

## INTRODUCTION

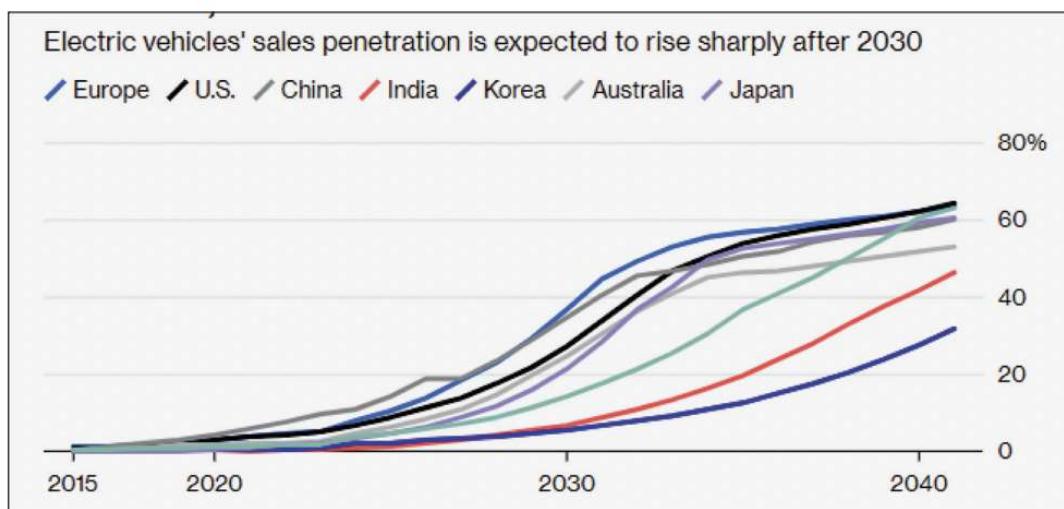
One of the greatest developments of modern technology is the development of Internal Combustion Engine vehicles. Automobiles have made great contributions to the growth of modern society by satisfying its needs for mobility in everyday life. And the rapid growth and development of the automobile industry have evoked the progress of human society to a highly expanded industrial band, making it the backbone of the world's economy and employing the greatest share of the working population.

However, the rapid growth of internal combustion engine vehicles and their use has caused and continues to cause many serious threats to the environment and the human race. Environmental pollution like air pollution, global warming and meteoric depletion of earth petroleum resources are now the problems of supreme concern. More and more rigorous emissions and fuel consumption regulations are invigorating interest in the development of safe, clean, and high-efficiency transportation. And from that, it has been well recognized that electric, hybrid electric, and fuel cell-powered drivetrain technologies are the most encouraging solutions to the problem of transportation in the future. [10]Therefore, to meet the comprehensive technological changes many Indian and American Engineering schools have introduced academic training on electric vehicles (EV's) and advanced vehicle technologies.

[10]The research and development from recent decades in clean, high efficiency and safe transportation have proposed to replace conventional vehicles with Electric Vehicles and hybrid electric vehicles in the future. Unlike vehicles with combustion engines, electric vehicles do not produce any harmful exhaust gases during propulsion. This makes electric vehicles and hybrid electric vehicles more environmentally friendly than internal combustion engine vehicles. Electric vehicles (EV's) use an electric motor for propulsion and the energy sources for the traction includes fuel cells, chemical batteries, etc. [10]Electric vehicles have a good deal of advantages over conventional combustion engine vehicles like the absence of emissions, high efficiency, petroleum independence, and safe and effortless operation. Earlier, Electric vehicles, on the whole, were mainly converted from the existing internal combustion vehicles by replacing the fuel tanks with a battery pack and an electric motor drive while holding on to the other components. Electric vehicles come in a wide range of technology two of which are hybrid electric vehicles (HEV's) and plug-in electric vehicles (PEV's). Hybrid electric vehicles have a battery which provides the vehicles with an extra boost of power along with the fuel tank as in an internal combustion engine. Plug-in electric vehicles, on the other hand, are solely powered by a battery and need to be charged by plugging into a power supply. Plug-in electric vehicles are further categorized into plug-in hybrid electric vehicles (PHEV's) and full battery electric vehicles (BEV's).

The electric vehicle market currently is very small in India. And with the rapid increase in the Indian automobile market, a promising channel towards improving air quality, economic growth and safety are Electric vehicles. The government of India recognises Electric vehicles as a sustainable mobility policy in a move for a cleaner environment and hence targeting for a big EV push in the country. The government of India has undertaken multiple initiatives to promote electric vehicle manufacturing in the country and aims at 10% of the newly registered vehicles to be electric ones by 2025.

The figure[5] below shows the adoption and sales penetration of electric vehicles worldwide.

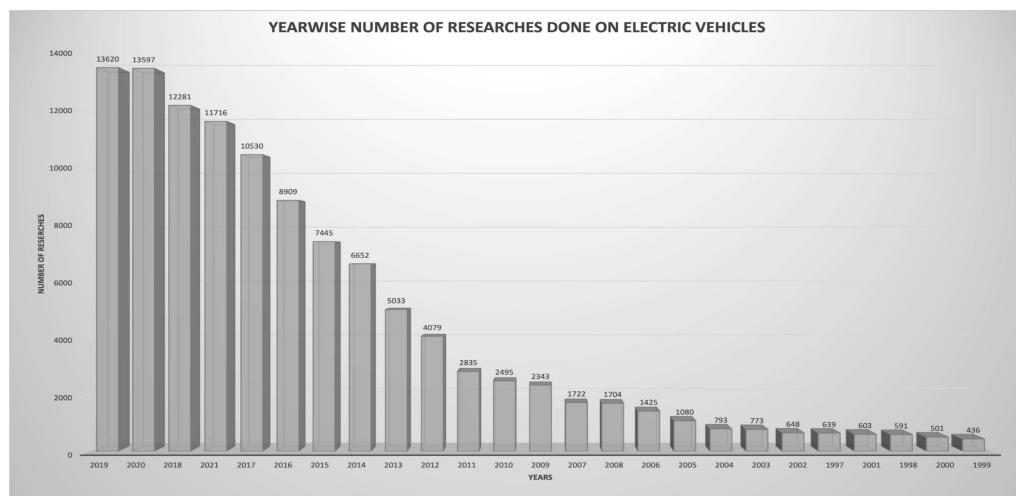


[5]Fig 1. Projection of Electric Vehicles (coloured lines)

This study mainly focuses on full battery electric vehicles for their contrasting features. One of the most important features of an electric vehicle is its powertrain system which generates the power required to move the vehicle and deliver it to the wheels. This research work carried out at Evoka Technologies as an intern was based on designing and implementing the powertrain including the battery pack of the concept electric vehicle being designed by Evoka Technologies. Evoka Technologies is a company centred on designing and implementing unique electric vehicles. This report deals with the modern technology and methodology of design of electric vehicles with faculty instructors and student interns in Electronics and Mechanical Engineering from our college.

## LITERATURE REVIEW

Numerous studies have been done internationally to understand consumer preference, designing better batteries, and better powertrain designing, energy generation, etc. for electric vehicles globally. Of which the factors include the cost of the EV, time to recharge the battery, battery cost and driving distance per charge, materials for solid-state batteries. [1]The U.S. Department of Energy (DOE) is working with its partners in the public and private sectors to research, develop, and install technologies that enhance the performance of electric vehicles. The below statistical data shows the number of searches done on electric vehicles so far. (figure2)



*Fig 2. Number of researches done on electric vehicles (source from the web of science)*

There has been significant progress in numerous aspects of the development of electric vehicles and the use of technology. Comparably, the efforts on research have also increased which has caused a significant increment in new jobs related to electric vehicles. The government of India recognises Electric vehicles as a sustainable mobility policy in a move for a cleaner environment and hence targeting for a big EV push in the country. India's commitment to containing pollution has increased gradually and by this, the adoption of Electric vehicles in India have also increased. One such research carried out by [2]Sanguesa, J.A. and the team reviewed the advantages of electric vehicles regarding battery technology trends and charging methods since the fundamental aspect of an electric vehicle is its battery. There arise several questions on today's electric vehicle battery trend and based on the [3]industry's current experience with lithium-ion batteries, the MIT researchers and their colleagues Gerbrand Ceder, the Daniel M. Tellep Distinguished Professor of Engineering at the University of California at Berkeley, suggest three broad questions that can help identify constraints on future scopes for better material selection for battery designing. Few studies also show the increasing adoption of electric vehicles across the world, for example, one such study by [4]Muratori and Mai include an overview of the status of the light-duty electric vehicle market and its scopes for future adoption. It also reviews the cost and performance evolution for the batteries, power electronics and electric machines that are the key components of an electric vehicle.

One such article by [5] Anil Khurana in A Study on the Adoption of Electric Vehicles in India: The Mediating Role of Attitude states the different problems and factors that affect a consumer's preference on the adoption of electric vehicles. Below is the list of some of the studies tabled down by him (figure 2).

Authors	Study Variable	Attributes
Bahamonde-Birke and Hanappi (2016), Helveston et al. (2015), Mabit, Cherchi, Jensen, and Jordal-Jørgensen (2015), Peters and Dutschke (2014), Rasouli and Timmermans (2016), Valeri and Danielis (2015), Barth, Jugert, and Fritzsche (2016), Beck, Rose, and Greaves (2016), Adepetu and Keshav, (2015), Plötz, Funke, Jochem and Wietschel (2017)	Driving range	Technology
Axsen, Bailey, and Castro (2015), Rasouli and Timmermans (2016), Moon, Park, Jeong, and Lee (2018)	Charging time	
Valeri and Danielis (2015), Bockarjova and Steg (2014), Jensen, Cherchi, and Mabit (2013)	Charging station	Infrastructure
Chorus, Koetse, and Hoen (2013), Glerum, Stankovikj, Thémans, and Bierlaire (2014), Wang, Li, and Zhao (2017)	Financial incentives	Policy

*Fig 3. Various studies on electric vehicles*

The basic difference between an electric vehicle and a hybrid electric vehicle is that an electric vehicle exclusively runs on the electric energy stored in the battery and the hybrid vehicle runs in the combination of conventional fuel and electric energy. Similar [6] research by Sonali Goel provides an overview of the studies of Electric vehicles, Hybrid Electric vehicles, Plug-in-Hybrid Electric vehicles and Battery Electric Vehicle penetration rates into the market and discusses their different modelling approach and optimisation techniques, which also provides a tabular format (figure 3) of differences between electric and hybrid vehicles.

	Electric Vehicle	Hybrid Vehicle
<b>CO<sub>2</sub> Emission</b>	Low	Medium(50–60% of Internal Combustion Engine)
<b>Price Range</b>	High	Similar to Internal Combustion Engine
<b>Fuel Usage</b>	None	40–60% of Internal Combustion Engine
<b>Charging</b>	Required	Not Required
<b>Equipped Charging facility in India</b>	Low	High
<b>Powered by</b>	Electric Engine	Internal Combustion Engine and Electric Engine

[6] Fig 4. Difference between electric and hybrid vehicles.

Based on these researches Evoka Technologies focuses on designing and manufacturing electric vehicles (both 2 wheeler and four-wheelers) with cell-powered drivetrains of minimum emissions, safe, clean and high-efficiency transportation. With compact cell design, Evoka technologies aim to design an efficient electric vehicle that can store more energy and is lightweight with maximum consumer adoption.

(figure 5) shows the statistical data on the number of electric vehicles both battery electric vehicles and plug-in electric vehicles in use as of 2020 in various countries, from which China is the country with the most number of battery electric vehicle using country followed by the U.S. Whereas, (figure 6) shows the sales of an electric passenger vehicle by manufacturers in India in the year 2021, where TATA leading the chart with followed by MG marque.

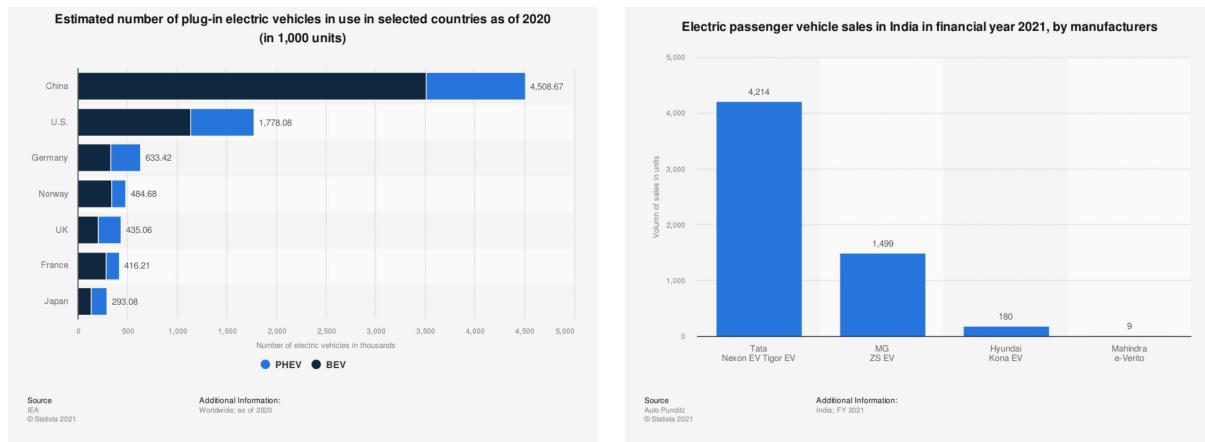


Fig 5,6. Source from Statista

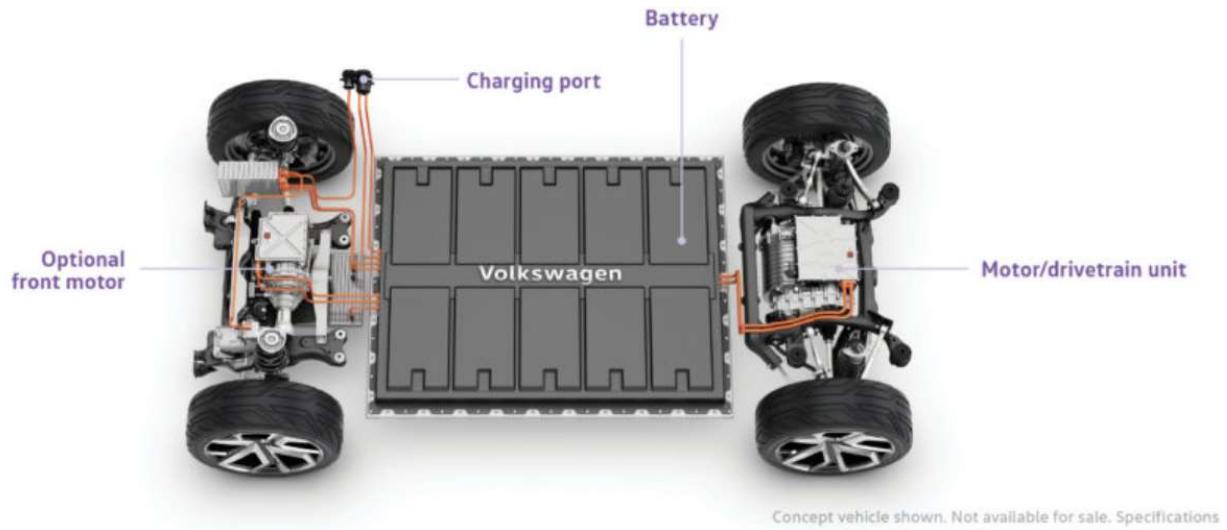
## DETAILS ABOUT THE STUDY/ INTERNSHIP

This report primarily focuses on the research, design and development of the powertrain of an electric vehicle. [9] The electric propulsion systems are the heart of electric vehicles. The major components of a powertrain (figure 8) of an electric vehicle include some important core parts such as a battery pack, electric motor, DC-AC converter, DC-DC converter, and thermal management system. Apart from that, there are multiple software and hardware components in an electric vehicle powertrain such as an Electronic control unit (ECU). It is an embedded system in a transport vehicle that controls electrical subsystems within it. There are various small ECU's in an Electric vehicle that performs some specific functions. The communication between several ECU's is carried over CAN protocol of communication. [7] Every electric vehicle needs an energy storage system. Generally, battery electric vehicles use lithium-ion battery cells due to their high energy density, and many notable electric vehicle companies such as Tesla have their own lithium-ion battery manufacturing. [8] (figure 7) the table shows the comparison of lithium-ion battery energy density to other battery types.

Battery Type	Energy Density (Wh/kg)	Power Density (W/kg)	Cycle Life (charge/discharge cycle)
Lead Acid	30-40	120-200	200-300
NiMH	50-80	250-1000	300-500
Lithium-Ion	100-150	1000-1500	500-1000

*Fig 7. Characteristics of commonly used batteries in the eclectic vehicle*

Which makes lithium-ion batteries the best in use for any electronics, electric vehicles and various aerospace applications. Lithium-ion batteries have a high energy density, long life and low self-discharge. The lithium-ion battery has good high-temperature performance too. This means that the batteries hold a lot of energy for their weight, which is vital for electric cars. We have used lithium-ion cells for the battery pack in this project for the powertrain system. The below representational image of a powertrain platform displays various components of an electric vehicle powertrain system.



Representational image – MEB powertrain platform for electric vehicles by Volkswagen

*Fig 8. Source from <https://evreporter.com/ev-powertrain-components/>*

## OBJECTIVES

Identifying the electric vehicle concepts as the fundamental necessity of this study was the first step towards this internship project which included learning about basic steering principles and mechanisms, types of power steering and their mechanism, also training ourselves on different types of axles present and their uses in how the axle system houses the suspension of the vehicle and carries the steering mechanism. This study also included learning about different differential systems, their types and the principle behind the differential mechanism in a vehicle. Studying 3D modelling software like CATIA designing tool for designing and stimulating car motor, battery pack, and cell. With compact cell design, Evoka technologies aim to design an efficient electric vehicle that can store more energy and is lightweight which can result in maximum consumer adoption.

## METHODOLOGY ADOPTED FOR THE STUDY

We have considered various types of electric vehicles existing at the moment across the globe for this study. The study behind electric vehicles is to replace the conventional internal combustion engine vehicles with an electric motor that gets its power from the energy stored in the batteries. As with the growing technology the use of electric vehicles will increase in the forthcoming future making it a reason to develop effective and safe batteries and powertrains for EV's. This internship program involved extended and individualized support to each intern through daily and meeting with weekly work submissions.

## OBSERVATION

The urgent need to cut down carbon emissions is an expeditious move towards promoting electric mobility. [10]More and more rigorous emissions and fuel consumption regulations are invigorating interest in the development of safe, clean, and high-efficiency transportation. If these solutions surge as expected, the need for better methods for storing electrical energy will increase. Various researches are focusing on adapting today's lithium-ion battery to make versions that are smaller, safer, and can store more energy for their size and weight. To fill these gaps evoka came out with a very identical and compact cell design that would be safer, smaller and can store more energy.

## VEHICLE STEERING MECHANISM

[12]The vehicle steering principle can be understood by a basic principle, that is the principle of wheels, the perpendicular lines from the front wheels while the vehicle is at rotation should meet the rear wheel axis at a common point, this principle is called the principle of steering. That is for perfect steering, left and right wheel turning angles should be different. This steering mechanism in modern vehicles is carried out by rack and pinion joints mechanism which manages to steer the vehicles.

This can be understood by the below figure.

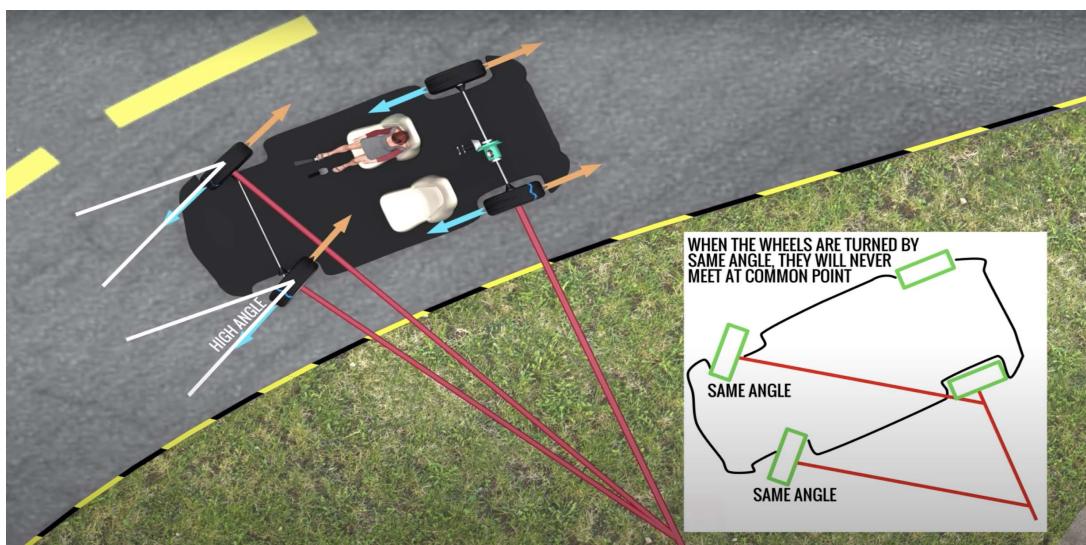


Fig 9. Source from youtube [12]

## KEY CONCEPTS OF ELECTRIC POWER STEERING

Power steering is an advanced form of the steering mechanism. The overall effort required by the driver is reduced in this system through a hydraulic or electric system. In power steering, the driver's input is read by the sensors on the steering column and relayed to the Electronic Control Unit (ECU). ECU analyses the inputs and sends an electric signal to the electric motor. The below (figure 10) image shows a schematic overview of a power steering and its components.

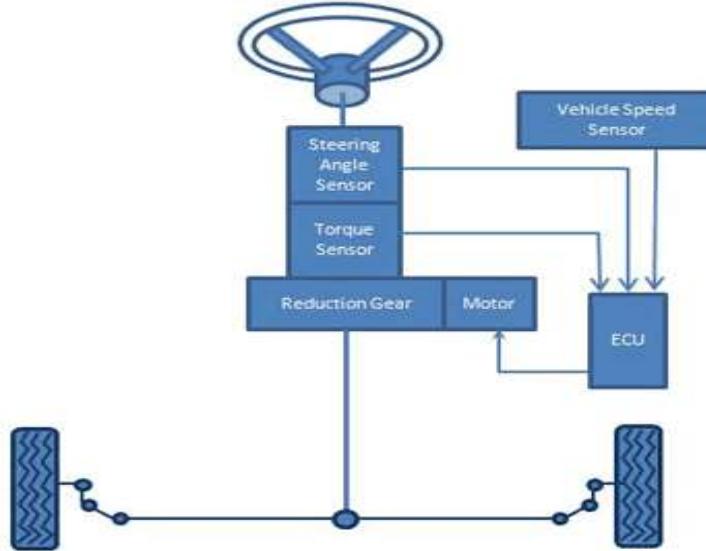


Fig 10. Source from the web

## DIFFERENTIALS AND CONCEPTS BEHIND THEM

To understand the principle of differentials, there is a very basic concept, that while taking a turn, say right turn, the left wheel has to travel more distance than the right wheel, and hence it has to rotate at a higher speed than the right wheel. [13] And if these wheels were connected by just a solid shaft, there would be slipping between the wheels to take a turn. And hence this is where the differential comes into action. The mechanism in the differential helps the wheels to rotate at different speeds with respect to each other while transferring power to both wheels. The image (figure 11) below shows a basic section of an open differential and its parts.

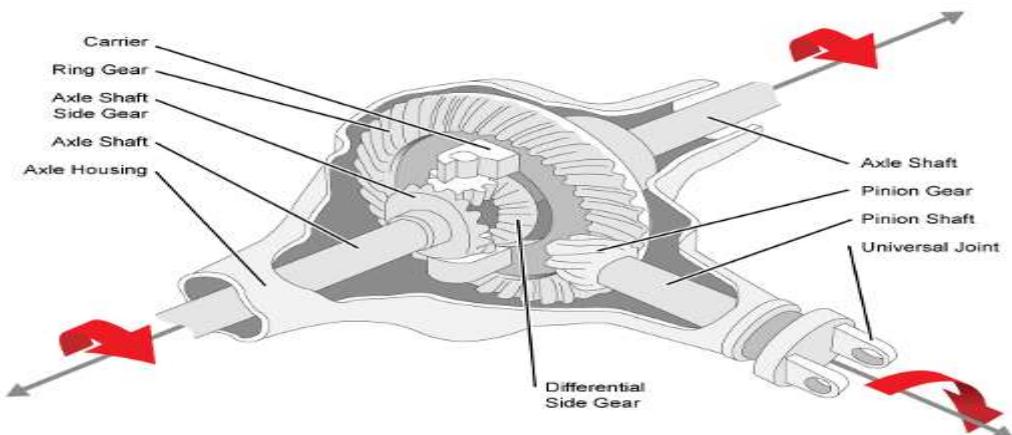


Fig 11. Source from Mathworks[14]

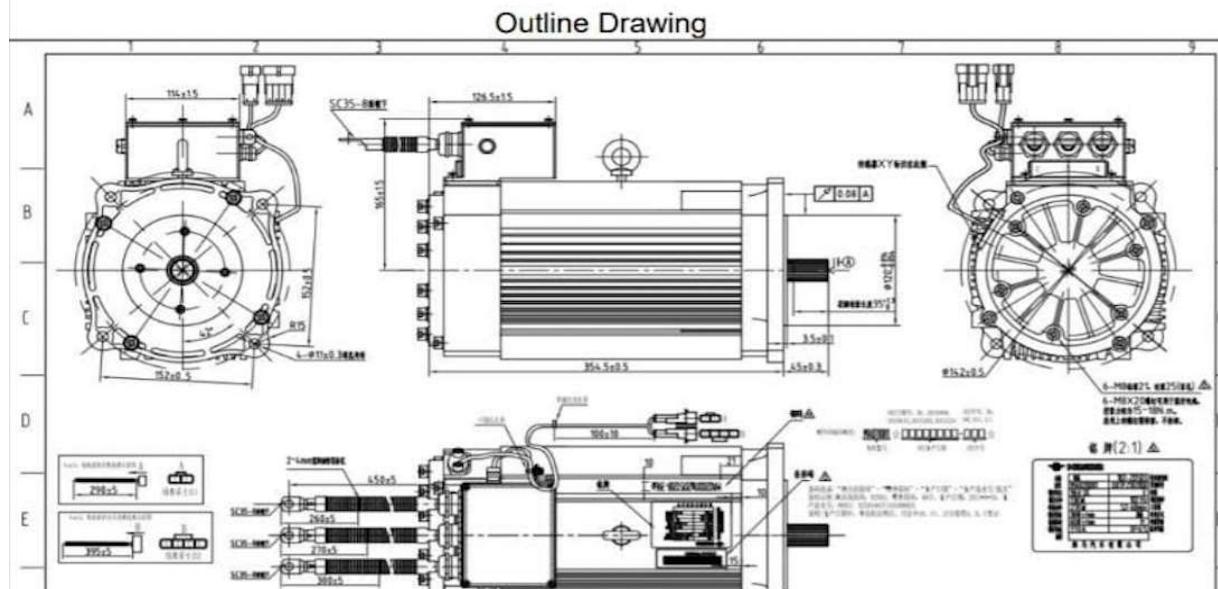
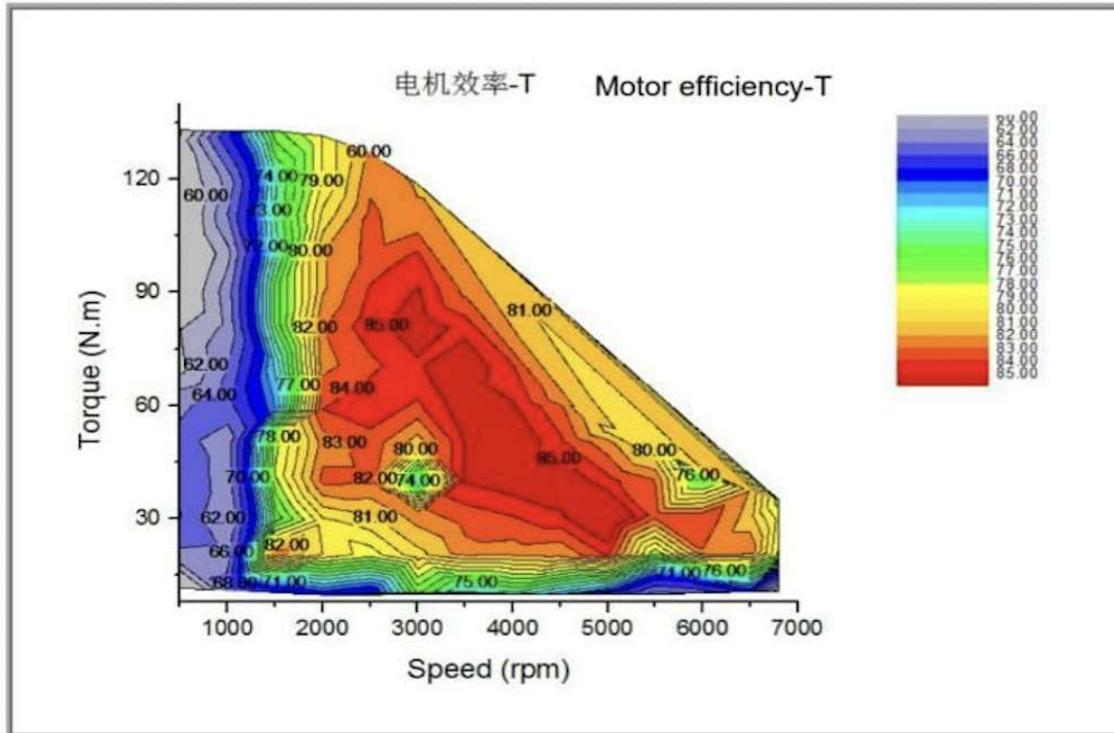
## FIELDWORK

- Learned CATIA designing tool for 3-D modelling.
- Designed car motor and differential.
- Designed cell washer and cell for the battery pack.
- Researched thermal management system of the battery pack.
- Designed a battery module for the four-wheeler prototype.
- Research and development of cell type for the battery pack.
- Rendered car design for the given 2-D car model.

## ANALYSIS

### MOTOR DESIGNING

The designing specifications and efficiency of the motor for the electric vehicle being built by Evoka Technologies having a total weight of 40kgs are in (figure 12) the 2D image provided by the company.



The result of the simulation is as in the below image (figure 13)

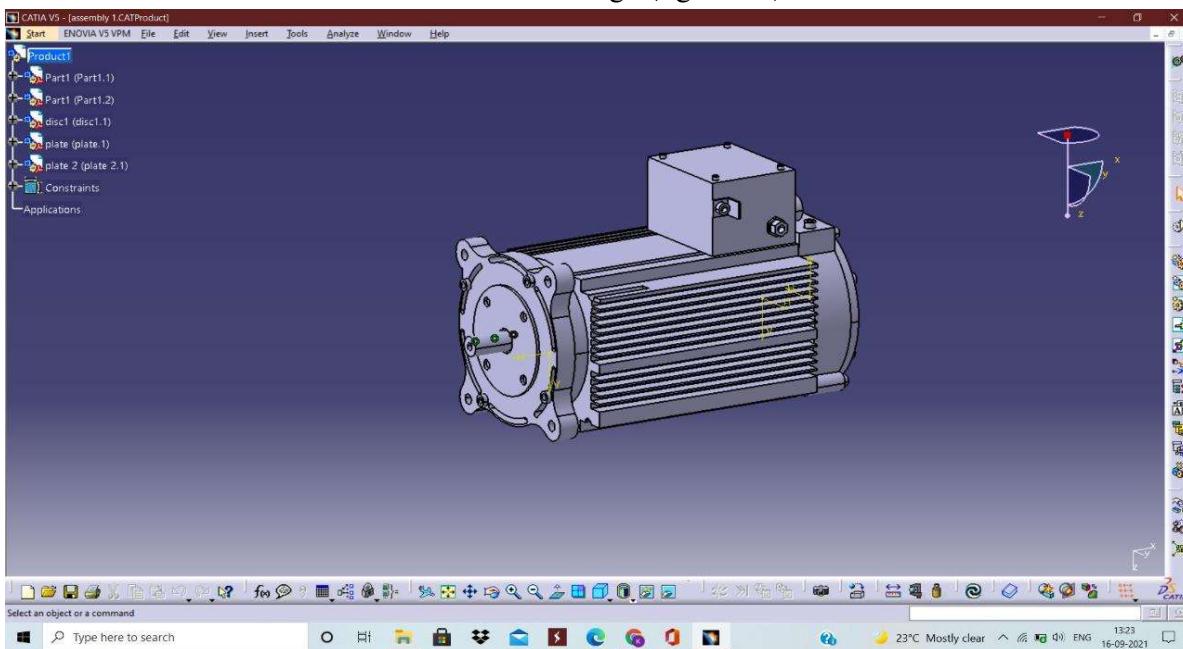


Fig 13. 3D Modelling of the motor via CATIA designing tool

## CELL DESIGNING

Most of the companies manufacturing electric vehicles have shifted towards lithium-ion batteries because of their high capacity and fast charging ability and various other advantages the cell designed by Evoka technologies is a compact cell design that can store a high amount of energy shown below (figure 14)

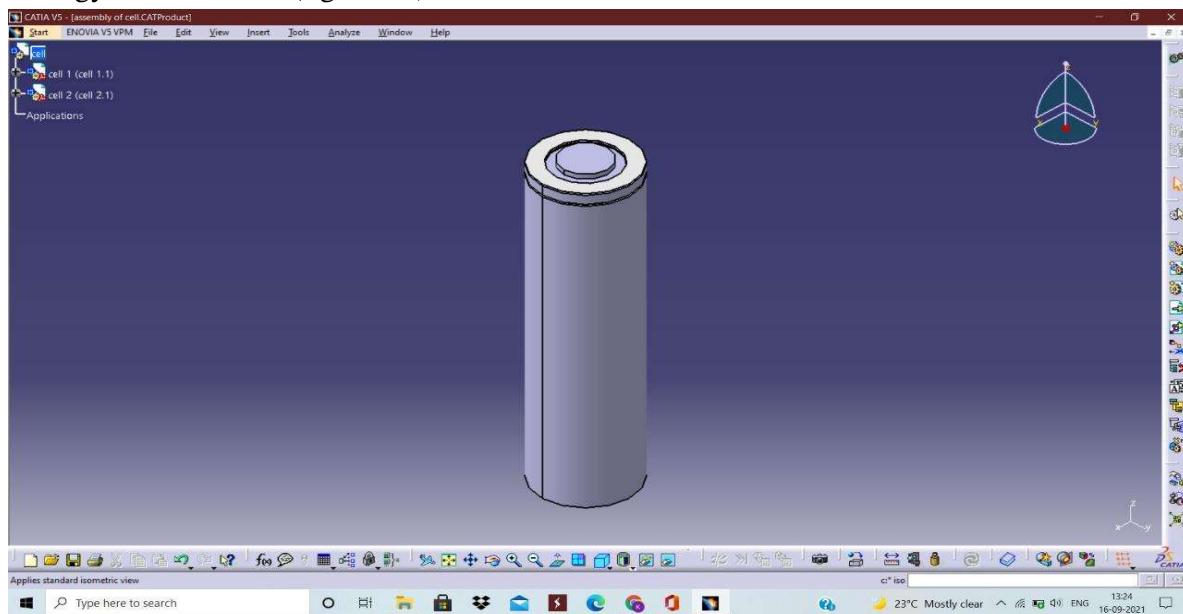


Fig 14. 3D Modelling of the cell for battery pack via CATIA designing tool

## BATTERY PACK DESIGNING

Evoka technologies built a battery pack with high cooling performance and with better structural safety. With the CATIA designing tool, the schematic cross-section of the battery pack with cell holders is as shown below (figure 15).

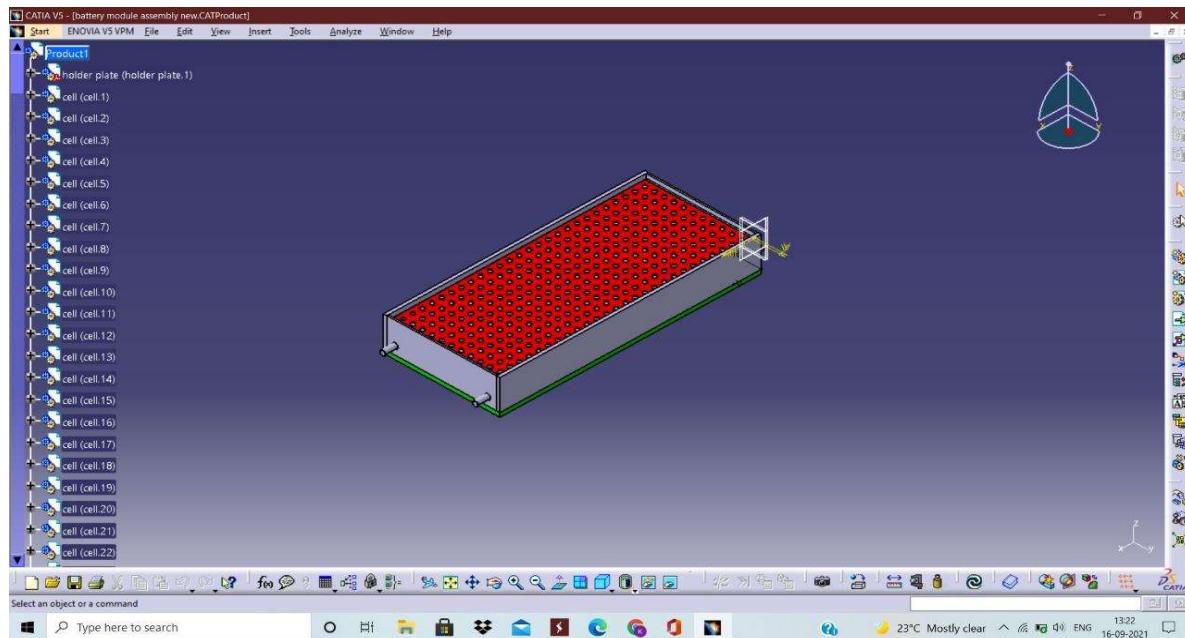


Fig 16. 3D Modelling of the battery pack via CATIA designing tool

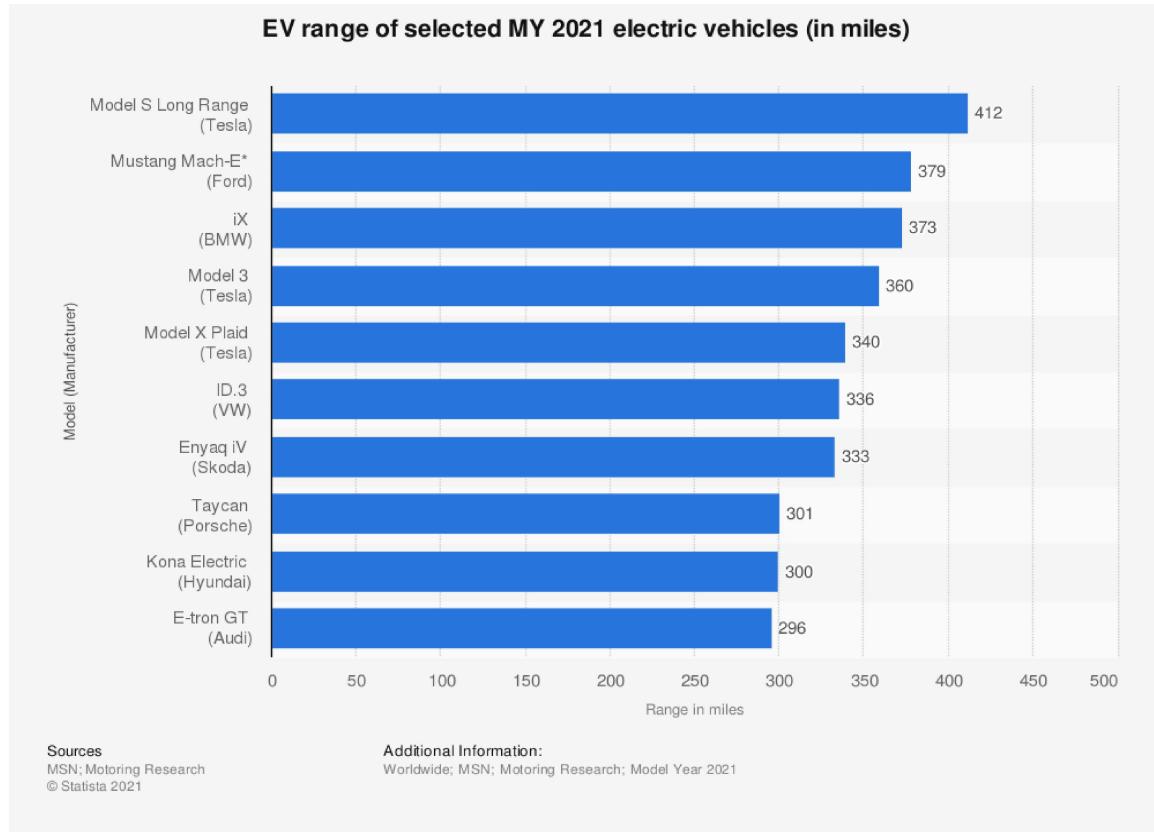
## CAR DESIGN

Evoka technologies came up with a very subtle yet simple car design. The below (figure 17) shows the 2D model of the car design which has been rendered via the Catia designing tool.



Fig 17. 2D Model of the car design

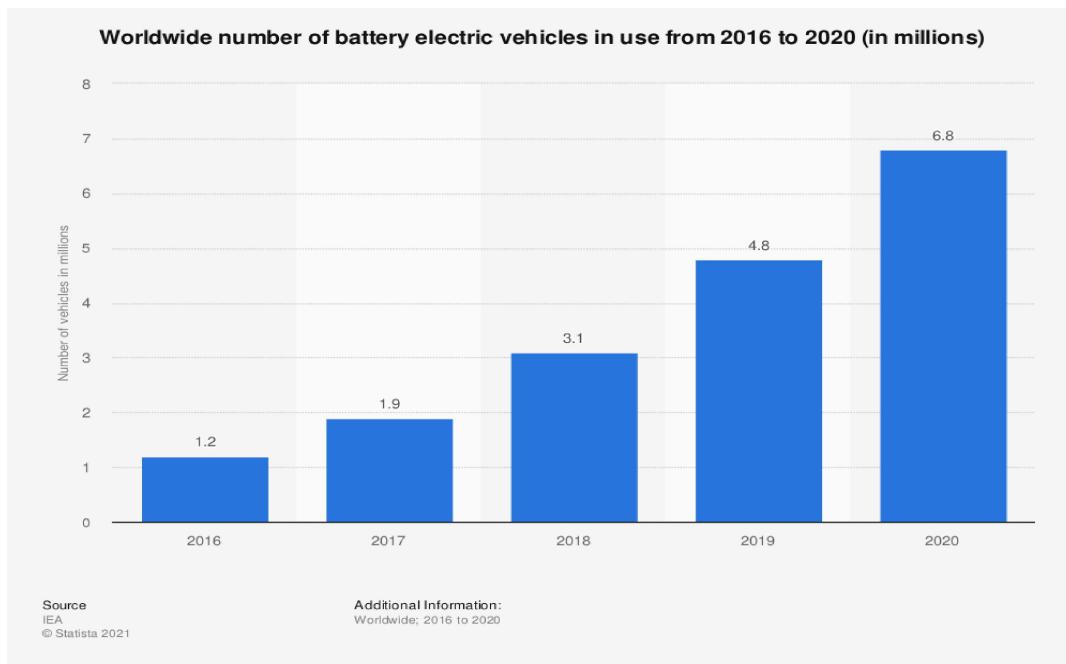
The electronic vehicle industry is rapidly evolving towards better and safer designs so that consumers prefer these electric vehicles for environmental safety. The lithium-ion cell for battery packs is drawing attention towards their various advantages like fast charging capability, safer, and has a high charge density. The below analysis (figure 18) shows the ranges provided by the top-selling electric vehicles (EV's) in the market.



*Fig 18. Ranges of various top-selling electric vehicles in the market*

## CONCLUSION

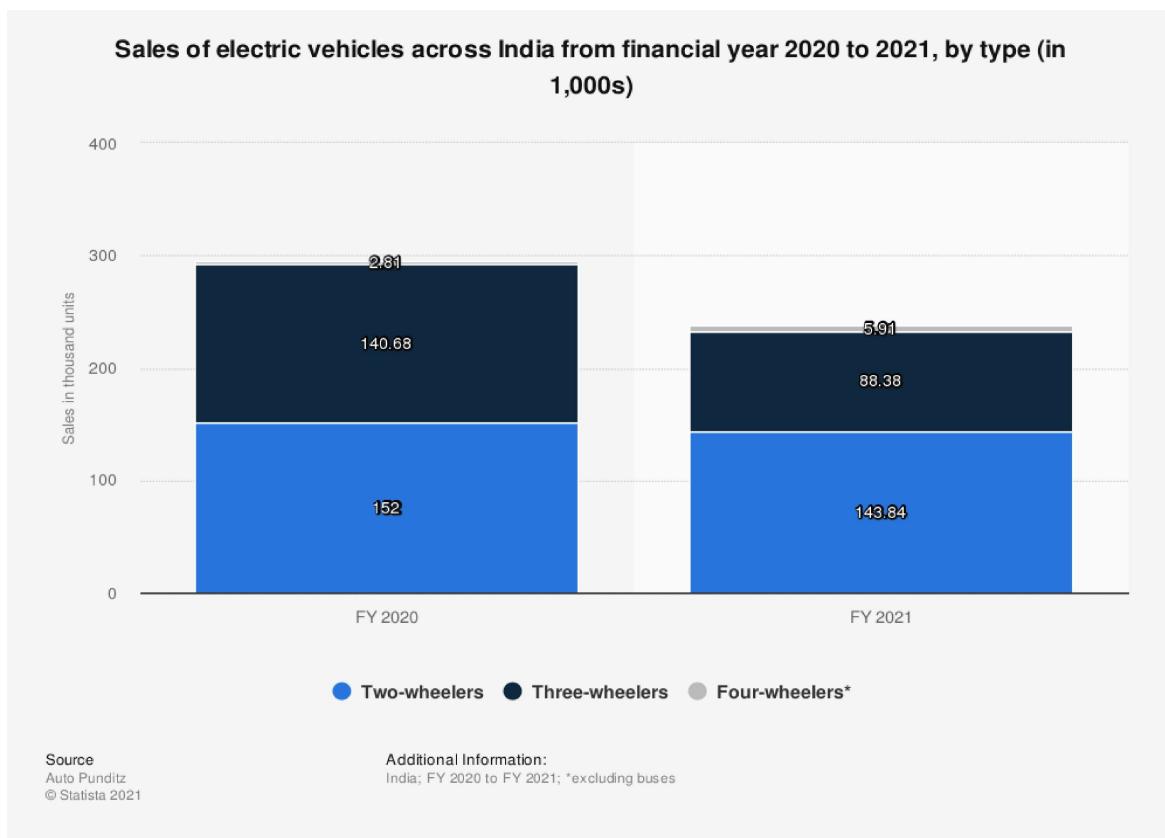
[6]The recent initiatives and various subsidies by the Indian Government will help push the e-mobility drive in India. Electric vehicles are a necessity for a cleaner and safer experience in transportation. With the increase in carbon and other hazardous gases more and more pollutants are causing various health-related issues which are of major concern. And with the increase in technology, it has become easier to address these problems with promising yet efficient solutions to electric vehicles. The electric vehicle is a relatively new concept in the world of the automotive industry. Many scientists and scholars hope to improve these environmental conditions and find many more methods to build more efficient and safer modes of transportation while still supporting the petroleum needs of our country. Researchers are continuing to find ways to combat these from their studies. Electric vehicles have a good deal of advantages, [11]largely electricity is less expensive than gasoline and petroleum. With electric cars the cost of gas each year can be reduced to a considerable percentage. The biggest advantage of a full battery electric vehicle is that it does not emit any harmful gases and is 100% eco-friendly. [11]Electric vehicles are quite popular and are growing in popularity, It is nearly three times as efficient as cars with an internal combustion engine, according to Wikipedia.



*Fig 19. Sourced from Statista*

The above image (figure 19) represents the statistical data of worldwide usage of electric vehicles from the year 2016 to 2020 in millions. The above data display the consumer adoption and popularity of electric vehicles in recent years.

Electric vehicles have become more popular recently because of environmental conditions lately. Everybody around the globe wants to contribute their part to the environment by embracing a safer and healthier lifestyle and by adopting environmentally friendly gadgets. The below (figure 20) statistical data shows the current situation of customers adopting electric vehicles, hence its sale in the financial year 2020-2021.



*Fig 20. Source from Statista*

A good deal of research and innovations are needed to fill the gaps that lack today and maintain the best in the industry. Electric vehicles are a healthier alternative to the environment but a lot of research and studies are required for better batteries and battery management systems, of which the studies will only grow in the future.

## **CONTRIBUTION AND LEARNING FROM THE PROJECT**

Evoka technologies is an electronic vehicle building platform working on futuristic electronic vehicle designing and development. Considering various types of environmental problems because of conventional internal combustion engine vehicles across the globe, evoka is focused on replacing these vehicles with electric motor vehicles powered by batteries. For the growing demand for technology and environmentally friendly methods evoka technologies Pvt. ltd. is targeted to rely on fuel cell-powered drive train technology which are more encouraging and promising solutions for the future.

### **RESEARCH**

An electric vehicle powertrain is responsible for taking energy stored in the vehicle's battery system and supplying it to the motors. The amount of power that it takes to move a fully-loaded vehicle is enormous, and delivery needs to be instantaneous and predictable. This needed research on various aspects of technology including using the perfect type of battery and powertrain design planning. We as a team researched the type of batteries that can be used in an electric vehicle. Traditional lithium-ion batteries continue to improve but they have limitations in part because of their structure. The current use of lithium-ion batteries in different consumer electronics has proved to be a great power storing device. Lithium-ion batteries have a higher energy density than lead-acid batteries and hence can be designed into smaller sizes while retaining the same storage capacity. And hence a spacial car structure can be designed.

### **LEARNING OUTCOMES**

- Applying various electric vehicle concepts including steering principle and mechanism practically.
- Differentiating various types of electric vehicles based on their powertrain systems.
- Creating 3-D models of car components.
- Understanding BMS (Battery Management System) of electric vehicles.
- An electric vehicle has 60% fewer components than the powertrain of an internal combustion engine (ICE).

## ACKNOWLEDGEMENTS

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