

Pollution Control and Sustainable Urban Transport System - Electric Vehicle

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Abstract—Recently electric vehicles are becoming popular as an alternative of conventional fossil fuel vehicles. Conventional Internal Combustion Engine (ICE) vehicle uses fossil fuel which contributing a major part of overall carbon emission in the environment. Carbon and other green house gas emission are responsible for global warming and resulting climate change. It becomes vital to evaluate performance of vehicle based on emission. In this paper an effort has been made to depict the picture of emission caused by vehicle and scenario of Australia has taken into account. Effort has been made to compare the fossil based vehicle with electric vehicle in phases. The study also evaluates advancement in electric vehicle technology, required infrastructure for sustainability and future scope of developments. This paper also includes the evaluation of electric vehicle concept for pollution control and sustainable transport systems in future. This study can be a benchmark for development of electric vehicle as low carbon emission alternative for the cities of tomorrow.

Keywords—Electric Vehicle, Fossil Fuel, Internal Combustion Engine, Green House Gas, In wheel motor, Smart grid

I. INTRODUCTION

AUTOMOTIVE industry has a vital role in today's society but current state of automotive industry needs improvements for sustainability concerning climate change, air pollution, global warming, and noise, congestion and accident prevention. Among these, pollution is of major concern due to increasing number of vehicles on the road. Most of the cars on the planet are Internal Combustion Engine Vehicle using fossil fuel as main source of energy. These internal combustion engine Vehicles emit toxic gas and still classified as less efficient engine. Millions of these vehicles on planet causing environmental issues like greenhouse effect as atmospheric heating and air pollution by their emission and wasted heat generated by their inefficiency. To effectively resolve these environmental issues, electric vehicle is chosen by many automotive manufacturers. Most of the manufacturers are already advancing in development of alternative fuel cars to address the issue of carbon emission. Government and regulatory bodies are studying safety, design and maintenance related issues for alternative fuel technologies.

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There are potential issues concerning development of electric vehicles mainly infrastructure include charging stations, effect on power grids, energy management. On the other side weight of the car due to number of batteries, range coverage, system integration, psychological acceptance, charging times and other issues to be resolved.

II. RESEARCH MOTIVATION

Automotive industry is a big contributor for economic development of a country. In Australia, around 14.8 millions of registered vehicles [1] are on the road, adding up export value of 3,123 million dollars to economy [2]. This includes 1,280 million dollars component export, component sales and more than 50,188 people working in the industry. There are several kinds of vehicle with alternative fuel other than oil-driven vehicle. The choices of travel will be essential for the success of sustainable transport which justifies the importance of more research on electric vehicle and its sustainability. Gasoline is troubled with serious environmental hazards and political risk. If the supply chain interrupts due to the confrontation in the oil exporting countries then it becomes a risk for the automotive industries all over the world. Public awareness, seeing the adverse situation of the environment, have increased around the world, the demand of less pollutant and more fuel efficient transports got a hike. This change in consumer's behavior has been already noticed by automotive industry. People are eager to have smaller cars with lower fuel consumption or use cheap alternative energy sources. Governments around the world are also imposing new rules and regulation to reduce emissions from cars. To fight against the global warming, an international environmental treaty, United Nations Framework Convention on Climate Change the UNFCCC has assigned amount of carbon reduction in Kyoto Protocol. According to the Kyoto Protocol developed country parties are to reduce greenhouse gas emission within the first commitment period from 2008 to 2012. Over the first commitment period Australia has the assigned target to limit greenhouse gas to 108 per cent of the levels they were in 1990. To implement this scheme, potential future transport system for having zero emission and possibility of managing energy crisis is the major reason for why study should be done on electric vehicle.

III. TRANSPORT AND ITS EFFECTS ON ENVIRONMENT

A. Transport and fuel consumption

Transportation is the mean of economic development which gives assess to market. So vehicle has to run to run the wheel of economy. Around the world the number of vehicle is increasing. Emphasizing the scenario in Australia some more information about the transport from Australian Bureau of

Statistics has been given here to observe the use of vehicle. According Bureau of Statistics (ABS)[1] survey of Australia over the period 1 November 2006 to 31 October 2007, there were about 14.8 million registered vehicles out of them passenger vehicles are 11,519,214. Figure 1 shows the number of vehicles where passenger vehicle made up the largest group of registered vehicles.

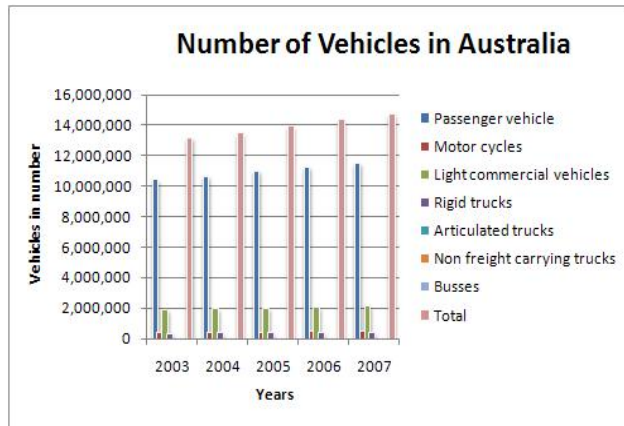


Fig.1 Number of vehicle in Australia

It is also important to find out more in terms of fuel consumption which vehicles are in the leading position. According to ABS [1] Motor vehicles consumed 30,047 million liters of fuel from 1 November 2006 to 31 October 2007 in Australia. During these 12 months, passenger vehicles used 15,910 million liters of petrol which was 87.9% of all fuel consumption. Figure 2 shows the fuel consumptions of several years where passenger car was leading always.

Considering the passenger car only it can be conclude that passenger cars are increasing in numbers which require more fuel consumption. Figure 3 shows the growth of the passenger car and their fuel consumption. It is also clear from the survey that the number of passenger vehicle is increasing and using maximum amount of fuel.

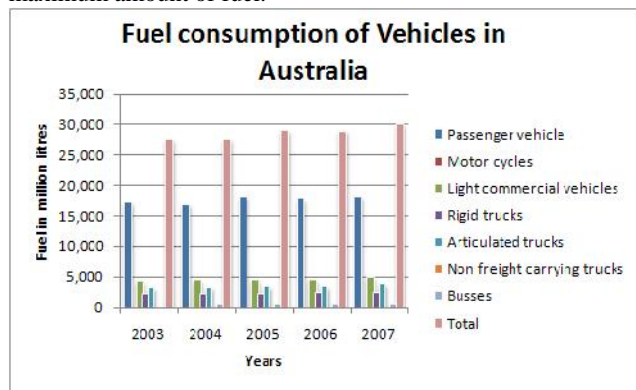


Fig. 2 Fuel consumption of vehicle in Australia

As road transport is mostly dependent on oil-driven fuel therefore today these passenger vehicle are responsible for a

significant and growing share of global emissions of carbon dioxide. There are several issues related to vehicle for creating environmental impacts among them carbon emission is the significant one for environment pollution. So carbon emission is taken as the single key for environmental impact.

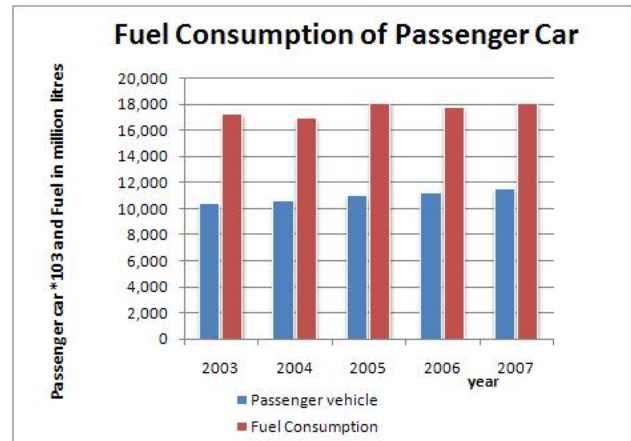


Fig. 3 Fuel consumption of passenger car

B. Carbon Emission and global warming

Driving Internal Combustion Engine Vehicles involve releasing exhaust of major greenhouse gas. Production of greenhouse usually expressed in equivalent of carbon dioxide (CO₂). Motor vehicle produces 2.3 kilogram of carbon-dioxide by burning a litre of petrol.

Around 1.5% of global greenhouse gas emissions causes by Australia [3]. Survey found that it's per person CO₂ emissions is nearly twice the OECD countries average and more than four times the world average emission [4].

Greenhouse gas emissions are classified into six sectors by the Department of Climate Change in Australia. Transport activity is the one of the major source of emissions related to the combustion of fossil fuels. According to ABS, in 2007, transport contributed 78.8 Mt CO₂ equivalent or 13% of Australia's net emissions[3]. Transport activity has become one of the largest sources of pollution in society shows in figure 4. Emissions from this sector are increasing and survey finds that it was 26.9% higher in 2007 than in 1990.

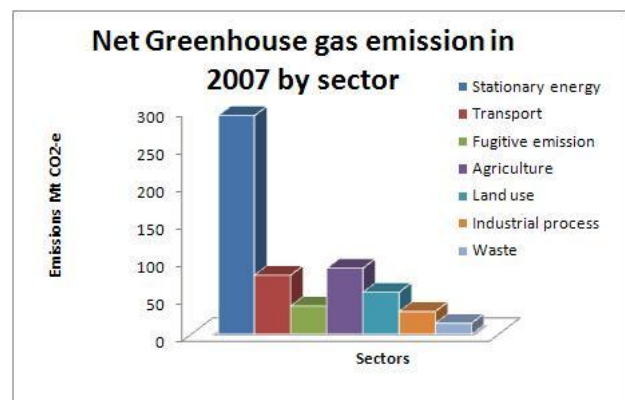


Fig. 4 Greenhouse gas emissions in 2007 in Australia

Global warming is a result of the greenhouse gas emissions induced by carbon dioxide and other gases in the atmosphere. These gases trap the energy in the atmosphere and increase the temperature to a level warm for life support. After a certain level of warm an increased earth temperature caused by increased amount of greenhouse gases results in major ecological damages to its ecosystems and in many natural disasters that affect human populations.

IV. EFFECT ON HUMAN HEALTH

Vehicle exhausts can create various health hazards which are dangerous for current and future generations. The combustion of fuel in combustion engines is always polluting the air. Besides carbon dioxide and water, the combustion products contain a certain amount of sulphur dioxide, nitrogen oxides and carbon monoxides which are toxic to human health[4].

Combustion of sulphur containing fossil fuels such as coal and heavy oil emit sulphur dioxide. Oil accounts 20 per cent of annual world wide energy related emissions of sulphur dioxide. Petrol engine emit little sulphur dioxide but diesel engine emit sufficient amounts of sulphur dioxide for pollution. According to World Health Organization annual mean levels should not exceed $100 \mu\text{g}/\text{m}^3$ to prevent chronic respiratory illness but in fact many major cities has average concentrations is $100\text{--}200 \mu\text{g}/\text{m}^3$ annually. This pollution causing asthma which is a disorder that narrows air passages of the lungs. Asthma causes wheezing and shortness of breath. Sulphur dioxide also sensitises people to asthma and which can be triggered by common allergens. Higher concentrations of sulphur dioxide and suspended particulates cause chronic cough, bronchitis and chest illness to the school going children in urban areas. It also causes for increasing of heart attack.

Carbon monoxide is produced by the incomplete combustion of carbon based fuels. More than 90% of the total emissions carbon monoxide comes from transport activities. Due to the increasing number of vehicle causing emission of carbon monoxide though there are strict emission controls. Poor maintenance of combustion engines while sticking in traffic is an important source of carbon monoxide. Carbon monoxide is a systematic poison which reduces the oxygen carrying capacity of the blood which makes the tissues and brain to have less oxygen. Carbon monoxide has 200 times more affinity for haemoglobin than oxygen has. After breathing carbon monoxide it easily makes bond with haemoglobin and forms carboxyhaemoglobin (COHb)[5]. Concentration on COHb causes headaches, decrease exercise capacity and causes drowsiness. High concentration of carbon monoxide can cause death. People working in the road like traffic police or cleaners in busy cities experience a high expose on carbon monoxide which can cause heart disease. Carbon monoxide is not only harmful for the pre existing heart illness, chronic bronchitis and emphysema but also harmful for the unborn children. Unborn baby's mental and physical growth can be retarded by carbon monoxide.

Nitrogen oxides come directly from motor vehicles which is 5 to 10 percent of total released. Depending on the availability of ozone 90 to 95 per cent nitric oxide emission converts to nitrogen dioxide. Nitrogen dioxide can be oxidised to fine nitrate and nitric acid aerosols which can soluble in water and causes acid rain. Acid rain, though it sounds strange but it causes by the nitric acid whose acidity kills plants and fish. Nitrogen dioxide together with sulphur dioxide cause respiratory problems which can worse as bronchitis asthma and emphysema.

Incomplete fuel combustion results volatile organic compounds (VOCs) in the air which is a greenhouse gas and contributes to global warming. Emissions of VCOs occurs in urban areas by un- burnt petrol or while refuelling by evaporation. People inside the vehicle have 2 or 3 times more concentration of VCOs like benzene than those walking outside on the road in traffic. VOCs cause irritations, coughing and sneezing, drowsiness. Some of these VCOs such as benzene and 1,3-butadiene comes from petrol can cause leukaemia. VCOs like benzo(a)pyrene can affect DNA of the cell. It is also found that long car journeys of the children have a higher rate of leukaemia.

Noise generated from the vehicles is not only irritation but also create harm to health. Survey says road traffic noise is a major source of disturbance. It affects the health gradually over a long time expose. The growing numbers of motor vehicles in urban area are affecting more to the people. This increases the blood pressure which leads to the risk of heart diseases. Hearing imparity may occur for exposure above the sound level of 70dB [6] and research found that road traffic can generate noise that is above 70dB.

V. POLLUTION CONTROL BY ELECTRIC VEHICLES

Electric vehicle is simple in architecture. It consists of electric motor, battery and controller. Electric motor drives the wheel, battery provides energy and controller regulates the flow of energy. Though fundamental principal of electric vehicle is similar to the internal combustion engine vehicle, the electric vehicle has advantages over conventional vehicle. Electric vehicle has high efficiency, quite in operation and significantly the absence of emission.

Running the internal combustion engine vehicle releases heat and combustion products. These combustion products include carbon dioxide, nitrogen oxide, carbon monoxide and unburned hydrocarbons which are creating impact on environment. Turning on the engine, through out the journey and intermediate interruptions in the journey, internal combustion engine pollutes environment by emission. In the starting the engine needs few minutes to warm up when emission is unchecked by the used converters and filter in the vehicle. Urban journey is mostly very short in length which is few kilometers so warming up for a short journey may cause inconsiderable amount of emission. The step by step emission occurs while running and operation of a petrol engine vehicle is depicted in the figure 5 to compare it with the electric vehicle.

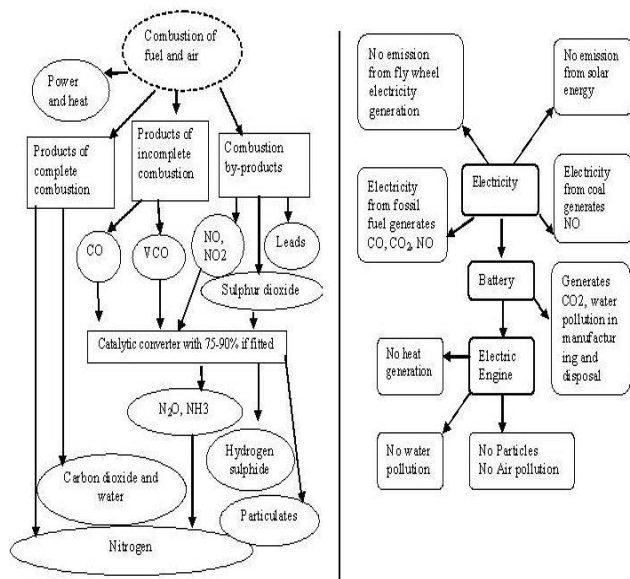


Fig. 5 Comparison of Gasoline and electric vehicle while operation

The figure also shows the step by step emission from the electric vehicle. These self descriptive diagrams of the pollution occur while operation for both of the vehicle gives a good comparison in favour of the electric vehicle for urban transport.

In the journey in cities, high way and free way vehicles face some interruption due to traffic. Research has been carried out to find the emission occurs due to interruption. Result from such research work [7] shows the relative impact of traffic interruption on emission which is significant in amount. In contrast electric vehicle has a greater flexibility in operation as there is no fuel is burning in interruption due to traffic which is not polluting the air.

With a simple architecture of an electric vehicle that includes the parts are motor, batteries, controllers and chassis. Different types of materials being used for making motor and batteries which are responsible for considerable amount of carbon emission. Considering the manufacturing of lead acid batteries, lithium ion batteries, motor and other parts of electric vehicle research shows the carbon emission estimated to be in total 6034 kg where as carbon emission from manufacturing gasoline vehicles are estimated to be 4580 kg [8]. Research also shows that driving the electric vehicle results less carbon emission than a gasoline vehicle. While manufacturing it is possible to reduce the emission by taking careful attention. Advance technology should be implemented for extending the lifetime of the parts and improvement should be done in manufacturing process to reduce the carbon emission.

Driving motor vehicle will generate noise from the engine and from rolling on the road. Internal combustion engine generates noise caused by combustion. In case of electric vehicle an electric motor is an engine which is much quieter. Noise pollution caused by engine can be reduced by using these electric vehicles. For rolling noise measures should be taken to reduce it with improved road construction but while

running in a high speed this rolling noise is almost unmanageable.

VI. SUSTAINABILITY BY ELECTRIC VEHICLE

“Sustainable transportation” may have several definitions given by people and organizations but the current alarming environmental situation reminds for immediate changes with readily available possible solutions which have some need of further improvements indicating the technical feasible current options. In case of urban transport sustainability, currently, factors those needs to be considered include:

- Reduction in environmental pollutions
- Use of renewable and cleaner energy to avoid cumulative emission
- Use of transport that is clean for current and future generations
- Improvement in vehicle technology

A. Bringing sustainability by using alternative energy sources

Electric vehicle need to charge the batteries to run and for charging electric is required. If the conventional way of electricity generation is used like burning fossil fuels then environment pollution will not decrease due to the increasing demand of electricity by these increasing electric vehicles. We have technology in hand for electricity generation in cleaner way for instance the renewable solar photovoltaic and wind power. Electric vehicle can be charged from these cleaner renewable energy sources. These sources can be placed stationary in certain suitable localities or sometimes feasible to have onboard with the vehicles. For charging batteries solar panels, wind generators, fly wheels and super capacitors are technically feasible to be attached onboard. Several passenger cars for city dwellers are readily available in the market with onboard solar panels.

B. Infrastructure development

Using conventional power sources for charging electric vehicles can create a significant impact on the grid as energy management is not fully automated for peak demand. On the other hand there is increasing number of distributed electricity generation facilities. In Australia and other countries [9] the use of photovoltaic energy sources are increasing as government grant and rebates have been made. The solar energy source using has been increased from 4% to 7% from 2005 to 2008 in Australia [10]. Integration of these generations required to utilize the power properly according to the demand. A two communication in an automated charging facility considering supply and demand is known as smart grid which has a significant importance in infrastructure development for electric vehicle. Smart grid can collaborate with the energy sources. It can support integration of scattered renewable energy sources. Figure 6 gives the concept of a smart grid where all the sources are connected in an intelligent network to manage the demand. For the electric vehicle it is a

bidirectional connection for charging battery or providing electricity to the grid when required.

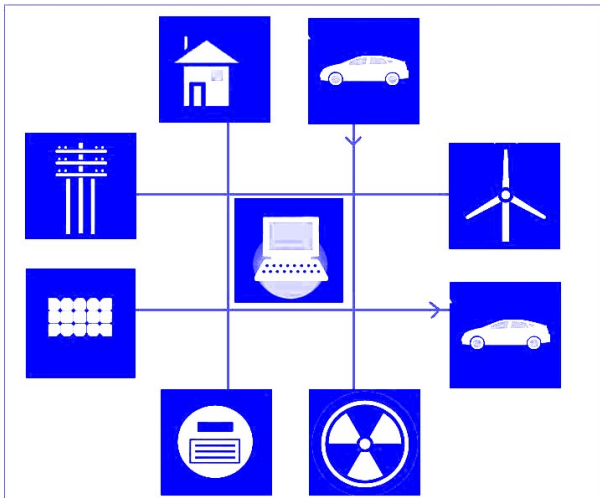


Fig. 6 Smart Grid

Smart grid creates intelligent energy network to utilize the existing capacity in an efficient way to reduce cost and manage demand. Further standardization [11] is required to apply this beautiful technology for electric vehicle which also cover the charging stations, charging devices and plugging facilities. Smart grid are using the renewable sources efficiently also promoting the reduction of carbon emission. The concept of smart grid for giving the optimized facilities will bring sustainability for charging electric vehicle.

C. Technical improvements of electric vehicle

Technological improvement is a major concern for sustainability of the electric vehicles. Advancement is going on and the current situation is not inadequate. Several components of electric vehicle have been improved significantly. Improvement in battery technology, battery management, electric motors and accident prevention technologies are key issues regarding the improvement of electric vehicle.

Electric vehicles have been using different kinds of electric motors and they differ in technology. Recent advancement in electric motors is the combination of motor and the wheel which is introduced as in wheel [12] motor. Figure 7 shows Electronically Controlled Vehicle and Integrated In-Wheel Motors.

This advancement has given a new drive train. In wheel motor gives the greater flexibility in controlling which also eliminated the gear box and drive shaft. It allows each wheel to rotate in any speed in any direction.

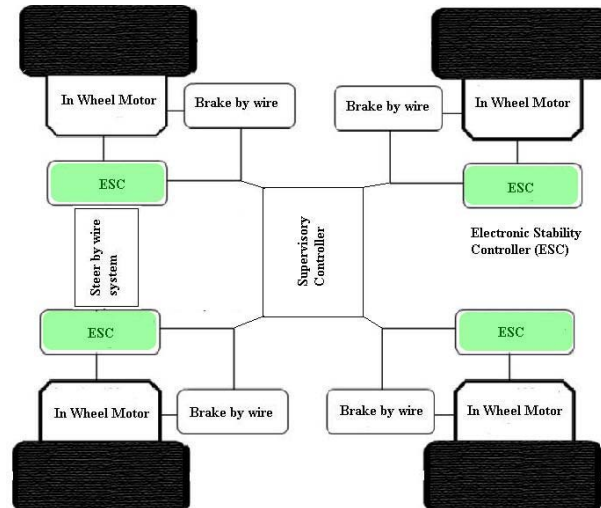


Fig. 7 Electronically Controlled Vehicle and Integrated In-Wheel Motors.

Flexibility of individual control of each wheel using in wheel motor also allow to implement effective accident prevention technologies like stability control. Reducing the toll in vehicle accident is also a factor for sustainable transportation as several researches and survey reported the higher toll by vehicle accident than emission. Stability control technology prevents single vehicle accident in sudden manoeuvre while spin out or drifting out. Stability control technology is getting advanced for a reducing the accident, research is being carried out for more controllability in stability considering the vehicle dynamics like centre of gravity[13].

Different technologies are being used for battery manufacturing so there are several options for using batteries in electric vehicle. Lead-acid battery, nickel-metal hybrid battery and lithium-ion battery are viable batteries for electric vehicle. Nickel-metal hybrid battery is being used in hybrid vehicles showing a good performance in long life and safety but it has some limitations in peak power density. Other mostly used battery is lithium-ion battery which has the higher peak power density and less in weight. It is lower in cost and mostly suitable in electric vehicle but it has some limitation in longevity and safety[14]. Improvement in battery is crucial as it is a major key factor for the success of electric vehicle which is being carried out in several researches. Current state of the batteries is also viable for a high performance electric vehicle for covering a long distance with minimizing the charging time. Researcher suggest the hybridization [4] of energy storages where tow or more different of batteries will be combined to use the advantages of the batteries. Basic concept is to hybridize the batteries consisting high specific energy with high specific power. Following figure 9 shows the suggested combination by researchers while there is a high power demand. Based on the available energy storages or batteries several viable hybridization can be done to meet the challenge of battery requirement.

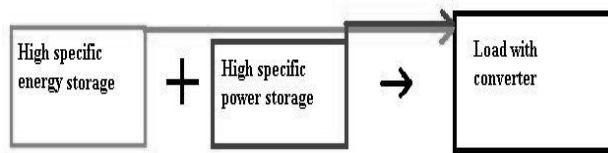


Fig. 8 Hybridization of Battery Sources

VII. CONCLUSION

Current climate change impacts remind the necessity of taking proper and immediate steps against those activities which are responsible for environment pollution. Local air pollution, carbon emission, noise pollution and accidents are impacts on environment responsible by transport activities which can not be considered as a sustainable one. The key issue is carbon emission and to reduce it focus has been given on electric vehicle for achieving more sustainable urban transport. A lot of research has been carried out for finding sustainability using electric vehicle. On the other hand much advancement has been achieved in electric vehicle technologies which allow us to rethink about it as an option. Technical achievements in isolations are reviewed so that they do not remain ineffective to fulfill the requirement. Improvements in different area of electric vehicle need to integrate for a sustainable system in the case of urban transportation. Lack of easily understandable information to the end user regarding the electric vehicle for making comparison with the others is also a major barrier for the electric vehicle. Confusions should be eradicated by taking measures like multiple day test drives and by providing information for better understanding. Review also found the importance of combined effort of technical development and current demand for urban transportation which can lead towards the goal.

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