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Literature Survey on E-vehicle Challenges with Some Solutions

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Abstract: Electric vehicles are an important option for reducing emissions of greenhouse gases. EVs not only reduce the dependency on fossil fuel but also diminish the impact of ozone depleting substances and promote large scale renewable deployment. Despite comprehensive research on the attributes and characteristics of electric vehicles and the nature of their charging infrastructure, electric vehicle production and network modelling continues to evolve and be constrained. The paper provides an overview of the studies of Electric Vehicle, Hybrid Electric Vehicle, Plug-in- Hybrid Electric Vehicle and Battery Electric Vehicle and also social, technical & economic challenges faced by EVs. The research on the essential barriers and insufficient charging facilities are addressed for a developing country like India that makes the study unique. The development of new concept of Vehicle-to-Grid has created an extra power source when renewable energy sources are not available. We conclude that taking into account, the special characteristics of electric vehicles are so important in their mobility.

Keywords: Electric Vehicle, Hybrid Electric Vehicle, Plug-in-Hybrid Electric Vehicle, Battery Electric vehicle, Challenges in adopting EV's**.**

I. INTRODUCTION

An electric vehicle (EV) is a vehicle that uses one or more electric motors or traction motors for propulsion. An electric vehicle may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels, fuel cells or an electric generator to convert fuel to electricity. EVs include, but are not limited to, road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft.

It's clear that the Indian automotive industry is experiencing a disruption. Electrification is leading the way and could have a huge impact on auto OEMs and auto component manufacturers. India is paving the way for EVs and their technologies by announcing its plans for the decade ahead. The country is focused on reaching a high level of EV adoption by 2030. These developments don't come as a surprise. Pollution is at an all-time high in major cities, and that calls for eco- friendly solutions. Plus, India spends colossal amounts on the import of crude oil. This can be reduced greatly via the widespread adoption of EVs.

II. EV TYPES

EVs can run solely on electric propulsion or they can have an ICE working alongside it. Having only batteries as energy source constitutes the basic kind of EV, but there are kinds that can employ other energy source modes. These can be called hybrid EVs (HEVs). The International Electro technical Commission's Technical Committee (Electric Road Vehicles) proposed that vehicles using two or more types of energy source, storage or converters can be called as an HEV as long as at least one of those provide electrical energy. This definition makes a lot of combinations possible for HEVs like ICE and battery, battery and flywheel, battery and capacitor, battery and fuel cell, etc. Therefore, the common population and specialists both started calling vehicles with an ICE and electric motor combination HEVs, battery and capacitor ones as ultra-capacitor-assisted EVs, and the ones with battery and fuel cell FCEVs. These terminologies have become widely accepted and according to this norm, EVs can be categorized as follows:

a) *Battery Electric Vehicle (BEV)*
b) *Hybrid Electric Vehicle (HEV)*
c) *Plug-in Hybrid Electric Vehicle (PHEV)*
d) *Fuel Cell Electric Vehicle (FCEV)*

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A. Battery Electric Vehicle (BEV)

EVs with only batteries to provide power to the drive train are known as BEVs. BEVs have to rely solely on the energy stored in their battery packs; therefore the range of such vehicles depends directly on the battery capacity. Typically they can cover 100 km–250 km on one charge, whereas the top-tier models can go a lot further, from 300 km to 500 km. These ranges depend on driving condition and style, vehicle configurations, road conditions, climate, battery type and age. Once depleted, charging the battery pack takes quite a lot of time compared to refuelling a conventional ICE vehicle. It can take as long as 36 h completely replenish the batteries, there are far less time consuming ones as well, but none is comparable to the little time required to refill a fuel tank. Charging time depends on the charger configuration, its infrastructure and operating power level. Advantages of BEVs are their simple construction, operation and convenience. These do not produce any greenhouse gas (GHG), do not create any noise and therefore beneficial to the environment. Electric propulsion provides instant and high torques, even at low speeds. These advantages, coupled with their limitation of range, makes them the perfect vehicle to use in urban areas, urban driving requires running at slow or medium speeds, and these ranges demand a lot of torque. Nissan Leaf and Teslas are some high-selling BEVs these days, along with some Chinese vehicles. Figure 1 shows basic configuration for BEVs: the wheels are driven by electric motor(s) which is run by batteries through a power converter circuit.

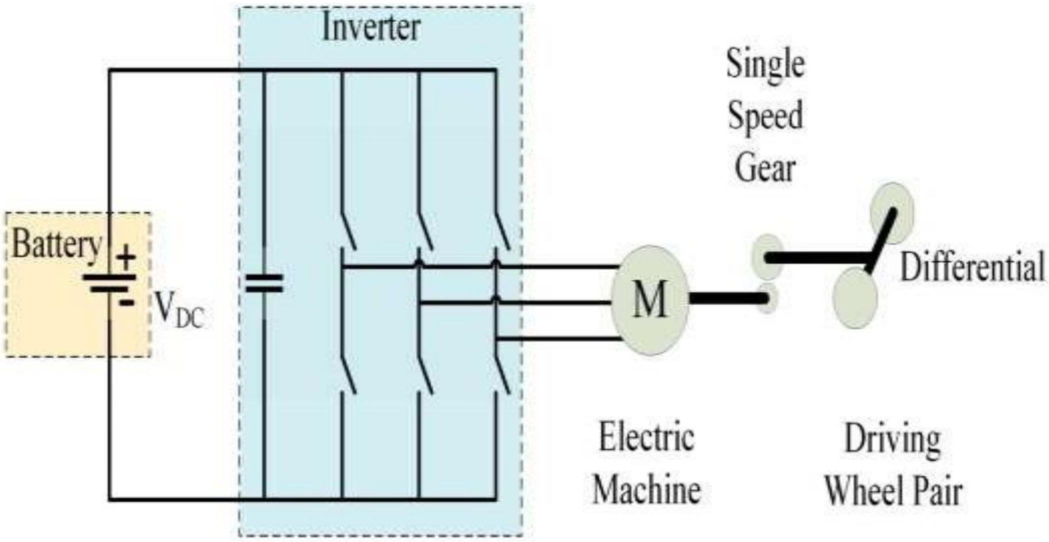

Figure 1. BEV configuration. The battery's DC power is converted to AC by the inverter to run the motor.

B. Hybrid Electric Vehicle (HEV)

HEVs employ both an ICE and an electrical power train to power the vehicle. The combination of these two can come in different forms which are discussed later. An HEV uses the electric propulsion system when the power demand is low. It is a great advantage in low speed conditions like urban areas; it also reduces the fuel consumption as the engine stays totally off during idling periods, for example, traffic jams. This feature also reduces the GHG emission. When higher speed is needed, the HEV switches to the ICE. The two drive trains can also work together to improve the performance. Hybrid power systems are used extensively to reduce or to completely remove turbo lag in turbocharged cars, like the Acura NSX. It also enhances performance by filling the gaps between gear shifts and providing speed boosts when required. The ICE can charge up the batteries, HEVs can also retrieve energy by means of regenerative braking. Therefore, HEVs are primarily ICE driven cars that use an electrical drive train to improve mileage or for performance enhancement. To attain these features, HEV configurations are being widely adopted by car manufacturers. Figure 2 shows the energy flows in a basic HEV. While starting the vehicle, the ICE may run the motor as a generator to produce some power and store it in the battery. Passing needs a boost in speed, therefore the ICE and the motor both drives the power train. During braking the power train runs the motor as generator to charge the battery by regenerative braking. While cruising, ICE runs the both the vehicle and the motor as generator, which charges the battery. The power flow is stopped once the vehicle stops. The one demonstrated here splits power between the ICE and the electric motor (EM) by considering the vehicle speed, driver's input, state of charge (SOC) of battery, and the motor speed to attain maximum fuel efficiency.

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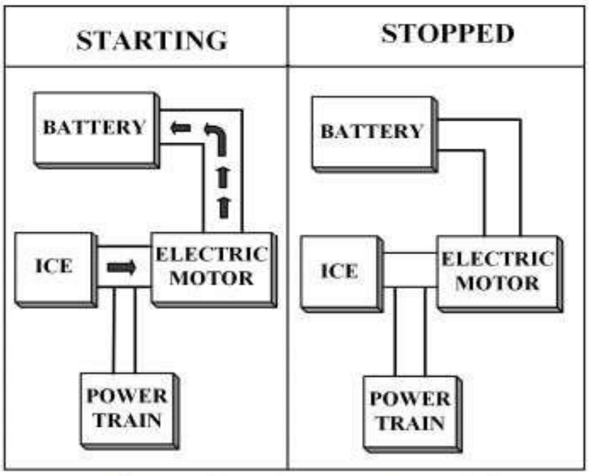
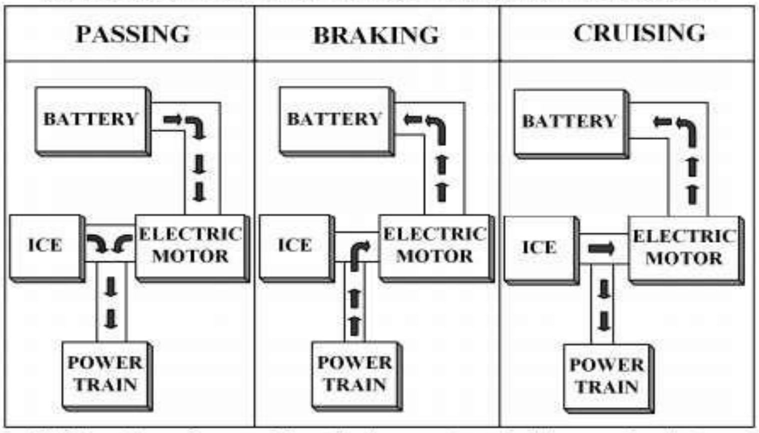


(a) Direction of power flow during starting and when stopped.



(b) Direction of power flow during passing, braking and cruising.

Figure 2. Power flow among the basic building blocks of an HEV during various stages of a drive cycle.

C. Plug-In Hybrid Electric Vehicle (PHEV)

The PHEV concept arose to extend the all-electric range of HEVs. It uses both an ICE and an electrical power train, like a HEV, but the difference between them is that the PHEV uses electric propulsion as the main driving force, so these vehicles require a bigger battery capacity than HEVs. PHEVs start in 'all electric' mode, runs on electricity and when the batteries are low in charge, it calls on the ICE to provide a boost or to charge up the battery pack. The ICE is used here to extend the range. PHEVs can charge their batteries directly from the grid (which HEVs cannot); they also have the facility to utilize regenerative braking. PHEVs' ability to run solely on electricity for most of the time makes its carbon footprint smaller than the HEVs. They consume less fuel as well and thus reduce the associated cost. The vehicle market is now quite populated with these, Chevrolet Volt and Toyota Prius sales show their popularity as well.

D. Fuel Cell Electric Vehicle (FCEV)

FCEVs also go by the name Fuel Cell Vehicle (FCV). They got the name because the heart of such vehicles is fuel cells that use chemical reactions to produce electricity. Hydrogen is the fuel of choice for FCVs to carry out this reaction, so they are often called 'hydrogen fuel cell vehicles'. FCVs carry the hydrogen in special high pressure tanks, another ingredient for the power generating process is oxygen, which it acquires from the air sucked in from the environment. Electricity generated from the fuel cells goes to an electric motor which drives the wheels. Excess energy is stored in storage systems like batteries or super capacitors. Commercially available FCVs like the Toyota Mirai or Honda Clarity use batteries for this purpose. FCVs only produce water as a by-product of its power generating process which is ejected out of the car through the tailpipes. The configuration of an FCV is shown in Figure 3. An advantage of such vehicles is they can produce their own electricity which emits no carbon, enabling it to reduce its carbon footprint further than any other EV. Another major advantage of these are, and maybe the most important one right now, refilling these vehicles takes the same amount of time required to fill a conventional vehicle at a gas pump. This makes adoption of these vehicles more likely in the near future. A major current obstacle in adopting

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this technology is the scarcity of hydrogen fuel stations, but then again, BEV or PHEV charging stations were not a common scenario even a few years back. A report to the U.S. Department of Energy (DOE) pointed to another disadvantage which is the high cost of fuel cells, that cost more than $200 per kW, which is far greater than ICE (less than $50 per kW). There are also concerns regarding safety in case of flammable hydrogen leaking out of the tanks. If these obstacles were eliminated, FCVscould really represent the future of cars. The possibilities of using this technology in supercars are shown by Pininfarina's H2 Speed. Reference compared BEVs and FCEVs in different aspects, where FCEVs appeared to be better than BEVs in many ways; this comparison is shown in Figure 4. In this figure, different costs and cost associated issues of BEV and FCEV: weight, required storage volume, initial GHG emission, required natural gas energy, requiredwind energy, incremental costs, fuelling infrastructure cost per car, fuel cost per kilometre, and incremental life cycle cost are all compared for 320 km (colored blue) and 480 km (colored green) ranges. The horizontal axis shows the attribute ratio of BEV to FCEV. As having a less value in these attributes indicates an advantage, any value higher than one in the horizontal axis will declare FCEVs superior to BEVs in that attribute. That being said, BEVs only appear better in the fields of required wind energy and fuel cost per kilometre. Fuel cost still appears to be one of the major drawbacks of FCEVs, as a cheap, sustainable and environment-friendly way of producing hydrogen is still lacking, and the refuelling infrastructure lags behind that of BEVs; but these problems may no longer prevail in the near future.

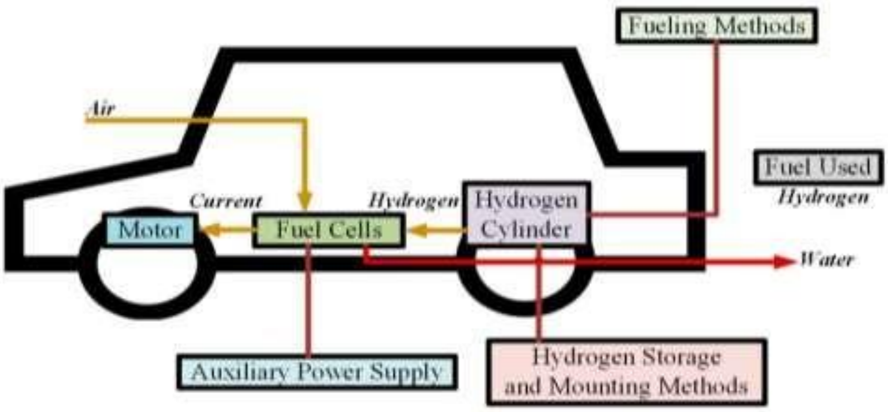

Figure 3. FCEV configuration. Oxygen from air and hydrogen from the cylinders react in fuel cells to produceelectricity that runs the motor. Only water is produced as by-product which is released in environment.

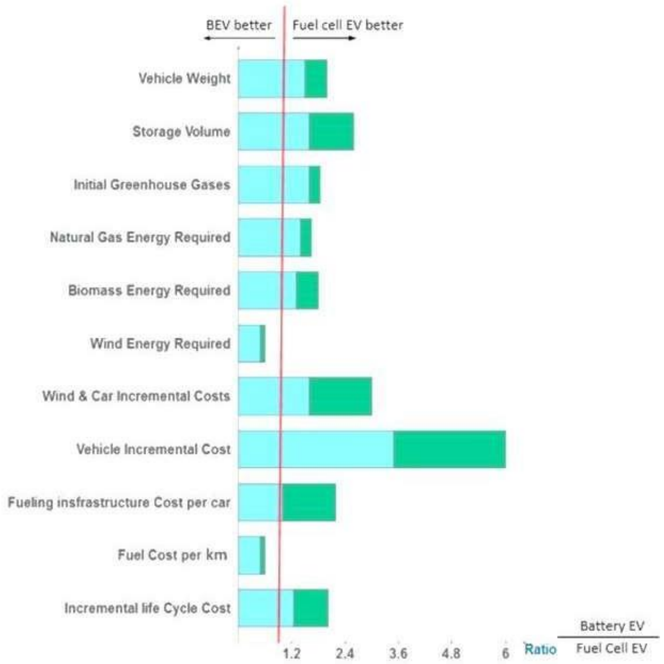

Figure 4. Advanced battery EV attribute and fuel cell EV attribute ratio for 320 km (colored blue) and 480 km (coloredgreen) ranges, with assumptions of average US grid mix in 2010-2020 time-range and all hydrogen made from naturalgas (values greter then one indicate a fuel cell EV advantage over the battery EV). Data from

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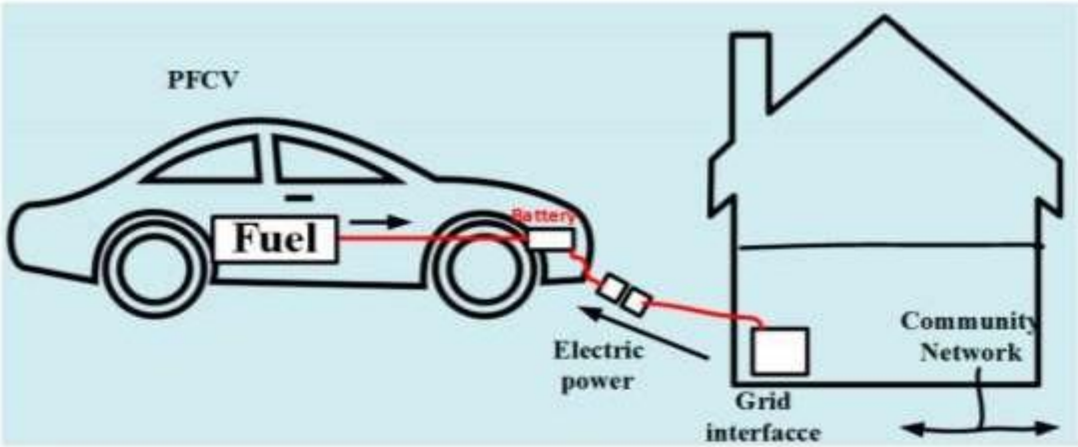

Figure 5. PFCV configuration. In addition to the fuel cells, this arrangement can directly charge the battery from apower outlet.

Table 1. Comparison of different vehicle types. Adapted from [4].

EV Type	Driving Component	Energy Source	Features	Problems
BEV	• Electric motor	• Battery • Ultracapacitor	• No emission • Not dependent on oil • Range depends largely on the type of battery used • Available commercially	• Battery price and capacity • Range • Charging time • Availability of charging stations • High price
HEV	• Electric motor • ICE	• Battery • Ultracapacitor • ICE	• Very little emission • Long range • Can get power from both electric supply and fuel • Complex structure having both electrical and mechanical drivetrains • Available commercially	• Management of the energy sources • Battery and engine size optimization
FCEV	• Electric motor	• Fuel cell	• Very little or no emission • High efficiency • Not dependent on supply of electricity • High price • Available commercially	• Cost of fuel cell • Feasible way to produce fuel • Availability of fueling facilities

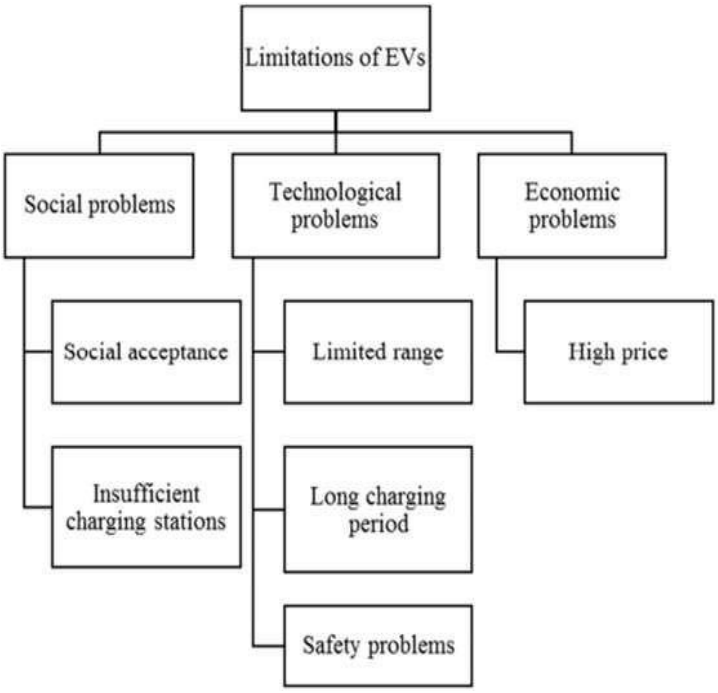

Figure 6. Social, technological and economic problems faced by EVs.

III. BARRIERS TO EV ADOPTION

Although electric vehicles offer a lot of promises, they are still not widely adopted, and the reasons behind that are quite serious as well.

A. Technological Problems

The main obstacles that have frustrated EVs' domination are the drawbacks of the related technology. Batteries are the main area of concern as their contribution to the weight of the car is significant. Range and charging period also dependon the battery. These factors, along with a few others, are demonstrated below:

i. Limited Range

EVs are held back by the capacity of their batteries. They have a certain amount of energy stored there, and can travel adistance that the stored energy allows. The range also depends on the speed of the vehicle, driving style, cargo the vehicle is carrying, the terrain it is being driven on, and the energy consuming services running in the car, for example air conditioning. This causes 'range anxiety' among the users, which indicates the concern about finding a charging station before the battery drains out. People are found to be willing to spend up to $75 extra for an extra range of one mile. Though even the current BEVs are capable of traversing equivalent or more distance than a conventional vehicle can travel with a full tank (Tesla Model S 100D has a range of almost 564 km on 19" wheels when the temperature is 70 ◦C and the air conditioning is off , the Chevrolet Bolt's range is 238 miles or 383 km), range anxiety remains a major obstacle for EVs to overcome.

This does not affect the use of EVs for urban areas though, as in most cases this range is enough for daily commutation inside city limits. Range extenders, which produce electricity from fuel, are also available with models like BMW i3 as an option. Vehicles with such facilities are currently being called as Extended Range Electric Vehicles (EREV).

ii. Long Charging Period

Another major downside of EVs is the long time they need to get charged. Depending on the type of charger and battery pack, charging can take from a few minutes to hours; this truly makes EVs incompetent against the ICEvehicles which only take a few minutes to get refueled. Hidrue et al., found out that, to have an hour decreased from the charging time; people are willing to pay $425–$3250.

A way to make the charging time faster is to increase the voltage level and employment of better chargers. Some fast charging facilities are available at present, and more are being studied. There are also the fuel cell vehicles that do not require charging like other EVs. Filling up the hydrogen tank is all that has to be done in case of these vehicles, whichis as convenient as filling up a fuel tank, but FCVs need sufficient hydrogen refueling stations and a feasible way to produce the hydrogen in order to thrive.

iii. Safety Concerns

The concerns about safety are rising mainly about the FCVs nowadays. There are speculations that, if hydrogen escapesthe tanks it is kept into, can cause serious harm, as it is highly flammable. It has no color either, making a leak hard to notice. There is also the chance of the tanks to explode in case of a collision. To counter these problems, the automakers have taken measures to ensure the integrity of the tanks; they are wrapped with carbon fibers in case of the Toyota Mirai. In this car, the hydrogen handling parts are placed outside the cabin, allowing the gas to disperse easilyin case of any leak, there are also arrangements to seal the tank outlet in case of high-speed collision.

B. Social Problems

i. Social Acceptance

The acceptance of a new and immature technology, along with its consequences, takes some time in the society as it means change of certain habits. Using an EV instead of a conventional vehicle means change of driving patters, refueling habits, preparedness to use an alternative transport in case of low battery, and these are not easy to adopt.

ii. Insufficient Charging Stations

Though public charging stations have increased a lot in number, still they are not enough. Coupled with the lengthy charging time, this acts as a major deterrent against EV penetration. Not all the public charging stations are compatible with every car as well; therefore it also becomes a challenge to find a proper charging point when it is required to replete the battery. There is also the risk of getting a fully occupied charging station with no room for another car. But, the manufacturers are working on to mitigate this problem. Tesla and Nissan have been expanding their own charging networks, as it, in turn means they can sell more of their EVs. Hydrogen refueling stations are not abundant yet as well.

It is necessary as well to increase the adoption of FCVs. In, a placement strategy for hydrogen refueling stations in California is discussed. It stated that a total of sixty-eight such stations will be sufficient to provide service to FCVs in the area. To get the better out of the remaining stations, there are different trip planning applications, both web based and manufacturer provided, which helps to obtain a route so that there are enough charging facilities to reach the destination.

C. Economic Problems

i. High Price

The price of the EVs is quite high compared to their ICE counterparts. This is because of the high cost of batteries and fuel cells. To make people overlook this factor, governments in different countries including the UK and Germany, have provided incentives and tax breaks which provide the buyers of EVs with subsidies. Mass production and technological advancements will lead to a decrease in the prices of batteries as well as fuel cells. Affordable EVs with a long range like the Chevrolet Bolt has already appeared in the market, while another vehicle with the same promises (the Tesla Model 3) is anticipated to arrive soon. while Table 2 suggests some solutions for the existing limitations.

Limitation	Probable Solution
Limited range	Better energy source and energy management technology
Long charging period	Better charging technology
Safety problems	Advanced manufacturing scheme and build quality
Insufficient charging stations	Placement of sufficient stations capable of providing services to all kinds of vehicles
High price	Mass production, advanced technology, government incentives

IV. OUTCOME

The goal of this paper is to focus on the key components of EV. The key findings of this paper can be summarized as follows:

- EVs can be classified as BEV, HEV, PHEV, and FCEV. BEVs and PHEVs are the current trends. FCEVs can become mainstream in future. Low cost fuel cells are the main prerequisite for that and there is need of more research to make that happen. There are also strong chances for BEVs to be the market dominators with ample advancement in key technologies; energy storage and charging systems being two main factors. Currently FCVs appear to have little chance to become ubiquitous, these may find popularity in niche markets, for example, the military and utility vehicles.

- EVs can be front wheel drive, rear wheel drive, even all-wheel drive. Different configurations are applied depending on the application of the vehicle. The motor can also be placed inside the wheel of the vehicle which offers distinct advantages. This configuration is not commercially abundant now, and has scopes for more study to turn it into a viable product.

- The main HEV configurations are classified as series, parallel, and series-parallel. Current vehicles are using the series-parallel system mainly as it can operate in both battery-only and ICE-only modes, providing more efficiency and less fuel consumption than the other two systems.

- Currently EVs use batteries as the main energy source. Battery technology has gone through significant changes, the lead-acid technology is long gone, as is the NiMH type. Li-ion batteries are currently in use, but even they are not capable enough to provide the amount of energy required to appease the consumers suffering from ‘range anxiety’ in most cases. Therefore the main focus of research in this area has to be creating batteries with more capacity, and also with better power densities. Metal-air batteries can be the direction where the EV makers will head towards. Lithium- sulfur battery and advanced rechargeable zinc batteries also have potential provide better EVs. Nevertheless, low cost energy sources will be sought after always as ESS cost is one of the major contributors to high EV cost.

V. CONCLUSIONS AND RECOMMENDATIONS

This paper reviewed the challenges and opportunities of electric vehicles (EVs) in mass market deployment. The challenges can be divided into four major categories according to various aspects, namely economic, technology, social, environmental aspect. Economic challenges are the major challenges reviewed, where high selling price of EVs have obstructed the mass adoption of EVs. Due to low EV adoption rate, high initial investment and low profitability of public charging infrastructure have downturned its economic performance and sustainability of its business model. For technological challenges, the manufacturing of energy storage system in EVs are still not economically justified, while thermal instability of Li-ion batteries under extreme environmental conditions is yet to be addressed. Also, energy density of current battery technologies is still much lower than fuel, resulting in limited driving range. Renewable energy generation using advanced technologies is also required to supply enough electricity to the power grid to cater for increasing charging load.

Moreover, from social aspect, range anxiety has raised negative perceptions of the society towards EVs, given that EVs have limited range, long charging time and insufficient charging infrastructure. Although EVs produce zero tailpipe emission, environmental challenges of EVs include greenhouse gases emitted from power generation to recharge the batteries. Manufacturing process and disposal of the batteries after its service life may also cause harmful pollution to the environment.

To accelerate the mass diffusion of EVs into the existing market, recommendations are made in accordance to the challenges identified. The high price of EVs is the main concern of consumers when considering the type of transportation vehicles to purchase. Government plays a very important role in reducing the price of EVs and instead of just promoting the advantages of buying an electric vehicle. Governments should collaborate with EV manufacturers to reduce the price of EVs by reducing the tax imposed on the raw materials required in manufacturing the components of EVs, especially the battery systems. Other than that, incentives such as tax credits and tax exemptions could be offered to consumers based on the battery capacity and vehicle size to encourage the purchase of EVs.

Besides, more funds should be allocated towards the research and development of EV technologies to speed up the development of EVs. Since more resources could be made accessible and more research can be done, EV technologies especially the battery density, capacity as well as its lifecycle can be further advanced. With the development of new technologies, mass production of EVs could be achieved easily thus further reducing the high price of EVs.

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