of this, the Indian government has set a target of 100% e-mobility by 2030. India embarked upon its e-vehicle journey in November 2017 by the deployment of 100 e-vehicle units and installation of four charging stations in a city.

The Indian automobile industry is ready to embrace vehicles without an IC engine and a hydrocarbon fuel. As per the Society of Manufacturing of Electric Vehicles, the population of e-vehicles is growing steadily at the rate of 37.5% in India. However, one of the major roadblocks in the growth of e-vehicles envisaged by SMEV(Society of Manufacturers of Electric Vehicles) is availability and viability
of charging infrastructure in India. In the light of the above background, it makes a compelling objective to study the commercial viability of e-vehicles and charging infrastructure required for it. Hence, it is proposed to investigate and perform detailed study on the leading countries in terms of electrification of automobiles. Shenzhen, China, serves as the perfect example for this, with Shenzhen having population density similar to India, yet being extremely proficient in generating world's first and largest fully electric bus and taxi fleets.

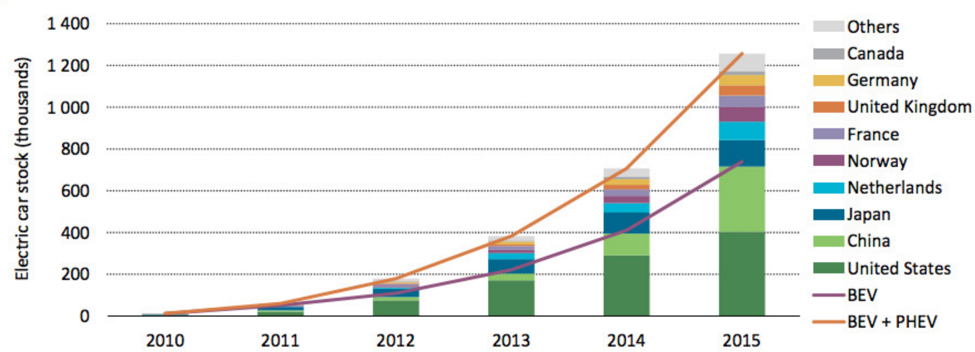
Apart from being much better for the environment, electric vehicles have many more salient features. Electric motors give electric cars instant torque, creating strong and smooth acceleration with almost no noise. Electric vehicles (EVs) are also considered to be technologically superior to their internal combustion counterparts from an efficiency perspective. EVs are about four times as efficient as vehicles with an internal combustion engine at using the energy delivered to the vehicle to overcome vehicle road load. All this creates a compelling case to analyze and plan the integration of the electric vehicles in the commercial domain.

Trends and Growths:

Why Electric Vehicles?

A global trend is seen with a shift in the use of electric vehicles over conventional fuel-powered vehicles. This move is entirely justified given the numerous advantages they have over gasoline vehicles.
The following are some justifications for this trend:

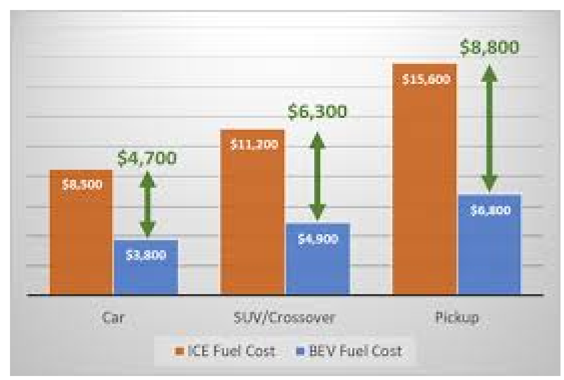
Figure 1 • Evolution of the global electric car stock, 2010-15



Note: the EV stock shown here is primarily estimated on the basis of cumulative sales since 2005.

Lower running costs

Electric vehicles are more cost-effective than fuel vehicles because of their increased efficiency, which, when factored in with the price of power, makes them less expensive. Moreover, the uses of electric vehicles can be more environmentally benign when renewable energy sources like solar energy is used.



Low maintenance cost

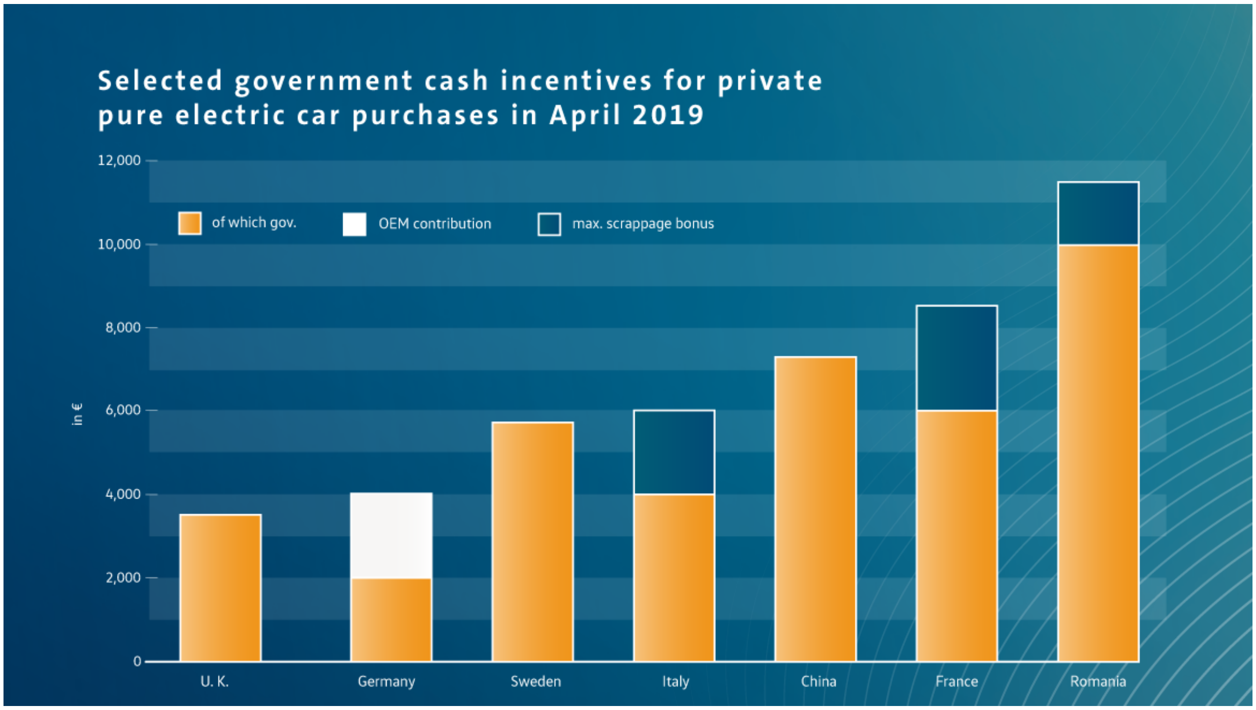
Electric vehicles require much less maintenance than ICE vehicles because they have fewer moving parts.

Zero Tailpipe Emissions

They reduce the carbon footprint due to zero tailpipe emissions. Even when electricity production is considered, petrol or diesel vehicles emit almost three times more carbon dioxide than the average EV. It is estimated that shifting to electric mobility will save India nearly one gigaton of CO2 emissions by 2030.

Tax and financial benefits

In most countries, the registration and road tax for electric vehicles are lower than those for gasoline or diesel vehicles. Governments around the world have a variety of policies and incentives in place to promote EVs.



Efficient fuel-to-energy conversion

Traditional gasoline and diesel vehicles can only convert 17%-21% of the energy stored in the fuel to the wheels. In contrast, electric vehicles can convert approximately 60% of the electrical energy from the grid to power the wheels.

Reduced Noise pollution

Electric vehicles have no gears and are extremely simple to operate. They also generate far less machinery noise, to the point where manufacturers must add false sounds to keep pedestrians safe.

Trends of Growth

India aims to achieve roughly 40% cumulative installed capacity from non-fossil fuel-based energy resources by 2030, which will aid EV growth in a variety of ways. Meanwhile the global Electric Commercial Vehicle Market size is projected to grow from 353 thousand units in 2022 to 3,144 thousand units by 2030, at a CAGR of 31.4%.

Various corporations have committed an increasing proportion of their resources to EV development. Tesla has been one of the world's most successful EV companies, but others, such as Mercedes-Benz, Tata, MG, GM, Audi, Hyundai, Nissan, BMW, and Renault, have also launched EVs that have received significant customer demand in various markets.

The Asia Pacific electric commercial vehicle market is expected to be the largest, with strong demand for electric public transportation and logistics services. Previously, electric buses dominated the ECV market; however, there is now significant demand for electric vans as well. In the coming years, a high demand for electric pickups can be expected with a large number of pre-booking in these vehicles.

Electric Vehicles Worldwide: Brief Timeline:

The history of electric cars can be broken up into five distinct periods: the early pioneers of electric mobility (1830-1880), the transition to motorized transport (1880-1914), the rise of the internal combustion engine (1914-1970), the return of electric vehicles (1970-2003), the electric revolution (2003-2020), and the tipping point (2021 and beyond)

1.The early pioneers of electric mobility (1830-1880)

Throughout the early 1800s, a series of technological breakthroughs in batteries and motors led to the first electric vehicles by engineering and automotive pioneers throughout the world. **The first electric car was developed** in the time between 1828-1832, with the combined efforts of inventors in Hungary, the Netherlands, the UK, and the US. While the first official display of electric vehicle took place at an industry conference in 1835 by a British inventor by the name of Robert Anderson. Robert Anderson’s vehicle used a disposable battery powered by crude oil to turn the wheels.

However, all these efforts were little more than prototypes of electrified carts—traveling at top speeds of 12 km/h with cumbersome steering, and little range.

Gaston Plante, a French physicist, made a significant breakthrough in rechargeable lead-acid battery technology in the 1860s. However, it wasn't until the late 1880s that William Morrison combined rechargeable batteries with electric motors to create the first "practical" EV (which could carry up to 12 people and had a top speed of 32 km/h).

2.The transition to motorized transport (1880-1914)

Around the turn of the twentieth century, many people began to replace their horses and carts with motorized vehicles. At the time, the various types of vehicles on American roads were fairly evenly distributed: roughly 40% of vehicles were powered by steam, 38% by electric, and only 22% by gasoline.

Compared to electric cars, gasoline-powered cars were far noisier and difficult to drive while at the same time also emitting pollutants from their exhausts. All this gave EVs a significant advantage.

As a result, electric cars quickly became popular with urban residents where electricity was readily available and as more people gained access to electricity, the more popular they became. This popularity caught the eye of many pioneers of the day: Porsche developed the world's first hybrid car while Thomas Edison even partnered with friend and former employee Henry Ford to build an affordable EV.

3.The rise of the internal combustion engine (1914-1970)

EVs suffered a huge setback when the mass-produced internal combustion engine (ICE) vehicle was introduced. Along with Ford's Model T, gasoline-powered cars became widely available and affordable. In this time, electric vehicles saw little advancement and by the mid-1930s, they had almost completely disappeared from the market.

4.The return of electric vehicles (1970-2003)

As the usage of the fuel driven vehicles increased, by the seventies, oil prices increased and gasoline shortages became quite common, peaking with the 1973 Arab Oil Embargo. Therefore interest in lowering the society's dependence on oil grew.

Automakers, feeling this social shift, started to explore options for alternative fuel vehicles, including electric cars. For instance, General Motors developed a prototype for an urban EV and even NASA helped raise the profile when their electric Lunar rover became the first manned vehicle on the moon. However, electric vehicles still suffered from several drawbacks compared to gasoline-powered cars including limited range and slow top speeds and consumers were not interested.

One of the most significant developments in this time period was the introduction of the Toyota Prius, released in Japan in 1997, it became the world's first mass-produced hybrid electric vehicle and further went on to become a success with high end crowd(the cars were more expensive than the gasoline cars) throughout the world. Since then, rising gasoline prices and growing concern over carbon pollution have helped make the Prius the best-selling hybrid worldwide.

5.The Revolution (2003-2020)

After seeing the growth of lithium-ion battery capacity in their previous venture, Eberhard and Marc formed Tesla Motors in 2003. By 2006 the Silicon Valley startup had announced it would start producing a luxury electric sports car that could go more than 320 km on a single charge.

Tesla's subsequent success spurred many big automakers to accelerate work on their own electric vehicles. Nissan raised the competition with its launch of the Nissan LEAF in 2010. This all-electric, zero-emission car would become the world's all-time top-selling EV.

At the same time, new battery technologies entered the market, helping to improve range and cutting EV battery costs. To demonstrate this, the price of lithium-ion batteries has declined by 97% since 1991. This, in turn, has helped lower the cost of electric vehicles overall, making them more affordable for consumers.

6.The tipping point (2021 and beyond)

The growth in electric mobility, and especially passenger electric vehicles, has been profound. From whichever metric you measure it—EV sales, EVs on the roads, government EV mandates, EVs as a percentage of all vehicle sales, or simply vehicle manufacturers making electric mobility pledges. Clearly governments, society, and consumers see electric mobility playing a large role in the future. Three numbers demonstrate this trend perfectly:

- The amount of EVs on the road has exploded—from negligible in 2010, to approximately 1 million in 2016 and by the end of 2020, there were as many as 10 million electric cars on the world's roads.

- Tesla is the most valuable automotive company on the planet—worth an estimated $1 trillion.
- Despite the global downturn in vehicle sales due to the Corona Virus pandemic, EVs sales doubled in 2021 from the previous year to a new record of 6.6 million. Nearly 10% of global car sales were electric in 2021.

This growth is not only limited to a few countries either. Around the world, there has been continuous growth in EV sales in all major markets, but nowhere has this acceleration been faster than in Europe. Although China continues to have the largest EV stocks in terms of numbers, Europe overtook China as the global driver of electric car sales in 2020, representing the 15 top markets for EV sales.

The top spot on that list goes to Norway, which has almost entirely phased out the sales of ICE vehicles already. Norway holds the title for highest EV penetration, with nearly 80 percent of new cars sold in Sept 2021 being fully electric. The Nordic country is predicted to hit the milestone of 100 percent electric vehicle sales as early as in 2022—the first country in the world to do so. By 2035, it's expected that all the largest automotive markets will go electric.

Electric Vehicles in India: Brief Timeline

1996:

The first electric vehicle i.e. **Three Wheeler VIKRAM SAFA** running on 72 volt lead acid batteries.
was developed by **Scooters India Pvt Ltd, Lucknow** and approximately 400 vehicles were made and sold.

1999:

Mahindra and Mahindra Ltd. Launched its first electric three wheeler and also launched a new company, based in Coimbatore, in 2001, to make and sell electric vehicles named **Bijlee**. In 2004, MEML was closed down due to lack of demand. Mahindra further started a plant at Haridwar in 2006 and continues to produce electric vehicles as per market demand.

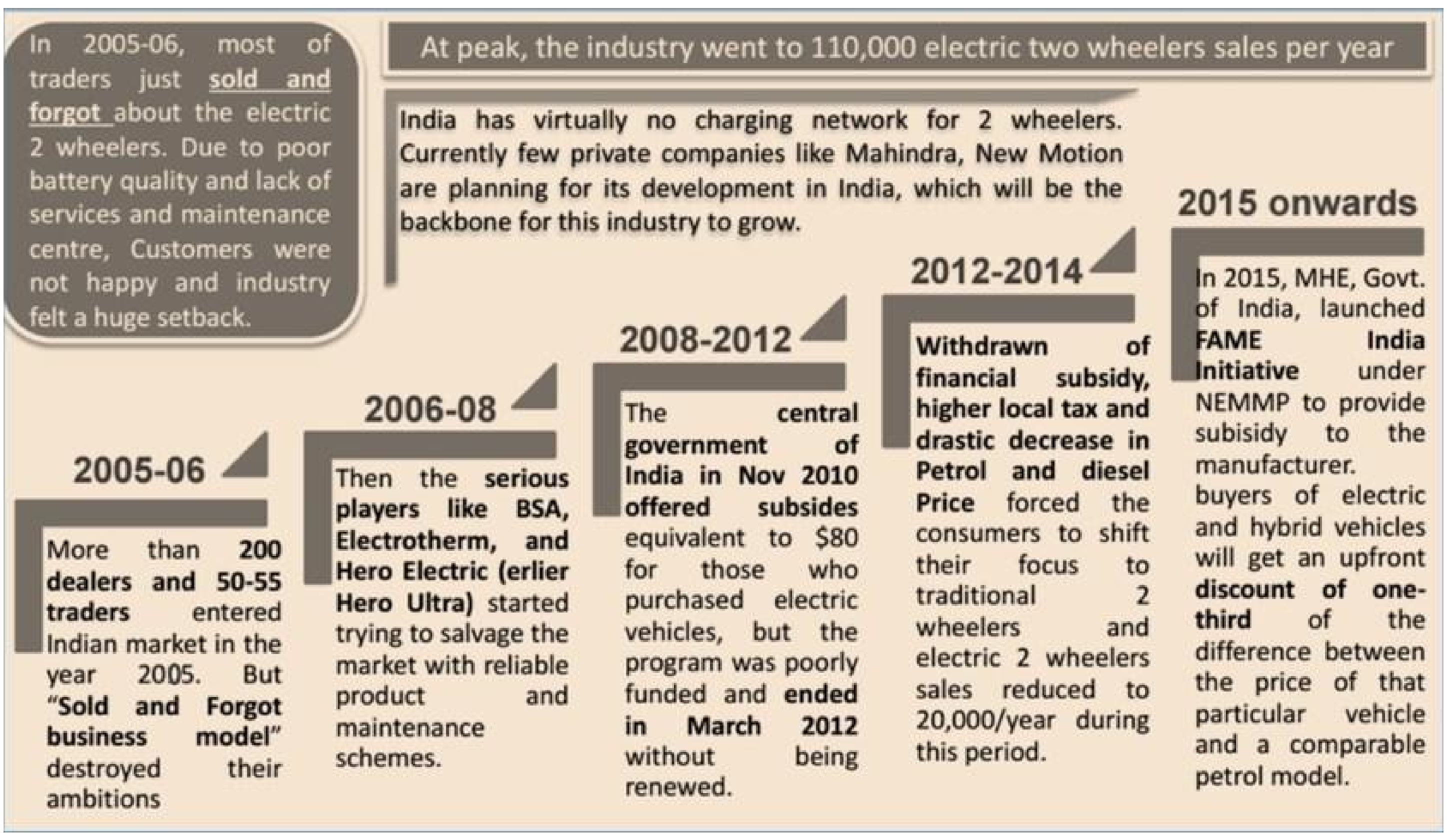
2001:

REVA, Bangalore, also entered the EV sector in the car industry with a vehicle developed by **American company (Amerigon)**. Some 3200 cars had been sold worldwide, including approximately 1500 cars that had been sold in India, mostly in Bangalore city.

2007

Hero cycles collaborated with UK based **ULTRA Motor** to launch a series of **bikes**. Other companies such as **Electrotherm India, TVS Motor, Hero electric** etc. are also manufacturing and selling their products.

2005 – 2015 : Period of huge set back in the Industry

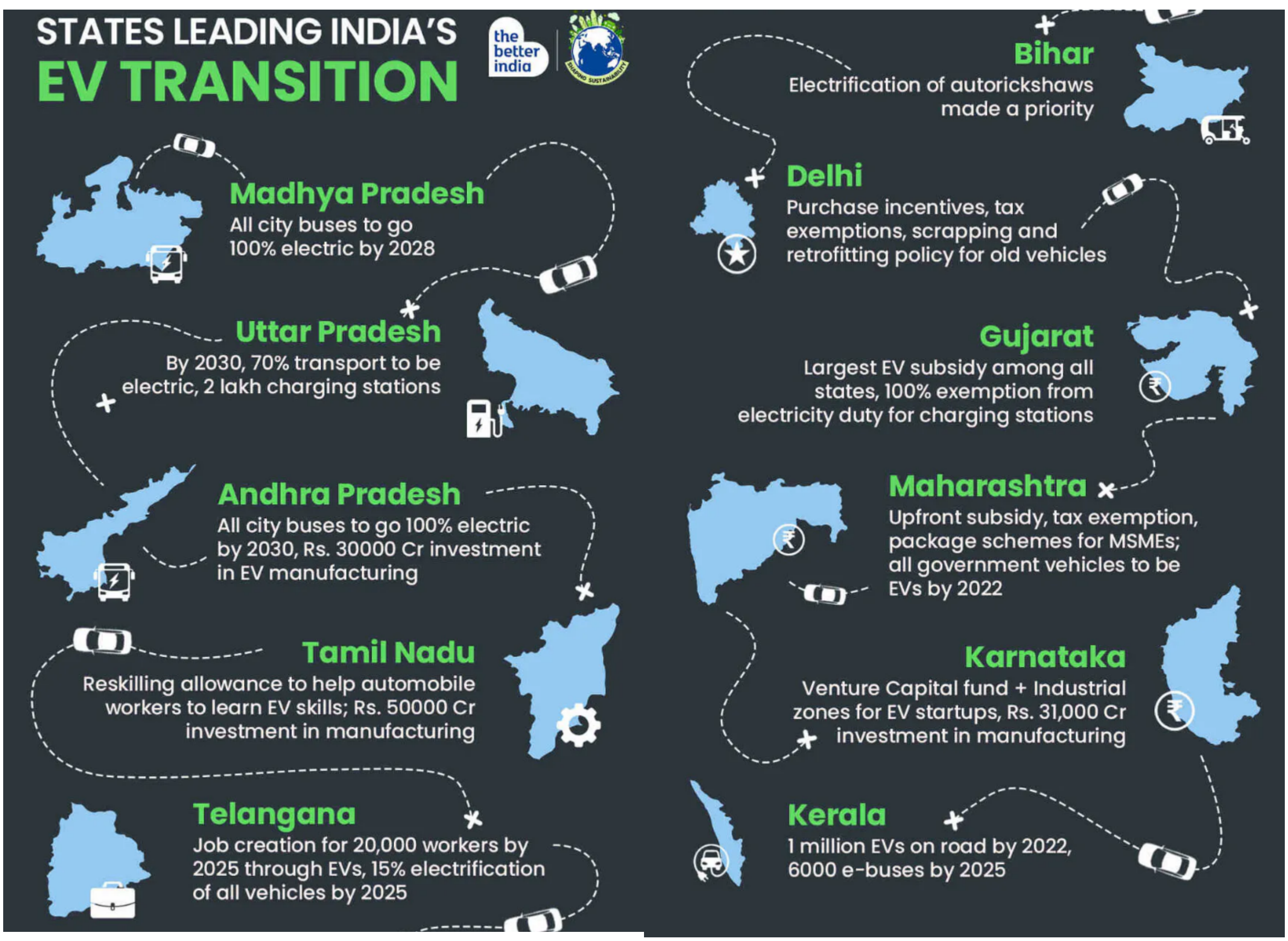


2021:

According to a recent report by the Federation of Automobile Dealers Associations (FADA), in February, India's electric vehicles segment saw a 58 per cent growth when compared to January, and around 297 per cent increase when compared to the previous year. This data definitely underlines the rapid growth in the EV segment of India, which has gained widespread acceptance over the last few years.

Data shows that among Indian states, Uttar Pradesh tops the list with 2,55,770 registered EVs, followed by Delhi with 1,25,347, Karnataka with 72,544, Bihar with 58,104 and Maharashtra with 52,506 EV registrations.

The increase in EV sales, even amidst a global pandemic, isn't attributed to the impending hike in fuel prices alone, but also to the increased awareness and changing public consciousness around understanding clean energy. The central government and different state governments have been encouraging the adoption and manufacture of electric vehicles by introducing several policies as well as tax deductions.



Policies by the government:

The government of India has launched various possibilities to date to integrate the EVs into the country – FAME-II, PLI SCHEME, and Battery Swapping Policy, Special Electric Mobility Zone, Tax Reduction on EVs.

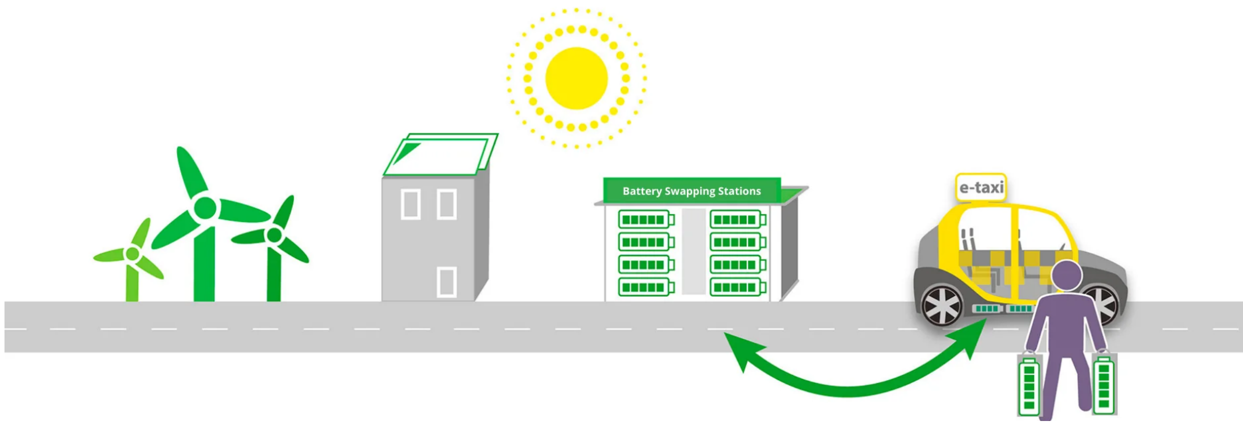
FAME-II:
The **FAME India initiative** was launched on **April 1, 2015**, by the Indian government to reduce the usage of petrol and diesel automobiles. This scheme was an essential part of electric mobility in India. The four focus areas of the Fame India Scheme are as follows:

- Demand for technology
- Pilot Projects
- Technology development
- Infrastructure for Charging.

The **FAME II** scheme was introduced in **April 2019** with a budget outlay of Rs 10,000 crore to support 5,00,000 e-three-wheelers, 7,000 e-buses, 55,000 e-passenger vehicles, and a million e-two-wheelers. The aim was to drive greater adoption of EVs in India. The scheme was **supposed to end in 2022**. But now, In the budget for FY2022-23, the Government of India has decided to **extend the FAME-II scheme till 31 March 2024.**

PLI SCHEME:
In **June 2021**, The Department of Heavy Industry launched the Production Linked Incentive for Advanced Chemistry Cell Battery Storage (PLI-ACC Scheme). Its goal is to entice domestic and international investors to invest in India's Giga scale ACC manufacturing facilities.
The scheme's overall pay-out is INR 18,100 crore. The policy stipulates that the manufacturing facility must be operational within two years to be eligible for subsidies, and the Bid Documents go on to say that a 60 percent domestic value addition must be achieved within five years after that.

Battery Swapping Policy:



This scheme will standardize the standards of batteries to be used in EVs across India. The legislation will help in promoting EVs in time-sensitive service sectors like deliveries and inter-city transportation, as swapping a drained battery for a fully charged one is a more practical option than on-the-spot recharging, which can take hours. If performed well, battery switching is expected to achieve acceptance in commercial applications such as 2W and 3W vehicles and will aid faster penetration in these segments.
The Battery Swapping Policy will also benefit the manufacturers. Furthermore, by leveraging economies of scale, this approach will assist battery producers in lowering costs.

Duty Reduction on Electric Vehicles:
The budget includes a proposal to lower customs duties on Nickel ore and concentrate from 5% to 0%, Nickel Oxide from 10% to 0%, and Ferro Nickel from 15% to 2.5 percent. Nickel Manganese Cobalt (NMC) is a vital part of lithium-ion batteries, which are utilized in electric vehicles (EVs). India has limited reserves of these ores, and battery manufacturing is highly dependent on them. Hence, nickel alloys are mostly imported. The customs tax decrease will help local EV battery producers lower production costs. There is also a proposal for a reduction in customs duty on motor parts from 10% to 7.5% to help lower the overall cost of EVs.

Special E-mobility Zone:
The government plans to establish dedicated mobility zones for electric vehicles. Only electric vehicles or comparable vehicles will be permitted to operate in the zones identified by the administration. Such policies are prevalent in many European countries and China.People moving through these zones need to travel in their EV of their own or take a public EV vehicle, thus increasing the market share of EVs.

Problems

1.Market:

Availability: India can be said to be in the take-off stage in terms of the availability in EVs. At present, the variety of EV models available for purchase is limited compared to the choices available in ICE vehicles. This reduces the chance of buyers considering EVs as their next vehicle.

Price: EVs ICE vehicles are generally more expensive than ICE vehicles due to its machinery, materials, high-end technology requirements with the most expensive component being he rechargeable lithium-ion battery. The shortage of metals such as cobalt and lithium (the main elements in making these batteries) has forced India to import them from other countries, pushing the price of EVs up. For example, the price of electric scooters (e-2Ws) is between INR 37,000 and INR 120,000, e-3Ws cost between INR 150,000 and 300,000, and electric cars are over INR one million. Buyers are also concerned about battery replacement costs. Electric scooter batteries last for about two to four years, whereas the life of an electric car battery is about eight years. The cost of a new electric car battery is around INR 600,000— a price point where a buyer can already purchase a brand-new ICE car.

Financing: Despite increasing public and private sector investments in the EV sector, the sale of EVs is still lower than expected. One of the problems observed in this regard is the slow pick-up of retail lending support to consumers and institutions financing EVs. A 2022 study by Niti Aayog and RMI India notes that financial institutions are hesitant in lending due to risks involved, such as product quality, and uncertainty of resale value.

Manufacturing: The proper development and growth of India's EV industry is affected by a number of challenges related to technical expertise of workers, R&D capabilities, ancillary auto components, backward linkages (with metal industries, capital equipment, trucking, warehousing and logistics), linkages with dealership, retail, credit and financing, repair and maintenance.

Public awareness: There is still very little understanding of EVs among the public, in terms of its benefits, risks, subsidies available, charging methods and tariff, battery life, maintenance costs, and resale value. The most common media such as radio, television, newspapers and magazines do not disseminate adequate information and most buyers continue to prefer ICE vehicles.

2. Technical

Electricity production: As India pushes for faster adoption of EVs, the demand for electricity for charging EV batteries will increase. At present, coal is the major source for electricity generation in India but it releases hazardous pollutants which create an impact on the environment and people's health. Therefore, to meet future electricity demand, it will be necessary to tap safer and cleaner sources.

Charging: EVs are usually charged in two ways: by plugging into a wall socket or an AC wall box charger installed at home, or by plugging into a DC charger installed at public places. Home chargers take a longer time (6hrs to 19 hrs) compared to those available at public places (over 1hr) for a full charge.

The cost of charging time is affected by two factors. First, although India produces sufficient power to meet the demand, there is a problem in efficient transmission and distribution leading to power outages which can create difficulties for EV owners. Secondly, the fewer public charging stations in cities and along highways, make buyers hesitant to buy EVs.

Driving range: EV faces some frequent challenges when it comes to long distance travels such as : few battery charging stations at public places in the country, and longer charging duration when compared to fueling time for ICE vehicles. EVs also provide less mileage compared to ICEs.

Battery disposal: The lithium-ion batteries used in EVs contain toxic substances, such as manganese, nickel, lithium, and cobalt. With the expected growth in the number of EVs, proper infrastructure and procedures would be required for safe disposal of end-of-life batteries. Besides catering to the requirement of the EV sector, such battery disposal facilities would be useful for other electronic goods powered by lithium-ion batteries.

Solutions

1. Using different charging systems :

The EV charging systems can be classified according the mode of energy transfer such as the conductive and inductive charging system :

1. **Conductive charging :** This is the conventional way in which we charge batteries, that is using direct contact between the vehicle and the charger using the charging cables. This method of charging is very efficient.
2. **Inductive Charging:**
    1. Taking inspiration from wireless chargers used for smartphones, this methodology doesn’t require any physical contact or linkage between the vehicle and the charger. It makes use of electromagnetic induction principles.
    2. As opposed to conductive charging, this method's main disadvantages are its high cost, low efficiency and power density. However, it is convenient because we no longer have to worry about chargers and charging stations, and any vehicle, regardless of battery type, can be charged anywhere.

2. Locating appropriate EV charging stations(EVCS):

1. **Residential Charging Station :** This is the most important of all because it significantly reduces the load on the grid. Now charging an EV usually takes anywhere between 7-8 hours using a level 1 charger as it draws less current compared to the fast chargers. While charging the EV at night can further help decrease the cost and be beneficial for the grid.
2. **Parking Charging Station :** As charging an EV takes a long time, we can setup charging facilities in parking lots. This can significantly reduce the stress on public charging stations and the grid. According to a survey, vehicles are parked around 5 hours a day at the working place which serves as the most ideal location for this setup. This can be further extended to Shopping Malls, Restaurants, Drive Thrus, etc.
3. **Public Charging Station :** These stations would function similar to a traditional gas station using a fast charger, which could provide 200 miles on your car in just 15 minutes.

3. Grid overload

To ensure that the grid is not overloaded, various new kinds of technologies are introduced :

1. **Smart grid Technology:** It is used to track how much load is required based on the area. A communication path is established between the grid and used to accurately track the load according to the region. Using this method, we can identify in advance the load requirements, to help ensure that there are no issues at the generation end and the grid can distribute load properly.

2. **Vehicle to Grid Technology :** A bidirectional energy flow between the grid and the vehicles is possible. So, when not in use, the vehicle will provide energy back to the grid. This is known as a vehicle to grid (V2G) system. This method can serve to be very useful for reducing the grid load**.**
3. **Intelligent Transport System :** To make the system smarter, the Intelligent Transport System (ITS) is deployed. So basically using sensors and preprocessors we'll track the traffic congestion of particular areas and then set up one or more communication channels between the grid or parking stations. IoT(Internet of Things) can be used for controlling and monitoring in this method. It can also be used to determine the SOC of the EV battery, which can then be shared with the grid. People can pre-book parking spaces at parking garages, and the status of available spaces can also be displayed.

4. Charging Techniques

1. **Constant Current and Voltage:** in this method we use 4 modes to charge a battery depending on its state of charge
    1. Pre-Charge mode : battery is charged till 10% using full current.
    2. Constant Current mode : The battery is below 1C charge rate until it reaches 4.2V
    3. Constant Voltage mode : The battery is charged at constant voltage of 4.2V until it reaches 100% SOC(state of charge)
    4. **Charge termination mode** :The **minimum charge current method** is used to terminate the charge. We reduce the charge to about 0.02-0.07C, then the charge is terminated, so we basically kill off the current gradually rather than abruptly.
2. **Multistage Charging Scheme :**
    1. All of the other methods have the drawback of taking longer to charge. This method addresses that issue by using higher currents to charge the battery faster, but higher currents raise the temperature of the battery, so at a certain temperature, we must switch to normal charging, and once the temperature has reached a certain lower value, we can resume fast charging.

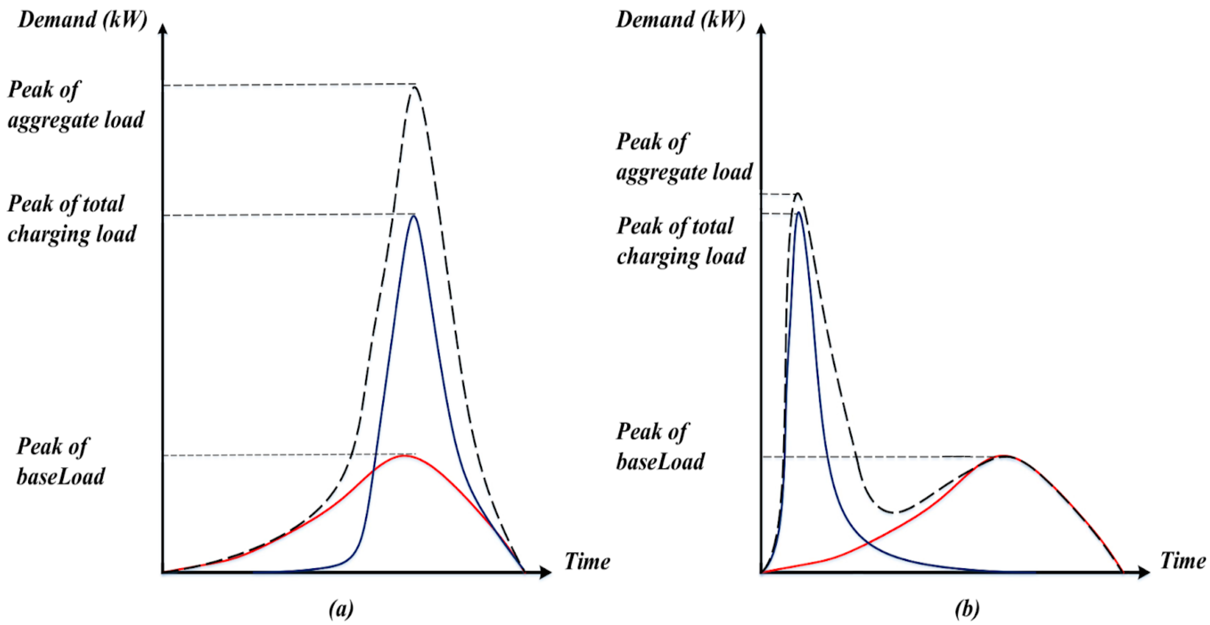
2. These upper and lower bounds are determined by examining the charging rate and SOC levels of the battery. This method is revolutionary in its own right because it charges the battery faster while preserving battery life.

5. **Peak Demand Charge and Electricity Bill :**

Commercial and industrial electricity rates, which primarily include a per KwH energy charge plus a per peak kW demand charge, are typically used to charge for electricity used by businesses. These demand charges are based on the maximum amount of power used in any interval (typically 15 minutes) during the month. These demand charges vary moderately by region and significantly by commercial facilities

We can rack up massive electricity bills if we charge commercial vehicles carelessly at any time of day. The demand charge increase is determined by whether the peak demand with the parking location's base load coincides with the peak demand of the total charging load of commercial vehicles.

As in fig(a), the peak demand of both the base load and the charging load coincide, significantly increasing the peak kW demand charge; however, in fig(b), by managing commercial vehicle charging, the peak of the base load is significantly separated from the peak of the charging load.

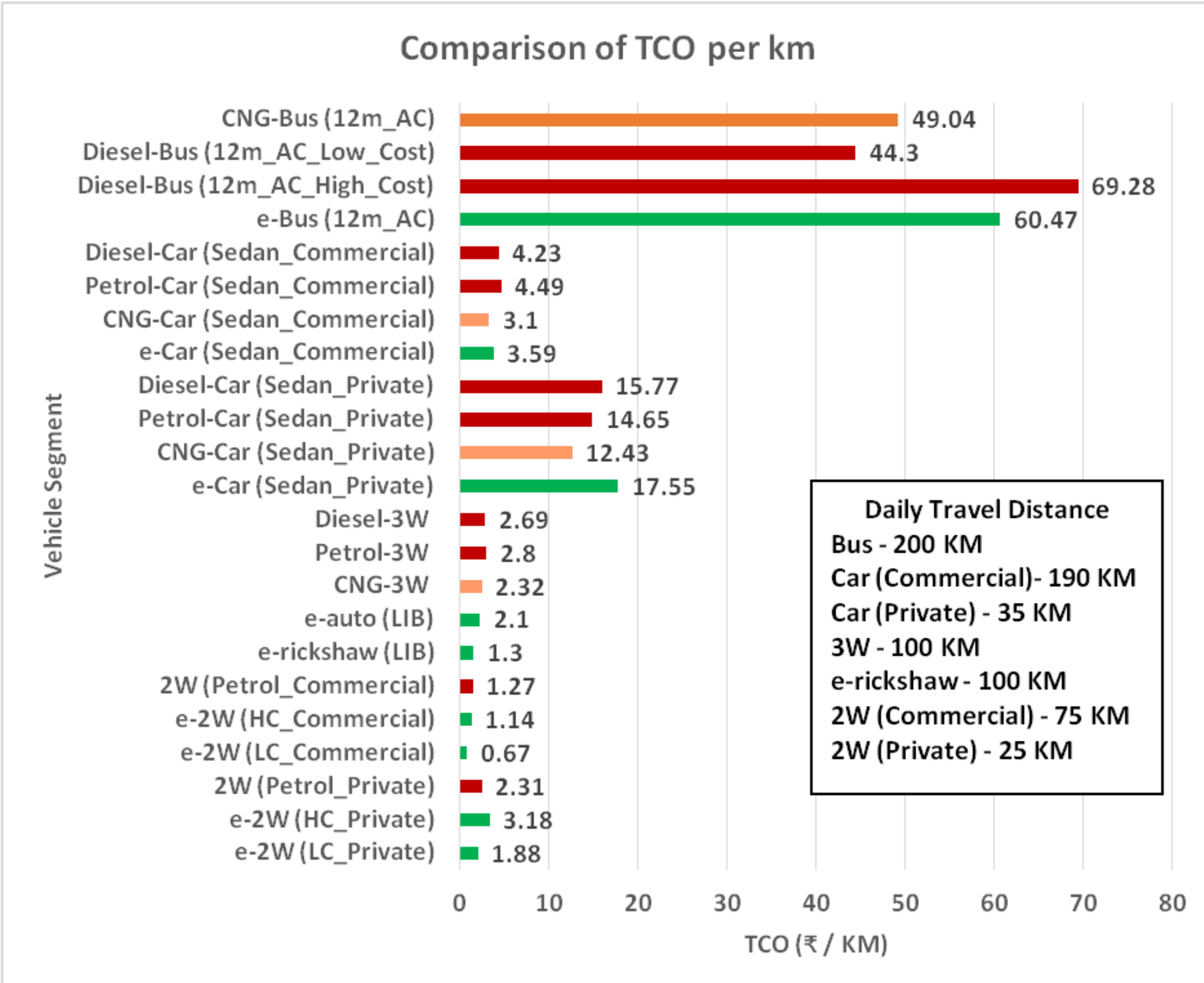


6. Creating Public Awareness:

The Indian government has launched a number of initiatives to increase public awareness. NITI Aayog, for example, developed and hosts the e-Amrit portal. This portal aims to be a one-stop site for all information on the adoption of electric vehicles in India.

7. Market and pricing issues:

As previously stated, EVs are typically more expensive than ICE vehicles.As previously stated, EVs are typically more expensive than ICE vehicles.. When we look at a vehicle's total cost of ownership (TCO), which is the amount of money we will spend on the vehicle in the next say 5 years in maintenance, fuel, repair, and so on, we can see the true picture, and many surveys have concluded that the running cost of EVs is far less than that of ICE.



The above graph shows that, when compared on a per-kilometer basis, petrol and diesel vehicles are significantly more expensive than EVs.

Addressing the Driving Range problem :

The Electric 2W and 3W vehicle segments are already economically competitive. In this segment EV’s are more economical than their ICE counterparts. For commercial use cases, with an assumed daily utilization of 75 to 100km for 2W, 3W respectively, all electric models considered have lower TCO per km as compared to ICE vehicles.

On a financial Level Electric cars still require financial incentives to be considered economically viable.

In order to reach the economic targets we have set for commercial electric vehicles, a high utilization rate is required. For long-term capital investment decisions to be future-proof, the public transportation bus fleets must be electrified.

Results

So theoretically speaking we have a lot of available solutions like what types of charging stations we need, charging scheme, charging systems, grid technologies, etc to solve the so called challenges we discussed. Is it feasible to argue that all of the solutions are viable?

In practice, this is the repertoire we would require if we were to transition to an all-electric automobile industry on a large scale. However, given the current situation in India and people's attitudes, our primary focus should be on raising awareness among the masses to shift to EVs, for which the government has launched the unpopular e-Amrit portal, and exploring options such as smart parking lots, using IoT to manage the load on the grid, and so on. Once a significant portion of the population has adopted EVs, inductive charging methods could be implemented, making them economically viable. But first, people would need a lot of incentives to buy EVs, such as tax breaks or the government covering a portion of the cost, etc.

We must also use renewable energy to generate electricity in order to meet the increasing demand for electricity once the majority of the population switches to EVs. Solar Energy, Wind Energy, and Hydro Energy may be the most advantageous to us.

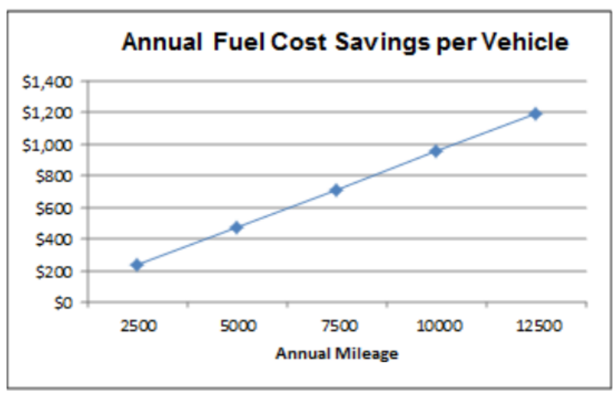
Case Studies

1) **Durham- Introducing electric vehicles to combat pollution**
In **2007 Durham** adopted a joint City-County Greenhouse Gas and Criteria Air Pollutant Action Plan. This Action Plan was mainly aimed to achieve a **reduction in government emissions by 50% and community emissions by 30%** in the time frame of 2005 to 2030.
This action plan was mainly focussed at the transportation sector, it being the largest source of emissions. To help achieve these goals, both the City and County governments adopted an Electric Vehicle and Charging Station Plan in 2011 and launched a pilot project to evaluate all-electric LDVs(Light Duty Vehicle). Though reduced emissions were the primary reason for implementing the pilot project, it was seen that electric vehicles (EVs) reduced operating and maintenance costs compared to conventional fuel run vehicles.

Main features of this program:

- The electric vehicle were to be based in a location that could accommodate installation of charging infrastructure
- The vehicle were used by multiple employees, to increase exposure and familiarization
- The vehicle application were visible to the public, to increase community awareness of EVs in use

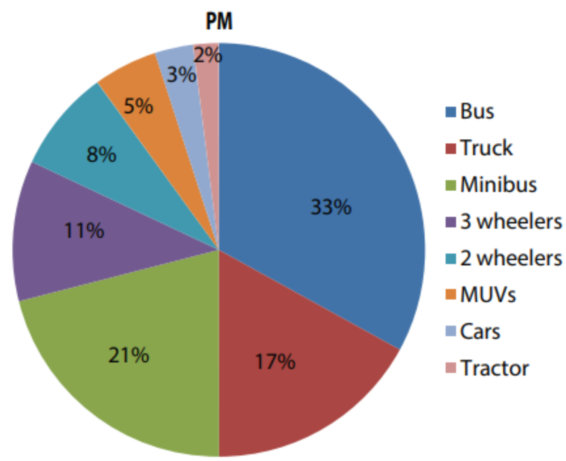
Results:



- The primary purpose for Durham's LEAF purchases was emissions reductions, and the Argonne National Lab fleet emissions calculator, AFLEET, predicts that all-electric light duty vehicles used in North Carolina **reduce greenhouse gas (GHG) emissions by 50%** or more. Total emissions of nitrogen oxides within the state increase somewhat based on North Carolina's current electricity generation profile, however overall NOx emissions are reduced when emissions from production and refining of gasoline are factored in. **Total emissions of particulate matter (PM10 and PM2.5), carbon monoxide (CO), and volatile organic compounds (VOCs) are virtually eliminated**.

- It was also observed that the **return to the investment increased in 2013 due to the drop in EV purchase prices in 2013.**

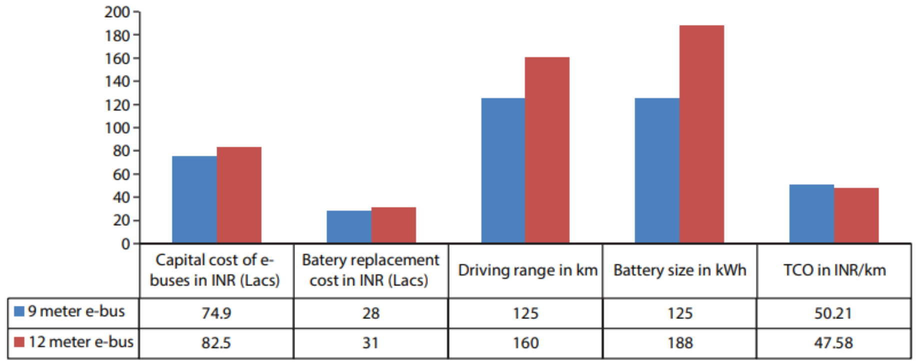
2) Electric Buses- Study of Kolkata



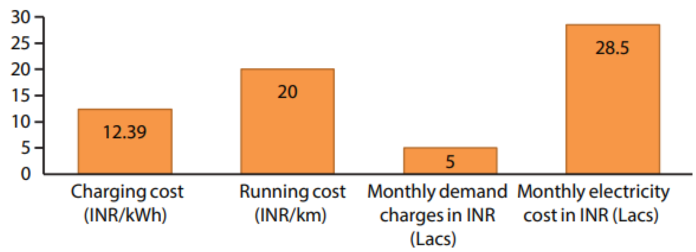
Kolkata has recorded the highest amount of particulate matter (PM) and NOx emissions per 0.1 million of vehicular population despite having lesser number of on-road vehicles as compared to other metropolitan cities in the country. This is primarily due to the operation of fleets of older vehicles. The contribution of different vehicle categories to total air pollution from the transport sector, shown in terms of PM emissions, is presented in the figure. The conventional diesel-based transport buses are observed to be the major contributors to air pollution (caused by PM, hydrocarbons and gasses like, CO2 , CO, SO2 & NOX) with 33% contribution to particulate matter emissions.

Aiming to reduce vehicular air pollution, the Government of India (GoI) has taken various initiatives and electric mobility has been the prime focus. To support the implementation of the same, Phase-II of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME-II) was launched in 2019 which focuses mainly on promoting low-emission electric vehicles including providing support to vehicle charging infrastructure. Consequently, under the FAME-II initiative, an outlay of about INR 3,500 Crores has been earmarked for deployment of more than 7,000 electric buses across the country. The Government of West Bengal has already taken several policy measures to introduce electric mobility in the state , including a complete shift towards STU owned electric buses by 2030 . In the case of Kolkata, the Department of Transport, Government of West Bengal (GoWB), herein WBTC, has already introduced 80 electric buses under the Phase-I of the FAME scheme (FAME-I initiative), operating in and around the city starting with 20 buses since February 2019 to the recently procured lot of 10 buses, introduced in January 2020.
As of now, 5% of the total conventional bus fleet has gone electric in the city. The e-buses are operational under 12 different routes with an average distance traveled per route equal to 20 km.

The electric buses are of two configurations based on bus length: 9 m and 12 m. The 9 m long buses are having 125 kWh(driving range: 130Km) battery packs while the 12m variants have 188 kWh(driving range: 160Km) batteries. The capital costs of the 9 m and 12 m type e-buses are INR 74.9 lacs and INR 82.5 lacs respectively.



Behind the successful running of 80 e-buses in the city is a smartly planned charging station placement and operation scheme. The WBTC leveraged the existing bus depots and terminus points for putting up charging infrastructure that includes both slow chargers and fast chargers. The fast chargers have a power rating of 120 kW and generally take 1.5-2 hours to fully charge the e-buses while the slow chargers, which are rated at 60 kW, take 3-5 hours to charge the same capacity. The chargers comply with the GB/T(Guobiao standards) charging standard and the communication protocol followed in the standard transfers the essential parameters between charger and battery management system (BMS). The chargers (manufactured by Tellus Power based in China) are installed at both bus depots and terminus locations. The total development cost of charging infrastructure for 9 DCFCs (costing INR 14.86 lacs/charger) and 61 DCSCs (costing INR 9.02 lacs/charger) has been around INR 12 Crore (USD 120 million), including civil and electrical works. In-addition, the average per unit electricity cost to charge the e-buses comes out to be INR 11-12.39/kWh, whereas the monthly demand charges are INR 5 lacs.



Monthly electricity consumption and cost associated with charging and operation

The Government of West Bengal (GoWB) has principally decided not to induct any new diesel buses in the city of Kolkata, and only CNG-based and electric buses are to be procured from now onwards. Further, the plan is to have an entire city fleet of 5,000 e-buses by 2030 which is expected to reduce the cumulative CO2 emission by 7,82,560 tonnes, and in this view the government is ready with a plan of setting up 241 EV charging stations across the city under KMA8 .

Further Challenge:

Although 80 e-buses have been accommodated into the existing depots and the capex was not so huge due to the utilization of the existing assets, setting up new charging infrastructure for **additional e-buses remains a major challenge in terms of identifying the appropriate location along-side the number of chargers required in each station based on traffic density & travel pattern**. In-addition, frequent tripping of chargers and grid-synchronizations issues were observed to be a major concern during initial phases (up to 4-5 months) however these issues were rectified through software re-configurations. Therefore, it becomes important to validate the operation of chargers during the installation phase itself so that the aforementioned issues do not arise during the running phase. Regular monitoring of bus charging and impact on the local distribution network is being followed. Accordingly, it is essential to monitor and analyze the power quality parameters originating due to e-bus chargers on a regular interval (WBTC has been performing this on a quarterly basis) in-order to ensure proper functioning of the electrical network.
Since, the price for a bus under the Opex model of FAME-II is a bit on the higher side, therefore, it could be considered as one of the potent challenges to transitioning towards cleaner and low carbon public transport systems. Furthermore, **point to point charging facility/ infrastructure** is required to better utilize the routes, though it was not possible for every case due to infrastructural constraints. Nine terminus points were set-up in-order to provide an intermediate charging facility for the currently operating 80 electric buses. WBTC has also planned to use cleaner sources of energy (solar PV along with battery storage) at its existing e-buses depots to charge the e-buses which is expected to result in lower electricity cost for charging e-buses.

3) Electric buses in Shenzhen, China

Shenzhen has the world's first and largest fully electric bus and taxi fleets. Its electrification journey offers a valuable opportunity to understand the challenges and opportunities of transitioning to a completely new technology for public transit.

By the end of 2017, all urban buses in Shenzhen, around 17 thousand buses, were electrified. SZBG's fleet of 6,053 electric buses is composed of 4,964 heavy-duty and 1,089 medium-duty (shorter than 10 meters) buses. SZBG electrified its whole bus fleet from 2009 to 2017: a demonstration stage in 2009-2011, followed by small pilots from 2012-2015, and a large-scale electrification from 2016-2017.

BUSES:
Aiming for large-scale adoption in a very short time, SZBG decided to choose a model that would require minimal changes to the current bus routes and scheduling. Shenzhen stuck to a single, proven vehicle technology – electric buses with a large battery – to achieve the daily mileage its operation requires.

CHARGING:
Charging. By June 2019, SZBG had 1707 charging terminals at 104 stations (mostly at bus terminals and depots). The charging facilities are constructed and managed by nine operators. **A state-owned enterprise, Potevio and a private company Winline,** are the major two operators with a share of 35% and 33%, respectively. The majority of the charging terminals are equipped with 150kw (50%) and 180kw (19%) DC fast chargers. The number of charging terminals, charging plugs and power of the charging terminals were decided based on the location of the charging station, number of buses to be served, space requirements and other factors. Overall, there is one charger for every five buses, while the targeted charger-bus ratio is 1:4. In 2016, SZBG piloted the 'network charging concept' with a compact design of one charging terminal having several charging plugs/chargers so that up to four buses can charge at the same time. Although this way takes a longer time to charge, the advantage of this arrangement is that it significantly reduced the need to move buses at nighttime, which saves labor cost. A more flexible charging concept was later introduced with the charging terminal adjusting the power output of each charger to maximize efficiency.

IMPACTS:

Impacts on bus operations:

At early stages, e-buses were only used on specific routes with shorter operating distance, making bus operations less flexible. Through improvements in technology and operational planning that balances the charging schedule to ensure that the route frequency is not affected, e-buses are now used on all routes.

Impact on local air pollution and GHG emissions:

A comparative analysis of emissions for e-buses operated by SZBG showed a significant reduction in

Table 2 GHG emission per 100 kilometers of one diesel and one electric bus (gCO2)

Stage	Diesel	Electric bus	Emission reduction after bus electrification (gCO_2/100 km)
Use phase	85529.50	0	85529.50
Fuel production	23573.60	47838.42	-24264.80
Battery production	Not applicable	9388.64	-9388.64
Total	**109,103.10**	**57227.06**	**51876.04**

both local air pollutants and GHG emissions as indicated in ***table 2 and 3***. The electric buses of SZBG save on average 194,000 tons of carbon dioxide annually, using the total annual bus operation mileage of 374.11 million kilometers in 2018.

Table 3 Comparison of emission of 100 kilometers for one diesel and one electric bus (g)

Pollutant	Diesel bus[a]	Electric bus[b]	Emission reduction after bus electrification
CO	116.80	/	116.80
NO_x	568.00	10.81	557.19
VOC	5.80	/	5.80
$PM_{2.5}$	11.00	/	11.00
PM_{10}	17.64	/	17.64
SO_2	2.50	11.38	-8.88

Impact on electricity grid.

The rapid roll out of electric buses from 2016 to 2018, required the acquisition of land for charging stations which is challenging in a large and densely populated city like Shenzhen, since there is no planned land area left for this purpose. The electricity capacity for each zone is also previously set. As the electricity consumption of a charging station adds new localized demand, the utility has to install transformers and electricity lines to allow for a capacity increase in the zone.

Impact on bus users.

For bus users according to a regular satisfaction survey, comfortability was rated highest, followed by safety and affordability. This is mainly due to the smoother and quieter ride with an electric engine, compared to diesel buses

Conclusion

The major lesson learnt from this case is the importance of creating a collaborative environment for transitioning to a new system. The partnership among bus operators, bus manufacturers, financial organizations and charging companies significantly alleviated the technology uncertainty and spread the cost burden. By working closely with government agencies, SZBG was able to be on top of policy developments and lobby for favorable support. Besides government and industry partners, SZBG also worked closely with private enterprises and nonprofit organizations including Huawei, Didi and the International Association of Public Transport (UITP) to pilot innovations including intelligent dispatch system, on-demand bus services, and autonomous driving technologies.

Conclusion:

In this paper, we primarily attempted to assess the commercial viability of electric vehicles in the Indian context. Despite the fact that India trails more developed countries like China and the United States in the race to electrify automobiles, the Indian government has taken several significant steps in recent years with the collaboration of various state governments.

The Indian government's vision of 100% electric mobility is a positive step toward reducing emissions from the transportation sector. However, proper governance and commoners' perceptions will be critical in determining the success of this magnificent transformation.

According to the findings of the pilot project, EVs have higher operating costs than equivalent ICE vehicles. As a result, a fleet operator's profit from an EV is the lowest. This is because the longer charging process wait time reduces operational hours and, as a result, profit generated.

The cost of an EV battery is higher than the cost of an ICE vehicle engine due to limited lithium metal resources and the high cost of imports from other countries. The higher initial investment in an EV is completely offset by the lower operating costs, which are less than half of those of an ICE vehicle.

In India, the current population of electric passenger vehicles (4-wheelers) is 0.1 million, which pales in comparison to the population of ICE vehicles, which is approximately 30 million. The total number of charging outlets required to provide charging infrastructure based on the actual time for which vehicles are charged is 75,832.

Furthermore, 42 fast charging dispensers are required for every 1000 e-vehicles. As a result, in order to achieve the goal of 100% e mobility by 2030, India will need to invest heavily in charging infrastructure.

We can learn from Shenzhen, China, about how they successfully electrified all commercial vehicles despite having a population density comparable to that of many Indian states.

Motivation and learning should also be drawn from the case of Kolkata, where the collaboration of the state and central governments aided in taking a large and significant first step in the electrification process by focusing on the Buses (the most common public transport system in the country). It exemplifies how fostering a collaborative environment among bus operators, bus manufacturers, financial institutions, and charging companies can significantly reduce technological uncertainty and spread the cost burden.

References

1. https://e-amrit.niti.gov.in/benefits-of-electric-vehicles
2. https://www.outlookindia.com/business/top-5-reasons-why-electric-vehicles-are-the-future-of-driving-in-2022-news-201722
3. https://www.marketsandmarkets.com/Market-Reports/electric-commercial-vehicle-market-16430819.html
4. https://evautocars.blog/2017/05/18/electric-vehicle-history-india/
5. https://www.thebetterindia.com/280360/ev-in-india-leading-state-policy-for-electric-vehicles-delhi-karnataka-maharashtra/
6. https://blog.evbox.com/electric-cars-history
7. https://e-vehicleinfo.com/government-policies-and-incentives-for-electric-vehicles-in-india/
8. https://github.com/arnav39/IIMB-Whitepaper-Competition/blob/main/Electric_Vehicle_Charging_Station_Challenges_and_Opportunities_A_Future_Perspective.pdf
9. https://github.com/arnav39/IIMB-Whitepaper-Competition/blob/main/fmech-08-896547.pdf
10. https://github.com/arnav39/IIMB-Whitepaper-Competition/blob/main/Charging_Infrastructure_for_Commercial_Electric_Vehicles_Challenges_and_Future_Works.pdf
11. https://www.sciencedirect.com/science/article/pii/S0973082621001502
12. https://www.drishtiias.com/daily-news-editorials/electric-vehicles-india-s-future
13. https://nccleantech.ncsu.edu/wp-content/uploads/2018/06/Possible-Followup-Project-2012-Toolkit-PEV-Case-Study.pdf
14. https://regridintegrationindia.org/wp-content/uploads/sites/14/2019/11/10C_4_RE_India19_125_paper_Sasidharan_Chandana.pdf
15. https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-TERI-Kolkata.pdf
16. https://iea.blob.core.windows.net/assets/db408b53-276c-47d6-8b05-52e53b1208e1/e-bus-case-study-Shenzhen.pdf
17. Commercial viability of electric vehicles in India