Review Study On Electric Vehicles, Its Battery Charging Systems, Charging Stations, And Standards In Indian Context

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***Abstract*—For the sake of economic and environmental benefits the emerging technology in the fields of transportation and power sector are Electric vehicles (EVs). To overcome the effects of global warming apart from other technologies, EVs are a necessity and realistic solution. This comprehensive review study presents an evaluation of various types of electric vehicles, accessories and equipment particularly types of battery, motors, battery chargers and charging stations. The development of EVs and hybrid EVs (HEVs) are taking place in acceleration, so commercially viable EV/HEVs becoming a reality. The different charging station and standards for charging the Electric vehicles and the effect of charging of EVs on power plants will be discussed. The USA and China promoted replacement of fossil fuel propelled vehicles by EVs. Indian government is also appetent to introduce the EVs to Indian market and keep in pace with the development of EVs globally. The transport sector of world major economies trying to reduce emission of Green House Gases (GHGs). Out of 20 most polluted cities in the world 15 cities are in India. India pledging to cut down its share of GHGs globally.**

Keywords—Electric Vehicles, Hybrid EVs, Motors, Batteries, Battery charging techniques, Standards, charging station, Green House Gases.

NTRODUCTION

Due to increase in number of internal combustion engine propelled automobiles associated with environmental pollution problems, the demand of fossil-based fuels in the international market has increased. That's why electric and hybrid vehicles has grown with the increased interest for research and development of its batteries, chargers, and charging stations. These vehicles propose solution for future road transportation with interest in reducing GHGs and sound pollution. [5,6]

In recent years, many existing automobile manufacturers and new dedicated companies have put a remarkable effort in transforming the conventional vehicle into an electric vehicle that provide green and reliable solution. In terms of market share, electric vehicle demand is rising. [9]

Electric vehicles are based on electric propulsion system and no internal combustion engine is used. All the power is based on electric power as the energy source [3]. Electric vehicle is powered by one or more electric motors, using rechargeable batteries which stores electrical energy in it [17]. Batteries started as converts of stored chemical energy into electrical energy, which produce electric current to perform work [10]. Electric vehicles are about four times as efficient as vehicles with an internal combustion engine.

This study presents the state of the art of electric vehicle Technology focusing on the types of electric vehicle ,types of motor, types of battery, types of battery chargers, charging stations, charging techniques and different standard that are being used in USA, Europe and Japan[8].

TYPES OF ELECTRIC VEHICLES

An Electric vehicle can be broadly categorised into [9]-

1. **Battery electric vehicle-** The battery electric vehicles uses high capacity batteries and electric motor for propulsion. It derives all the power from its battery pack and has no internal combustion engine, neither fuel cell nor fuel tank (Fig1).
2. **Hybrid electric vehicle-** The international technical committee define Hybrid electric vehicle as "Vehicle utilizing two or more energy source or storage such that at least one provides electrical energy. The Hybrid electric vehicle that uses mechanically a combination of electric motor and a conventional internal combustion engine. HEVs could be further classified into four types based on drivetrain structure(Fig2):
   - Series hybrid
   - Parallel hybrid
   - Series parallel hybrid
   - Complex hybrid

2.1 Plug-in hybrid electric vehicle- Plug-in hybrids were developed to increase the range of Hybrid electric vehicles. Plug-in Hybrid electric vehicles utilize an electric motor and a battery that could be charged via the power grid. The battery is also supported by an internal combustion engine that can be recharged when the vehicle is running on a low battery.

3. Range extended electric vehicle - The main third type is the Extended Range Electric Vehicles (EREV or REEV); in this structure (Fig3), vehicle propulsion is driven only by an electric motor powered by high capacity batteries. These batteries are maintained charged by a small engine generator unit. Its small consumption, less than two litters of fuel at 100km, offers an extended range of autonomy and distance to be reached. The latest REEV introduced to the market this year are the all-new 2014 Cadillac ELR, the AUDI A1 e-Torn and Jaguar's Limo-Green series

4. Fuel cell electric vehicle - Fuel cell electric vehicles has been introduced to perform long distance. It uses a fuel cell system to power it's on board electric motor. A fuel cell has properties of both a battery and an internal combustion engine, it generates electricity from an electrochemical reaction like a battery. In addition, fuel cells are being developed for buses, boats, motorcycles and many other kinds of vehicles (Fig4).

5. Solar electric vehicles -Solar electric vehicle is an electric vehicle powered importantly or completely by direct solar energy. Through solar array installed on the top of the vehicle. Often photovoltaic cells, solar energy is converted directly into electrical energy. Since converted solar energy is the only source, it powers all the parts of solar electric vehicle propulsion, electronic communication, navigation, security and other auxiliary features (Fig5).

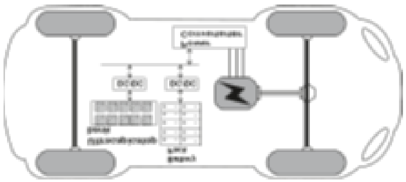

Fig. (1) Battery electric vehicle

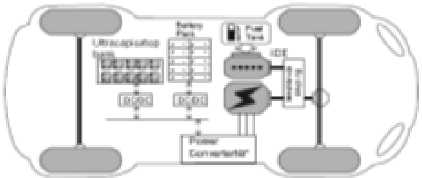

Fig. (2) Hybrid electric vehicle

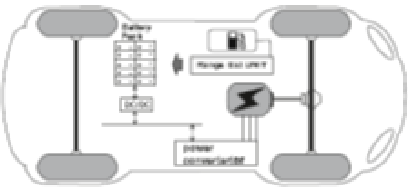

Fig. (3) Range extend electric vehicle

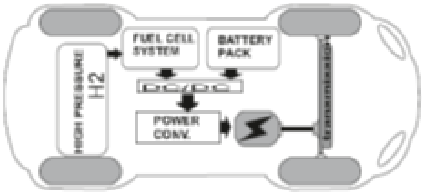

Fig. (4) Fuel cell electric vehicle

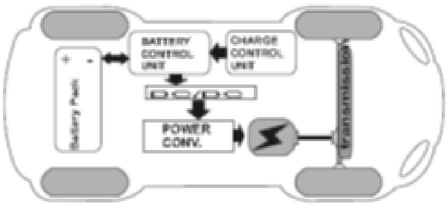

Fig. (5) Solar electric vehicle

Table (1) Comparison among Internal Combustion Engine, Hybrid and EVs [4]

Parameters	ICE Vehicles	Hybrid Vehicles	Electric Vehicles
Efficiency	Converts 20% of the energy stored in gasoline to power the vehicle	Converts 40% of the energy stored in gasoline to power the vehicle	Converts 75% of the chemical energy from the batteries to power the vehicle.
Speed (Average Top Speed)	199.5 km per hour (kmph)	177 km per hour (kmph)	48-153 km per hour (kmph)
Acceleration (average)	0-96.5 kmph in 8.4 seconds	0-96.5 kmph in 6-7 seconds	0-96.5 kmph in 4-6 seconds
Maintenance	High maintenance owing to more number of moving parts	Same as an ICE vehicle	Maintenance is minimal due to lesser number of moving parts.
Mileage (average)	Can go over 480-500 kms before refuelling. Typically achieves 10-12 kmpl	Typical achieves 20-25 kmpl	Can travel 120-200 kms before recharging.
Cost (average)	INR 0.7-1.1 million	INR 1.2-2 million	INR 0.9-6 million

THE KEY COMPONENTS IN ELECTRIC VEHICLE

The electric vehicles are simple in structure. Fig shows the configuration. The key components are the propulsion parts. The battery is the main energy storage. The battery charger is to convert the electricity from mains to charge the battery [2]. The battery voltage is DC and current is inverted into switched-mode signal through power electronic inverter to drive the motor. The other electronic components in an electric vehicle can be equipped to the battery through DC-DC converter that step down the voltage from the battery pack to lower voltage such as 5V-20V.

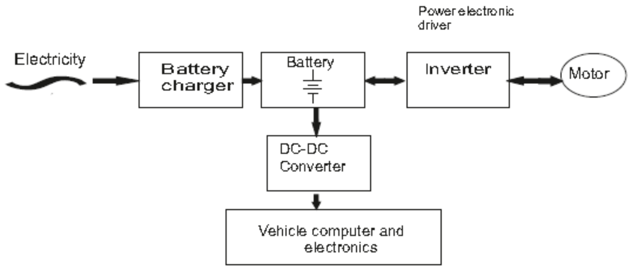

Fig. (6) The key component of an electric vehicle

TYPES OF ELECTRIC MOTORS

The electric motors convert the electrical power to mechanical power and drive the EVs. The electric motors also help in regenerative braking where the electric motor acts as generator and converts the mechanical energy into electrical energy. There are many types of electric motors and they classified as follows [18]:

a) Brushed DC motor:

The stator of these motors made up of permanent magnets. The rotor consists of brushes, which provides supply to stator. At low speed, they have the ability to provide maximum torque, which is very much desirable. However, the disadvantage with these motors are that they are very bulky and operate under very low efficiency. Hence, they are usually not preferred in EVs.

b) Permanent Magnet Brushless DC Motor (BLDC):

These motors are smaller and light in weight. They have improved heat dissipation and carry higher specific power. There are no rotor copper loss associated with them. However, the cost of permanent magnet is high.

c) Permanent Magnet Synchronous Motor (PMSM):

These motors do not employ any gear system and have a wide operating speed range. They are efficient and very compact; the disadvantage is that they carry huge iron loss at high speeds.

d) Switched Reluctance Motor (SRM):

These motors are relatively simple and robust in construction. They are small and operate at high speeds. The disadvantages are that they are very noisy and operate at low power factor. The PM machines are also heavier and costlier.

e) Induction Motor (IM):

They have matured commentator less motor drive system technologies and operated like a separately excited DC motor. India should encourage the indigenous manufacturing of motors. The kind of design needed for designing of motors for Indian road conditions is quite different from those of other countries. The average speed of vehicles in India is 25 Km/hr. as opposed to 45 Km/hr. in the western countries. Hence, it is important that the motors developed should have their peak efficiency at 25 Km/hr. This will help in power savings. Importing of motors for Indian EVs will increase the price of EVs and they are not assuring of working efficiently for Indian road conditions.

DIFFERENT TYPES OF BATTERIS FOR EVs

Battery powered electric vehicles has started to play a significant role in today's Automotive Industries. There are many types of batteries found in the construction of today's electric vehicles [15,16]

- Lithium-sulphur (Li-S)
- Molten Salt (Na-NiCl2)
- Lead Acid (Pb)
- Nickel Metal Hydride (Ni-MH)
- Lithium Ion (Li-Ion)
- ***Lithium Sulphur (Li-S)*** – The Li-S battery has showed a lot of interest from researchers mostly due to increased theoretical specific energy, among its theoretical specific capacity. Thus, being considered a strong competitor for the technology used to day, representing a viable solution in the development of future electric vehicles. At the moment due to reduced lifespan and energy retention capacity the use of this battery type is limited.
- **Molten Salt (Na-NiCl2) -** Na-NiCl2 batteries, also known as ZEBRA batteries, (Zeolite Battery Research Africa) were used for equipping some concept cars and buses used in urban public transportation. These types of batteries are remarkable especially for their increased energy density (90 . 120 WH/kg), and also due to lower price, compared with other existing technologies. Other advantages are: overcharge and over discharge resistance, increased cycle life, and constructive robustness, which permits their utilization in harsh environments, their performances not being affected by low temperatures.

The big downsize of the Na-NiCl2 batteries it's represented by increased internal operating temperatures in contrast, 12 to 15 hours are needed in order to defrost the battery and to bring it back to its functional parameters.

That is why, it is necessary to have one external system which maintain the battery's operating temperature under functional parameters.

- **Lead Acid (Pb)** - Lead-acid batteries have a long shelf life, are inexpensive, reliable, easily recyclable, and are safe when properly handled and maintained. The lead-acid battery provides the functions of starting, lighting, and igniting the vehicles ICE, cabin, and lighting systems. These batteries employ lead oxide as positive active material; spongy lead as negative active element and sulphuric acid used as the electrolyte medium. The advantaged of lead-acid batteries are that are very commonly available and cost very less. The technology has been around fifty years and has matured now. The disadvantages are that they have a limited life cycle and low power density. They also weigh heavier. One of the greatest limitations of the lead-acid battery is its considerably poor specific energy compared to modern technologies and also, they have a limited life cycle and low power density.

- **Nickel Metal Hydride (Ni-MH)** - At the beginning of 2000, Ni-MH batteries represented the most advanced technology used in hybrid and electric vehicles. Ni-MH batteries were used to supply energy to the electric motor because they offered a higher specific energy than lead-acid batteries and had a much better energy density as compared to a lead-acid battery. NiMH batteries are also highly reliable, and safe similar to lead-acid batteries. These batteries caries Nickel Hydroxide as positive electrode and Titanium or nickel as negative electrode. The electrolyte solution is alkaline solution. The disadvantages of Ni-MH batteries are increased weight and obsolete technology.
- ***Lithium Ion (Li-Ion)*** - The next step in the progression of battery technology and its implementation with relation to HEVs, and battery electric vehicles (BEVs or EVs) was the lithium-ion battery. Lithium Ion batteries are nowdays representig the most used technology in EV's. Nowadays, Li-ion batteries have the biggest market segment in equipping electric vehicles. Moderate energy consumption, continuous decline of the cost price, advanced manufacturing technology, increased cycle life, low weight and high energy storage potential make Li-Ion batteries an optimal choice in this field. These features also explain why lithium ion batteries are already widely used for consumer electronics such as cell phones, laptop computers, digital cameras/video cameras, and portable audio/game players. Other advantages of lithium ion batteries compared to lead acid and nickel metal hydride batteries include high energy efficiency, no memory effect, and relatively long-life cycle.

The disadvantage of Li-Ion batteries is represented by high developed operational temperature, which could affect energetic performances, along with lifetime and safety in exploitation.

TYPES OF CHARGING SYSTEM

I. **An Alternating Current and an on-board charger (Normal Charging)** - In this system of charging, the vehicle is plugged into an AC source (normal 16 A socket- household charging) from which alternating current is transmitted to an on-board charger. The function of the charger is to convert AC to DC and deliver the resulting current to the Li-ion battery. Hence it takes 6-8 hours (in Indian context) to fully charge an e-vehicle [9].

II. **A Direct Current and an off-board charger (Fast Charging)** - This system of charging involves an off-board charger or a fast charging equipment which directly converts AC supplied from the grid to DC for the battery use. The fast charging system takes around 90-110 minutes (Indian context) to fully charge an e-vehicle. This system of charging requires increased initial investment and is a costlier system of charging [9].

III. **Wireless charging system**- This system of charging makes use of coupled magnetic field to transmit power without any physical connection. There are three types of wireless charging techniques [1] by using the principle of electromagnetic induction, electromagnetic resonance and high frequency radio waves to transmit power.

IV. **Battery management system**-It is also referred as BMS. The battery system is formed by a number of battery cells. They are connected in parallel or series that is according to the design. Each of the cell should be monitoring and regulated. The conditioning monitoring includes the voltage, current and temperature. The measured parameters are used to provide the decision parameter for the system control and protection [3].

TYPES OF CHARGING TECHNIQUES

Mainly three charging techniques are available [2].

- **Conductive charging** - This is a direct electrical connection (typically through an insulated wire/cord set) between the source and the charging circuitry. The circuitry and its controls may be housed within the vehicle or external to it. All new EVs are compatible with this approved standard. It is popular, simple in design, higher efficiency.
- **Inductive charging** - No wiring is required; instead the energy is transferred between the charger and the "Paddle" inside the vehicle's inlet via a magnetic field generated by a high AC current. Inductive charging is still expensive and complicated to set up for end user. The main advantage of inductive type EV battery charger is electrical safety under all weather conditions. However, its disadvantages are long charging time and relatively poor efficiency.
- **Batteries swapping** - Instead of recharging EVs from electrical socket, batteries could be mechanically replaced in a couple of minutes in some special stations. Here battery size and geometry should be standardized in order to relay on Battery swapping technique.

TYPES OF CHARGING STATION

- EV charging stations when categorised in terms of voltage rating, power rating and place of application, can be classified into three different types of charging stations, namely, [8]
- Domestic charger at residential area,
- Off-street and robust charger at commercial and office area,
- Rapid charger at strategic location.

However, a charging station may be required due to the following reasons:

1. Charging can be provided for multiple EV owners at one time,
2. The facility may have additional current or connection sensing mechanisms to disconnect power when the EV is not actually charging,

Readily provide option for suppliers to monitor or charge for the electricity actually consumed.

Table 2 : IEC EV charging modes based on IEC61851-1[8]

Mode	Supply	Duration	Charger configuration	Example charger
Mode 1	AC	Slow	Standard household-type connector	1 – or 3-phase plug
Mode 2	AC	Slow	Standard household-type socket-outlet with an in-cable protection device	the Park and Charge or the PARVE systems
Mode 3	AC	Slow/Fast	Specific EV socket-outlet and plug with control and protection function permanently installed	SAEJ1772 and IEC 62196
Mode 4	DC	Fast	External charger	CHAdeMO

Table 3 : Levels of EV charging according to SAE[8]

Source	Level	Voltage	Phase	Max current	Max power (kW)	Time (h)
AC	Level 1	120	Single	16	1.9	6 – 24
	Level 2	240	Single	80 (typical 40)	19.2	2 – 8
	Level 3	TBD	TBD	TBD	TBD	THD
DC	Level 1	200-450	DC	<= 80	<= 19.2	□ 20
	Level 2	200-450	DC	200	90	□ 15 min
	Level 3	TBD (may cover 200-600)	DC	TBD (may cover up to 400)	TBD (may cover up to 240)	TBD

TBD-to be defined

Table 4 : Types of coupler for EV charging[8]

Type	Coupler	Example
Type 1	Single-phase vehicle coupler (vehicle connector and inlet)	Yazaki or SAEJ1772-2009 (Japan, North America)
Type 2	Single- and three-phase vehicle coupler and mains plug and socket-outlet without shutters	VDE-AR-E-2623-2-2
Type 3	Single- and three-p phase vehicle coupler and mains plug and socket-outlet with shutters	SCAME plug developed by the EV Plug Alliance

Society of Automotive Engineers (SAE) and International Electro technical Commission (IEC) both have come up with standards which define EV charging. The term 'level' used by SAE and 'mode' used by IEC essentially means the same thing. According to IEC 61851-1, there are 4 modes for charging EVs as described in Table 2. However, SAE defines 6 levels of EV charging as shown in Table 3. Some information in the table is still to be defined (TBD) by the standard[8].

From Table 2, essentially 'Level 3' does not exist yet and the charging standard everybody has been thinking of as 'Level 3' is really either 'DC Level 1' or 'DC Level 2'.

STANDARD FOR EV CHARGING STATIONS

Different type of standard is being used in different region of the globe for charging of EV. This section is comparing different standard that are being used in USA, Europe and Japan. Standards that have been published are described as follows [8]:

- **IEC 61851(IEC, 2010):** The IEC 61851 standard covers the overall EV conductive charging systems. In this standard, the IEC defines the four modes of EV charging that has been described above. This standard became the basis for IEC 62196. A few important sections in IEC 61851 are:

IEC 61851-1: This standard defines three cables and plug setups which can be used to charge EVs:

Case A: Where the cable is permanently attached to the EV

Case B: Where the cable is not permanently attached to anything

Case C: Where the cable is permanently attached to the charging station.

IEC 61851-23: This standard defines the requirements for DC fast charging stations in terms of electrical safety, harmonics, grid connections and communication architecture. The standard is expected to be published in November 2012.

IEC 61851-24: This standard defines digital communication for DC charging control between the charging controller in the EV and the charging controller in the Electric Vehicle Supply Equipment. The standard is expected to be published in September 2013.

- **IEC 62196-Plugs, socket-outlets, vehicle connectors and vehicle inlets (IEC, 2011):** The IEC 62196 is the latest standard for EVs by IEC which is based on the IEC 61851 standard. A few important sections in IEC 62196 are:

IEC 62196-1: This standard is entitled 'Plugs, socket outlets, vehicle couplers and vehicle inlets. This standard contains the general requirements for EV connectors

IEC 62196-2: It standardizes three types of mains connecting systems, known as Types 1, 2 and 3 that are applied only to modes 1, 2 and 3. Which of these is appropriate depends largely upon the electrical infrastructure and regulatory conditions in each country.

IEC 62196-3: This standard defines connectors and inlets for fast DC charging to be used with mode 4 charging according to IEC 61851-1. The standard is expected to be published in December 2013.

- **IEC 60309-Plugs, socket-outlets and couplers for industrial purposes (IEC, 2012):** IEC 60309, formerly known as IEC 309 is an international standard from the IEC for 'plugs, socket-outlets and couplers for industrial purposes'. The maximum limits under this standard include; voltage 690V AC or DC, current 125A, frequency 500 Hz and temperature range -25 to 40oC. The two parts of IEC 60309 are:

IEC 60309-1: General requirements and

IEC 60309-2: Dimensional requirements.

- **IEC 60364-electrical installations for buildings (IEC, 2005):** IEC 60364 'Electrical Installations for Buildings' is the standard on electrical installations of buildings. This is the standard attempting to harmonize national wiring standards in one IEC standard. The latest versions of many European wiring regulations (e.g., BS 7671 in the UK) follow the section structure of IEC 60364 very closely, but contain additional language to cater for historic national practice and to simplify field use and determination of compliance by electrical tradesmen and inspectors. National codes and site guides are meant to attain the common objectives of IEC 60364 and provide rules in a form that allows for guidance of persons installing and inspecting electrical systems. The standard has several parts described as:

Part 1: Fundamental principles, assessment of general characteristics, definitions

Part 4: Protection for safety (including sections on electric shock, thermal effects, over current, voltage disturbances and electromagnetic disturbances)

Part 5: Selection and erection of electrical equipment (including sections on common rules, wiring systems, isolation, switching and control, ear thing and safety services)

Part 6: Verification

Part 7: Requirements for special installations or locations (for range of locations such as bathrooms, swimming pools, rooms/cabins, construction sites, caravans, external lighting, mobile units and others).

- **SAE J1772:** This SAE Recommended Practice covers the general physical, electrical, functional and performance requirements to facilitate conductive charging of EV/PHEV vehicles in North America (SAE International, 2013). This document defines a common EV/PHEV and supply equipment vehicle conductive charging method including operational requirements and the functional and dimensional requirement for the vehicle inlet and mating connector's J1772- 2009 is the most recent standard in use and maintained by the SAE.

Global Trend

According to the Paris climate agreement, which was introduced in December 2015 and Enforced in November 2016, 194 participating countries pledged to limit the global increase in average temperature below 20C in this century and further limit the temperature rise to 1.50C in the next century. China, USA and India being the top three countries with highest GHG emissions annually, account for almost 50% of world GHG emissions. Hence, in order to comply with the Paris agreement, the major economies of the world are gearing up their technologies and framework on how to reduce their GHG emissions and contribute to limiting the global average temperature rise. The transport sector, which alone contributes to 23% of global GHG emissions, has to deliver major cuts in emissions for countries to achieve their environmental goals [7]. The electrification of the transport sector will play a pivotal role in decarbonizing the energy system. Countries like USA, China and Norway have already placed huge bets on electric vehicle initiative. Apart from zero tailpipe emissions which is the case in full-electric driving vehicles, EVs also serve as clean alternative to the vehicles using Internal Combustion engine by helping to reduce pollution which arises from fuel combustion and noise from the moving parts. These vehicles can be especially relevant in urban areas and along major transportation axes. The Electric Vehicle Initiative (EVI) is a multi-government forum established in 2009 under Clean Energy Ministerial (CEM) which constantly works on policies and frameworks for accelerating the deployment of EVs worldwide. As of May 2017, EVI comprises of ten member countries- Canada, China, France, Germany, Japan, Netherlands, Norway, Sweden, UK, and USA. Countries like Korea and India also engaged themselves in EVI activities and in 2017 shared their data on electrification of road-transportation. The USA and China have the highest stock of e-vehicles in the world, together comprising of about 50% of the world stock. However, as of 2016, Norway has the highest EV market share in the automobile sales annually accounting for almost 28% of the total sales [14].

INDIAN SCENARIO

India is shifting gears- the fifth largest auto market in the world is readying for a stupendous transformation in order to achieve 100% e-mobility by 2030. As per projection of the Indian government, the transport sector's transformation is believed to cut the oil imports by approximately $60 billion and emission reduction by 37%. As per the Paris Climate agreement, India has pledged to bring down its share of GHG emissions by 2030. Out of 20 world's most polluted cities, 15 cities are in India suffering utter degradation over the years, and pollution from transport sector is one of the major causes for this. According to World Bank study, the health cost of ambient air pollution may run into billions of dollars for the country as a whole. In Delhi alone, it is estimated to be $100-400 million per year [1]**.** Apart from this, India imports 82% of its oil requirements, making world's sixth largest economy desperate for alternatives fossil fuels [17]. The nation is expected to spend up to $85 billion in 2018 on oil imports, according to Petroleum Ministry of India, of which automobile sector forms the bulk. National Electric Mobility Mission Plan (NEMMP) was launched in 2013 to provide with structured framework on adoption of electric vehicles with an estimated investment of INR 3 billion. After 3 years of relative inaction, India has made progress in adoption of EVs in the past 1-2 years. India plans to deploy 5-7 million e-vehicles by the year 2020 under the revised NEMMP 2020, released in August 2017. From 2016 India has been adding 25,000 EVs annually with a growth rate of 37.5%. Faster Adoption and Manufacturing of E-Vehicles in India (FAME), established in 2015, is aided by the Government of India and has the following objectives [12]:-

a. To achieve the targets set by NEMMP.
b. Strengthen the technological capabilities of EVS and its infrastructure through research and development.
c. Set up charging infrastructure for electric vehicles.
d. Spread field-studies and awareness to build the consumer confidence and scale up adoption.

CONCLUSION

Electric vehicles are best option to reduce air pollution and Green House Gases emission. By year 2030, EVs will arrive all over the world. This study outlines the different types of EVs, types of battery, types of motors, types of charging station, techniques, standards etc. In this paper also discussion about EVs as a solution for developing nations, which put the slump of Global Carbon Emission. In the upcoming years Electric bikes, e-rickshaws and electric buses are accepted by the public transportation. The major factor for growth of EVs is battery technology and charging time. For production of EVs and develop charging stations Indian government has to play a vigorous role to attract the investors. Some types of application must be developed for pre-booking battery charging for drivers to minimize the waiting time at the charging station. In India a big challenge for shifting the transportation sector from ICE to EVs. This requires a lot of planning, research and development. India must be focus on improving the energy efficiency of EVs and reduce the battery charging time.

REFERENCES

[1] Biswas, T. K., & Biswas, N. M. (1999). Electric vehicle: A natural option for India? IETE Technical Review (Institution of Electronics and Telecommunication Engineers, India), 16(3–4),] 367–373.
https://doi.org/10.1080/02564602.1999.11416852

[2] Hyunjae Yoo; Seung-Ki Sul; Yongho Park; Jongchan Jeong, "System Integration and Power-Flow Management for a Series Hybrid Electric Vehicle Using Supercapacitors and Batteries", IEEE Trans. on Industry Applications, Vol. 44, Issue 1, Jan.-Feb. 2008, pp. 108 – 114.

[3] K.W.E. Cheng, June 2009, "Recent development on electric vehicles" 2009 3rd International Conference on Power Electronics Systems and Applications9 (conference paper).

[4]Rony Argueta (2010). A Technical Research Report: Electric Vehicles, Submitted to University of California Santa Barbara College of Engineering.

http://www.writing.ucsb.edu/faculty/holms/Writing_ 2E- _EV Technical Research Report .pdf

[5] J. Brady, M. O'Mahony, 2011, Travel to work in Dublin. The potential impacts of electric vehicles (Elsevier: Transportation Research Part D: Transport and environment, vol 16, issue 2) p. 188

[6] T.R. Hawkins, B. Singh, 2012, Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles (Journal of Industrial Ecology, vol 17, issue 1) p 53

[7]Vilchez J.J.G., Jochem P., Fichtner W. (2013). EV Market Development Pathways- An Application of System Dynamics for Policy Simulation. EVS27 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium.https://ieeexplore.ieee.org/document/6914829/

[8] Afida Ayob, Azah Mohamed, Mohd Zamri Che Wanik, Mohd Fadzil Mohd Siam "Review on Electric Vehicle, Battery Charger, Charging Station and Standards" Research Journal of Applied Sciences, Engineering and Technology 7(2): 364-373, 2014, DOI:10.19026/rjaset.7.263

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[9] Dr. Chokri MAHMOUDI, Dr. Aymen FLAH, Pr. Lassaad SBITA, November 2014, "Overview of Electric Vehicle Concept and Power Management Strategies" Conference Paper · November 2014, DOI: 10.1109/CISTEM.2014. 7077026

[10]Elie Ayoub, Nabil Karami, "Review on The Charging Techniques of a Li-ion" Battery Conference Paper · April 2015 DOI: 10.1109/ TAEECE.2015.7113599

[11] Zhang, F., Zhang, X., Zhang, M., Edmonds, A. S. E., Electric, H., & Corporation, E.

(2016). Literature Review of Electric Vehicle Technology and its Applications, 832–837.

https://ieeexplore.ieee.org/document/8070276/

[12] Ghatikar, G., Pillai, R. K., & Ahuja, A. (2017). Electric transportation action plan for India. 20161st International Conference on Sustainable Green Buildings and Communities, SGBC 2016. https://doi.org/10.1109/SGBC. 2016.7936085

[13] Barton, B., & Schütte, P. (2017). Electric vehicle law and policy: a comparative analysis.

Journal of Energy & Natural Resources Law, 35(2), 147–170. https://doi.org/10.1080/ 02646811.2017.1262087

[14] International Energy Agency, 2017. Global EV Outlook-2017. Retrieved from : https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf

[15]C Iclodean1, B Varga, N Burnete, D Cimerdean, B Jurchiș "Comparison of Different Battery Types for Electric Vehicles" IOP Conf. Series: Materials Science and Engineering **252** (2017) 012058 doi:10.1088/1757-899X/252/1/012058

[16] Comparison of Different Battery Types for Electric Vehicles To cite this article: C Iclodean *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **252** 012058

[17] Ankit kumar, S K choudhary, Chethan K N **"**COMMERCIAL VIABILITY OF ELECTRIC VEHICLES IN INDIA" Volume 9, Issue 6, June 2018, pp. 730–745, Article ID: IJMET_09_06_082

[18] Mr. A. Rakesh Kumar 1, Dr. Sanjeevikumar Padmanaban " EVs for India: Overview and Challenges" IEEE India Info. Vol.14 No.2 Apr-jun 2019 (page 139-142)