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A Review on Electric Vehicles: Innovation and Challenges

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ABSTRACT

Electric vehicles (EVs) are gaining popularity due to several factors, including falling prices as well as climate and environmental awareness. This article reviews advances in electric vehicles from the perspective of trends in battery technology, charging methods, and new research challenges and opportunities. In particular, an analysis of the situation on the global electric vehicle market and its future prospects is carried out. Since one of the fundamental aspects of electric vehicles is the battery, this article provides a comprehensive overview of battery technologies, from lead-acid batteries to lithium-ion batteries. In addition, we review the various standards available for the EV charging process, as well as proposals for power control and battery energy management. Finally, we conclude our work by presenting our vision of what is expected in the near future in this field, as well as aspects of research that are still open to both the industry and the academic community.

Keywords: Electric Vehicles; **battery charging**; **batteries technology**; **charging modes**; **EV plugs**

INTRODUCTION

The automobile industry has become one of the most important industries in the world, not only from an economic point of view, but also from a research and development point of view. More and more technological elements are being introduced into vehicles to improve the safety of passengers and pedestrians. In addition, there are more vehicles on the roads, allowing us to move quickly and comfortably. However, this has led to a sharp increase in air pollution levels in urban environments (i.e. pollutants such as particulate matter, nitrogen oxides (NOX), CO, sulfur dioxide (SO2), etc.).

Moreover, according to a European Union report, the transport sector accounts for almost 28% of total carbon dioxide (CO2) emissions, and road transport accounts for more than 70% of transport sector emissions [1]. Therefore, authorities in most developed countries encourage the use of electric vehicles (EVs) to avoid the concentration of atmospheric pollutants, CO2, as well as other greenhouse gases. In particular, they promote sustainable and efficient mobility through various initiatives, mainly through tax breaks, shopping assistance or other special measures such as free public parking or free use of motorways. Electric vehicles have the following advantages over traditional vehicles:

• Zero Emissions: This type of vehicle emits no pollutants, CO2 or nitrogen dioxide (NO2) into the tailpipes. Manufacturing processes also tend to be more environmentally friendly, although battery production does have a negative impact on carbon emissions.

• Simplicity: The number of components in an electric vehicle (EV) engine is fewer, resulting in much cheaper maintenance. Engines are simpler and more compact, they do not require a cooling circuit, and there is no need to include a gear shift, clutch or components to reduce engine noise.

• Reliability: Fewer and simpler components reduce the likelihood of failure in this type of vehicle. In addition, electric vehicles do not suffer from the normal wear and tear associated with engine knock, vibration or fuel corrosion.

• Cost: The cost of maintaining the vehicle and the cost of the electricity required are much lower compared to the maintenance and fuel costs of traditional internal combustion engine vehicles. The energy cost per kilometer of electric vehicles is significantly lower than that of traditional vehicles, as shown in Figure 1.

• Comfort: traveling in electric vehicles is more comfortable due to the absence of vibrations and engine noise [2].

- Running Cost Is Lower than Petrol and Diesel-Powered Cars.
- Low Maintenance Cost.
- Emits Zero-Emission and Reduces Noise.
- Tax Benefits.
- Convenient to Drive.
- Easy-to-Charge at Home.
- Convenient Cabin Space and More Storage Facility.
- You Do Not Need to Face Fuel Price Hikes.

Energy efficient. EVs convert over 77% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 12%–30% of the energy stored in gasoline to power at the wheels

Environmentally friendly. EVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear-, hydro-, solar-, or wind-powered plants causes no air pollutants.

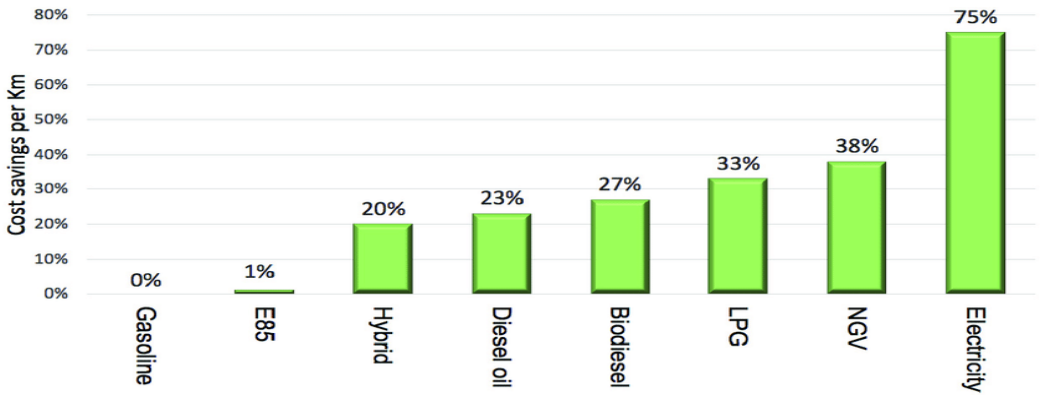

Figure 1. Comparison of savings in cost per kilometer offered by vehicles powered by Gasoline, Ethanol (E85), Hybrid, Diesel oil, Biodiesel, Liquefied Petroleum Gas (LPG), Natural Gas Vehicle (NGV), and Electricity [**5**].

On the other hand, EVs do, however, face significant battery-related challenges:

- Driving range: range is typically limited from 200 to 350 km with a full charge, although this issue is being continually improved. For example, the Nissan Leaf has a maximum driving range of 364 km [**6**],
- Charging time: full charging the battery pack can take 4 to 8 h. Even a "fast charge" to 80% capacity can take 30 min. For example, Tesla superchargers can charge the Model S up to 50% in only 20 min, or 80% in half an hour [**7**].
- Battery cost: large battery packs are expensive.

In the coming years, EVs will have a very important role in Smart cities, along with shared mobility, public transport, etc. Therefore, more efforts to facilitate the charging process and to improve batteries are needed. The main drawback of the EVs is their autonomy. However, researchers are working on improved battery technologies to increase driving range and decrease charging time, weight, and cost. These factors will ultimately determine the future of EVs.

ELECTRIC VEHICLES CLASSIFICATION

Nowadays, we can encounter different types of EVs, according to their engines technology. In general, they are sorted in five types (See **Figure 3**):

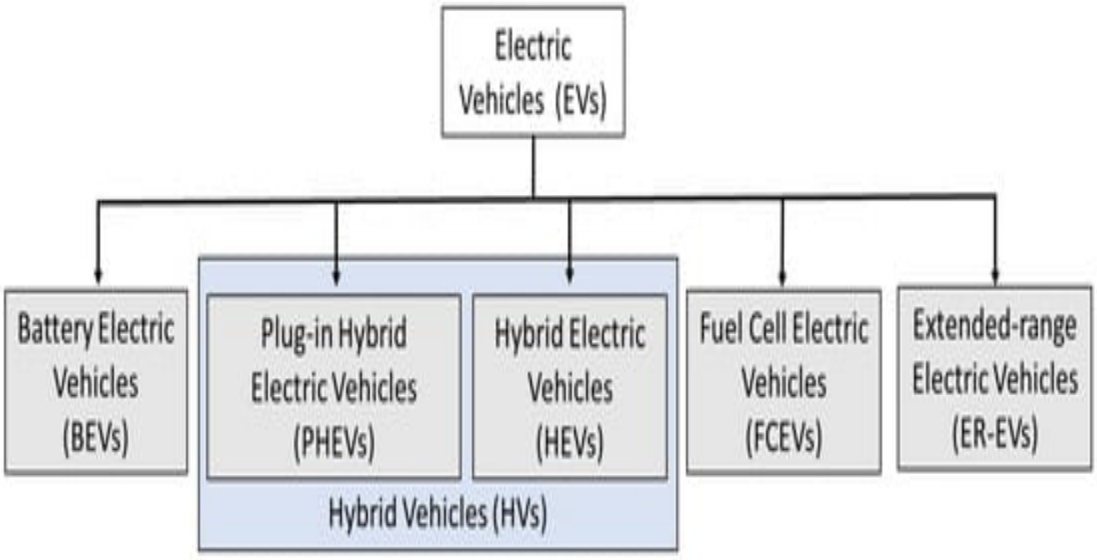

Figure 3. Electric vehicles classification according to their engine technologies and settings.

- Battery Electric Vehicles (BEVs): vehicles 100% are propelled by electric power. BEVs do not have an internal combustion engine and they do not use any kind of liquid fuel. BEVs normally use large packs of batteries in order to give the vehicle an acceptable autonomy.
- Plug-In Hybrid Electric Vehicles (PHEVs): hybrid vehicles are propelled by a conventional combustible engine and an electric engine charged by a pluggable external electric source. PHEVs can store enough electricity from the grid to significantly reduce their fuel consumption in regular driving conditions.
- Hybrid Electric Vehicles (HEVs): hybrid vehicles are propelled by a combination of a conventional internal combustion engine and an electric engine.
- Fuel Cell Electric Vehicles (FCEVs): these vehicles are provided with an electric engine that uses a mix of compressed hydrogen and oxygen obtained from the air, having water as the only waste

resulting from this process. Although these kinds of vehicles are considered to present "zero emissions".

- Extended-range EVs (ER-EVs): these vehicles are very similar to those ones in the BEV category. However, the ER-EVs are also provided with a supplementary combustion engine, which charges the batteries of the vehicle if needed.

CONCLUSIONS

In this paper, we analyzed the types of EVs, the technology used, the advantages with respect to the internal combustion engine vehicles, the evolution of sales within the last years, as well as the different charging modes and future technologies. Regarding EVs, batteries are a critical factor, as these will determine the vehicle's autonomy. We analyzed several kinds of batteries, according to these features. We also presented the possible technologies that can be used in the future, such as the graphene, which is expected to be a solution that enables the storage of higher amounts of power, and charge in shorter periods of time. The development of batteries with higher capacities will also favor the use of the fastest and most powerful charging modes, as well as better wireless charging technologies. The creation of a unique connector that can be globally used is another aspect that could benefit the deployment of electric vehicles.

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