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Analysis of Electric Vehicle (A Review)

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Abstract—*Since the past few decades IC Engines have been the standard prime movers for most commercial & domestic applications. The rise in demand for IC Engines also increased the demand for crude oil, a commodity that is present in few countries around the world in excess while being scarce in others, thus they relied on importing it. Expansion in the volumes of IC Engine powered vehicles and their widespread usage in the past few decades have slowly caused degradation of our environment due to release of harmful gases and pollutant as bi-products. This has lead to the increase in popularity of electric vehicles that are powered by electricity. A commodity which need not be always imported and can also be produced from green & renewable resources thus promoting independence from imports of crude oil. This report contains critical examination & detailed investigation about the EV. It concludes with a short note on the future prospects of the EV.*

INTRODUCTION

1. HISTORY OF ELECTRIC VEHICLES

Thomas Davenport was an American inventor who is credited for building the first practical electric vehicle (a small locomotive which ran on a track) in the mid 1830's. In the following years many new Electric vehicles were invented and launched, mostly in USA. The decline in use and production of the electric vehicle occurred in the 1920s.

2. PRESENT SCENARIO OF ELECTRIC VEHICLES

In present times, electric cars are becoming more popular since they have greater range per charge and lower charging duration but they are still expensive because of high component cost.1

3. CONSTRUCTION OF AN ELECTRIC VEHICLE

The electric vehicle consists of a rechargeable battery, electric motor, electronic controller (for speed control) & simple transmission for sending power to wheels.

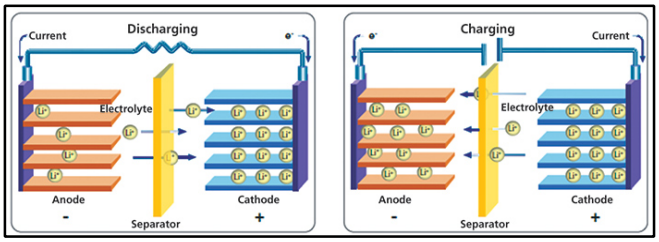
4. MAIN PARTS OF AN ELECTRIC VEHICLE AND THEIR FUNCTIONS

4.1 Battery

Rechargeable batteries are used as energy storage devices. They supply DC electricity

4.1.1 Lithium Ion Battery

These are the most commonly used batteries in electric cars. It consists of an electrolyte, cathode and anode. Electron transfer occurs b/w anode & cathode for discharging and energy is released. The reverse occurs during charging of battery



[3.]

Figure 1: Working of Li-ion Battery

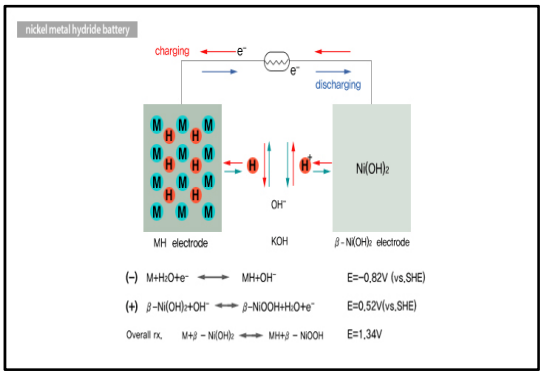
Table 1: Advantages & Disadvantages of Li-ion battery

Advantages of Li-ion Battery	Disadvantages of Li-ion Battery
High energy density,	Risk of explosion due to over-charging/heating.
Low self discharge rate,	Expensive due to high production cost
Longer cyclic life	New and relatively immature technology.

4.1.2. Ni-MH Battery

They were used in older electric cars instead of Lead acid ones. It consists of a cathode & anode immersed in electrolyte.

Release of electrons occurs due to reaction of electrolyte with electrodes during discharging. The exact reverse happens during charging of battery.



[4.]

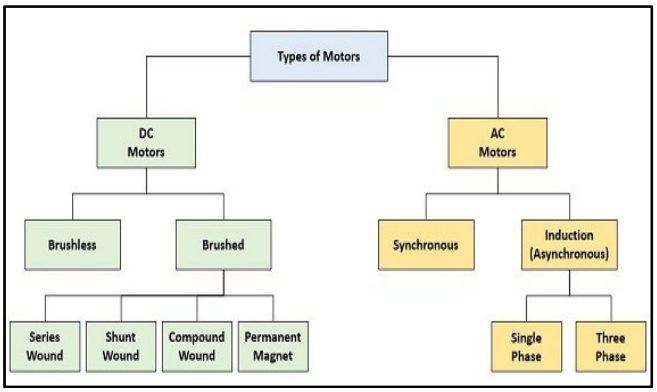
Figure 2: Working of Ni-MH battery

Table 2: Advantages & disadvantages of Ni-MH batteries

Advantages of Ni-MH Batteries	Disadvantages of Ni-MH Batteries
Higher energy density than lead acid battery.	Fast loss of energy due to high self-discharge.
Lower memory effect	Restrictions on battery storage

4.2 Electric Motor

Its used as a prime mover in electric cars, it converts elect. energy to mech. energy.



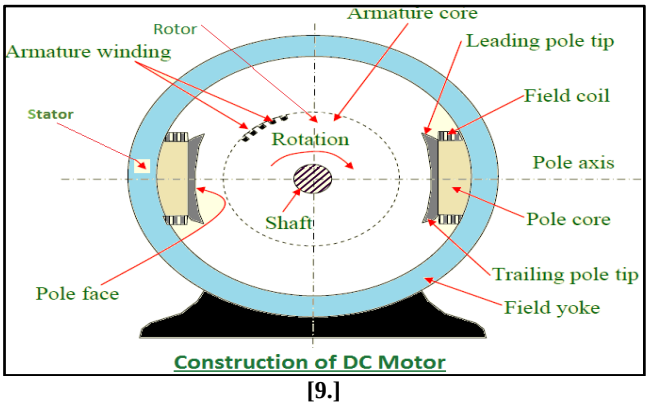
[9.]

Figure 4: Classification of Motor

Here are the different types of motors used in Electric vehicles:

4.2.1 Brushed DC Motors

These are the simplest motors & used in electric cars due to high starting torque.



[9.]

Figure 5: Cross-section of DC motor.

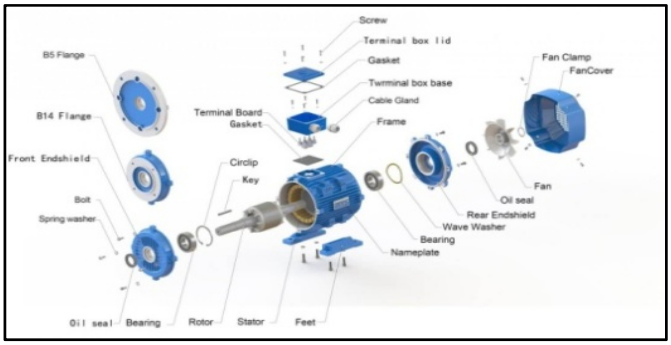
In this, the current carrying stator winding experiences a force due to its presence in a magnetic field and thus rotates, producing mechanical energy.

Table 4: Advantages & disadvantages of DC motor

Advantages of DC Motor	Disadvantages of DC Motor
High starting torque	High cost compared to AC motor.
Lower harmonic effect.	Higher maintenance cost.

4.2.2. AC Induction Motors

It works on the principle of electromagnetic induction and is cheap to produce hence its used in some electric cars. The consists of a stator and rotor, the rotor induces EMF & current in it hence rotor shaft turns.



[13.]

Figure 6: Constituents of an Induction motor.

Table 6: Advantages & disadvantages of Induction motor.

Advantages of AC Induction Motor	Disadvantages of AC Induction Motor
Simple and rugged construction.	Low starting torque
Low production cost due to simple construction.	Very high starting current, almost 10 times the value at full load.
Low maintenance cost.	Constant speed operation without use of electronics.

4.3. Power train

Hence, electric cars mostly use single-speed transmissions for delivering power and electronic speed controllers for varying speed. Differential units may or may not be used. Some arrangements for power delivery in electric cars are given below:

4.3.1 Central Drive

Its used in most front wheel drive electric cars as its relatively compact and simple as the major components like motor, transmission & controller are stacked upon each other to form a pillar. The motor powers the half axles using a single speed reduction gear and differential.

[28.]

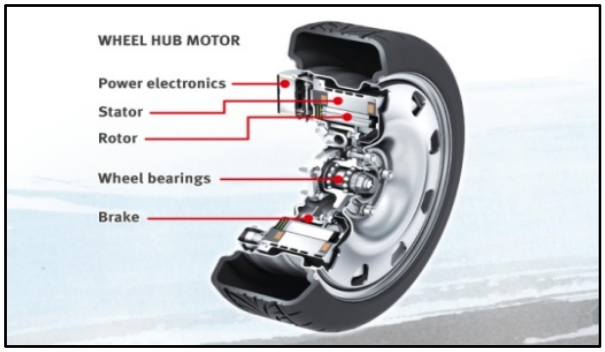
Figure 7: Central drive assembly

Table 7: Advantages & disadvantages of central drive

Advantages of Central Drive	Disadvantages of Central Drive
Occupies lesser weight & space.	Reduces driving pleasure.
Low production & maintenance cost of single speed transmission.	Efficiency of the system drops near boundary conditions.

4.3.2. Wheel hub drive or In-wheel drive

This is a popular arrangement for electric scooters and bicycles. It involves centrally fitting the motor in the wheel's hub.



[14.]

Figure 8: X-section of wheel hub drive

Table 8: Advantages & disadvantages of wheel hub drive.

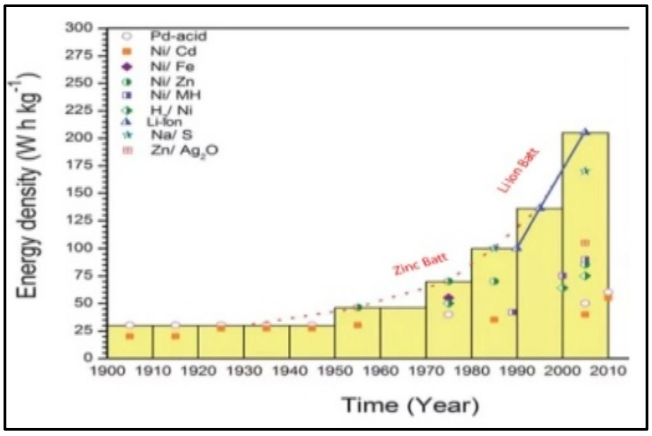
Advantages of Wheel Hub Drive	Disadvantages of Wheel Hub Drive
Space, cost & weight saving due to absence of many transmission components.	Greater complexity as all the electronics are present in the wheel hub.
Allows for independent control of wheels.	Prolonged use of the vehicle on bad roads may cause physical damage.

5. ARGUMENTS AGAINST ELECTRIC CARS

Electric cars are beneficial for the environment but they're in their nascent stages. Many barriers & challenges still surround the electric car, which engineers & researchers must overcome to ensure their large scale adoption. Below are a few barriers and critics of electric cars and how they are proven wrong with facts.

5.1. Range & battery life

This is one of the most important factors as the success of EV's depends upon the advancements in battery technologies.



[15.]

Figure 9: Projected growth in energy density of batteries each decade.

As can be seen on the above graph, the energy density of batteries is continually on the rise. This resulted in a greater range per charge and the energy density will continue to rise over the next decade. Regenerative braking is a popular technology used in electric vehicles. It aims at harnessing the energy lost during braking by using the motor as a generator

Use of this technology results in increased efficiency & increase in range however its negligible.

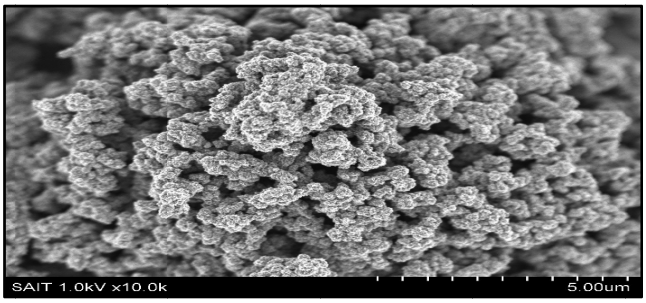
5.2. Charging duration

This refers to the time taken for the batteries to charge from 0% to 100%. This has always been a major issue of electric cars as charging times were notably long.

While conventional charging requires up to 5 hours, fast charging achieves the same result in s single hour. [17.] Fast charging involves boosting the input current so as to increase the rate of reaction in the battery. That's an 80% improvement in charging time, although the fast charging time varies from vehicle to vehicle since every manufacturer has a different design, etc.

Recently, a team of researchers at the 'Samsung Advanced Institute of Technology' (SAIT) developed a "**graphene** ball," a unique battery material that enables a 45% increase in capacity, and five times faster charging speeds than standard lithium-ion batteries. [18.] In theory, a battery based on the "graphene ball" material requires only 12 minutes to fully charge. Additionally, the battery can maintain a highly stable 60 degree Celsius temperature, with stable battery temperatures particularly key for electric vehicles.[19.]

Here's a microscopic image of 'Graphene balls' used in the battery



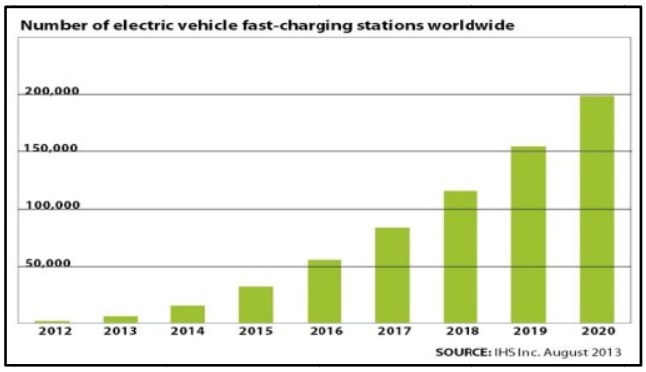
[20.]

Figure 11: Microscopic view of Graphene balls

This recent development by Samsung SDI hints a promising future for Lithium-ion battery technology.

5.3. Charging Infrastructure

This is a supplementary issue which affects the success of EV's indirectly. Electric cars are criticized for having less charging stations however this situation is improving globally year on year now.



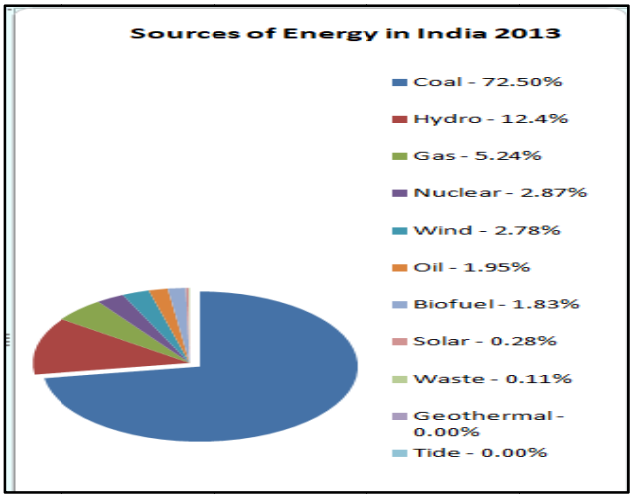
[21.]

Figure 12: Projected rise in no. of electric car fast-charging stations globally

As you can see in the data above, the no. of charging stations around the world have increased by a significant 32% in the past 3 years and it will further increase by 2020.

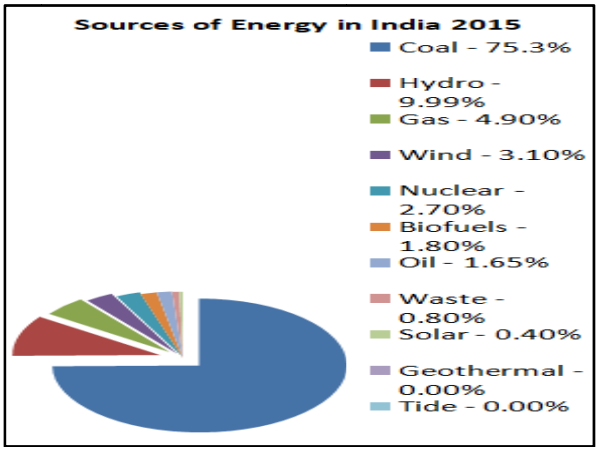
5.4. EV's shift emissions from the tailpipe to the power plants

This has been one of the most criticized topic regarding electric vehicles. Since they increase the demand for electricity being produced by non-renewable and polluting means they are ultimately equally polluting the environment. While this statement is true, it remains so for less than a decade more. This is because the dependence on non-renewable sources of energy is reducing due to their demerits and alternatives like renewable energy are gaining popularity.



[26.]

Figure 13. Various sources of electricity in India and their share in the total output as of 2013.



[27.]

Figure 14. Various sources of electricity in India and their share in the total output as of 2015.

As the statistics portray, the share of renewable energy sources like Solar, Wind, Hydro, Geo-thermal etc in the total capacity has been steadily increasing over the few years although marginally it will increase with reduction in cost of components for harnessing the electricity.

5.5. Cost

This is by far the biggest factor that has differentiated electric cars from conventional ICE cars. While electric cars have a very low maintenance cost, what sets them apart is a rather high initial cost.

Lets do a cost analysis of an electric car and its similarly priced petrol counterpart. The 2 cars considered for the analysis are Maruti Ignis Petrol AMT & Mahindra E2O Plus. Both are 4 door sub 4 meter hatchbacks sold in India

Below are the costs involved with ownership of an Electric car.

Mahindra E2O Plus P4	
Price	Rs 6.26 lakh
Engine / Motor	19kW electric
Transmission	2-speed direct drive
Power	26 bhp @ 3500 rpm
Torque	70 Nm @ 1000 rpm
Mileage	NA
Range per charge / tank	110 km
Fuel cost	Rs. 5 per unit
Full tank / charge cost	Rs. 50
Cost per km	Rs. 0.45
Cost for 12,000 km / year	Rs. 5,400
Cost for 60,000 km in 5 years	Rs. 27,000
Service cost / year	Rs. 1500
Service cost in 5 years	Rs. 7,500
Battery replacement in 5 years	Rs. 2.5 lakh
TOTAL RUNNING COST	**Rs. 2,84,500**
Without battery replacement	Rs. 34,500

[23.]

Figure 15: Various costs involved in ownership of a 'Mahindra E2O' electric vehicle

Below are the costs involved with ownership of a similar Petrol car.

Maruti Ignis Zeta Petrol AMT	
Price	Rs. 6.30 lakh
Engine / Motor	1.2 litre petrol
Transmission	5-speed AMT
Power	82 bhp @ 6000 rpm
Torque	113 Nm @ 4000 rpm
Mileage	20.89 kmpl
Range per charge / tank	668 km
Fuel cost	Rs. 67 per litre
Full tank / charge cost	Rs. 2,144
Cost per km	Rs. 3.20
Cost for 12,000 km / year	Rs. 38,400
Cost for 60,000 km in 5 years	Rs. 1,92,000
Service cost / year	Rs. 8,000
Service cost in 5 years	Rs. 40,000
Battery replacement in 5 years	Rs. 3,000
TOTAL RUNNING COST	**Rs. 2,35,000**
Without battery replacement	Rs. 2,32,000

[24.]

Figure 16: Various costs involved in ownership of a 'Maruti Suzuki Ignis' petrol vehicle

The biggest differentiation factor between both of them is the battery replacement cost which is very high and recurring every 5 years in the Mahindra E20 but is very low in the Maruti Suzuki Ignis.

However, Electric vehicle battery cost dropped 80% in 6 years down to $227/kWh – Tesla claims to be below $190/kWh.[25.] Given this trend, it's safe to assume that battery prices will drop further. Hence, the 'battery replacement cost' is slated to drop in a period of 5 years.

6. FUTURE OUTLOOK OF ELECTRIC VEHICLES

Since electric cars were popularized recently and are gaining momentum, they have a wide scope of improvement and are constantly evolving with newer features.

Below are some technologies that I consider will be inducted into electric cars in the near future.

6.1 Autonomously driven cars

These are also know as self-driving cars as they can operate without or with minimal human intervention. Such cars are commercially available in some markets although are very expensive.

These autonomously driven vehicles use a GPS unit, a no. of IMU's i.e. internal measurement unit sensors & a complex laser based system called LIDAR i.e. Light detection and ranging. All these components work in harmony to propel the vehicle towards its destination with little or no human intervention.

These vehicles work in a pre-determined loop. Here is a diagram of the loop.

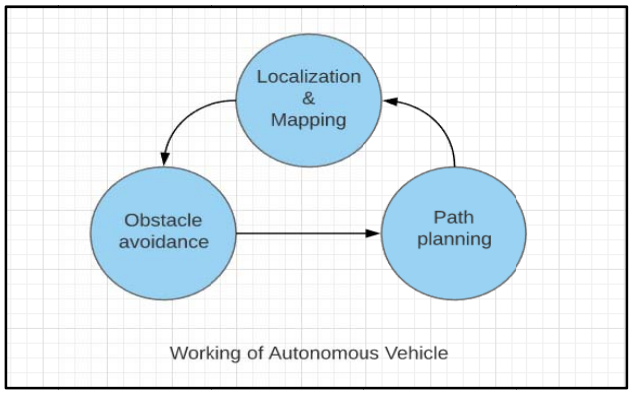


Figure 18: Working of an autonomous vehicle.

Localization & mapping is the first stage wherein all the components work in harmony to create a virtual map of the vehicle's surrounding and its exact location in the surrounding. Secondly, comes obstacle avoidance. This involves scanning the virtual map created in the previous phase and identifying/detecting various obstacles in its vicinity. Since the virtual map contains an approximate location of all stationary and moving obstacles in the vehicle's field of vision, its used along with a camera and an on-board directory of obstacles having pre-determined shapes and sizes.

Path planning is the final process. It involves utilizing the vehicle's virtual map to safely navigate it to its destination while avoiding all obstacles and complying with all traffic rules.

The loop of localization & mapping, obstacle detection, and path planning continuously repeats until the vehicle has reached its destination.

Table 10: Advantages & disadvantages of autonomously driven cars

Advantages of Autonomously driven cars	Disadvantages of Autonomously driven cars
Reduction in no. of road accidents.	Security & privacy concerns as car is vulnerable to hackers.
Better passenger comfort due to zero intervention.	Loss of jobs and livelihood for drivers and chauffeurs.
Mobility for elderly & disabled people who can't drive due to health constraints.	Very high initial cost due to technical complexity.

6.2 Connected cars

Connected cars are a small constituent of the larger IoT i.e. 'Internet of Things'.

Similarly, a connected car is a car that's connected to the internet seamlessly and can utilize this connection for doing various things. The scope and possibilities of connected cars are numerous. The main aim of connected cars will be to tackle the following three factors which influence transportation:

- Mobility – It will allow all cars on a road to have access to information about that road based on feedback & communication of other cars so that smarter decisions pertaining to navigation can be made thus reducing travel time & improving comfort.
- Safety – Nearly 1.3 million people die in road crashes each year, on average 3,287 deaths a day. An additional 20-50 million are injured or disabled.[31] Connected car technologies will inform and warn other cars coming in that direction about changing weather conditions or occurrence of any accident or natural disaster thus granting a foresight.

Below are some pros & cons of this tech.

Table 11: Advantages & disadvantages of connected cars.

Advantages of connected cars	Disadvantages of connected cars
Improved safety due to prediction of hazards & accidents.	Security concerns as such cars are vulnerable to malicious hacking.
Improved road traffic management due to better communication among cars.	Lack of adequate supportive infrastructure will prevent its development.

6.3 Self charging electric cars

These are electric cars capable of charging themselves when in motion or not, without any external energy source. Regenerative braking, as explained earlier, is an example of this technology. Solar charging electric cars are another example, they had solar panels on their roof which would generate electricity during the day. Although, this was discarded due to its low cost-effectiveness. Another technology is under research currently, it's called 'wind powered electric cars'. This involves placing a turbine coupled with generator on the car's exterior. When the car attains a certain velocity, due to force of wind the turbine rotates and generator generates electricity.

This technology was proven by a Chinese farmer named Tang Zhengping. He built a single seating car, 1m high and 3m tall which was propelled forward a motor and 2 batteries which would be charged by a wind turbine and 2 solar panels. The turbine was at the front end. When the car exceeded 40 mph, the wind would strike the turbine vanes and cause the turbine to rotate thus turning the generator shaft and producing electricity. The panels would also continuously be producing some extra electricity whenever under bright sunshine. This electricity would be stored one of the 2 batteries. When one battery drains the other would be used to power the motor.

[32.]

Figure 19: Wind powered electric car made by a Chinese farmer

7. CONCLUSION

To conclude, despite being a century old electric cars didn't evolve & commercialize exponentially due to fierce completion from their ICE counterparts but due to rising environmental & economic concerns in the recent times, electric cars are becoming popular and are gaining momentum. Many aforesaid technologies explained by me in this paper are evolving continuously and can potentially be outdated or replaced by better one in the future.

Considering the reduction in cost of various components due to high rate of technological advancements & the supportive opinion of people towards electric cars in general, Electric cars may see massive commercialization in the coming decade/s.

8. ACKNOWLEDGEMENTS

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