

## A REVIEW ON HYBRID VEHICLES, EMISSIONS COMPARISON WITH CONVENTIONAL VEHICLE AND POLICIES ADOPTION FOR PROMOTION

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### ABSTRACT

Hybridization of a vehicle is one of the praising step as the substitution of conventional vehicle and also one of the best alternative solution to reduce the amount of automotive emissions that why these vehicle over a last decade gain great attention due to eco friendly nature and lower green house gas emission as compare to conventional vehicle .But due to expensiveness and limited driving range hybrid vehicle is not getting too much approbation from consumer side.

This paper present comprehensive overview of hybrid vehicle, new technology and, energy storage unit used in these vehicle and also comparing the CO<sub>2</sub> emission between the conventional vehicle and hybrid vehicle and to make understand why need to adopt the hybrid vehicle and also discussion of policies that is adopted by governments of different countries globally for the promotion of hybrid vehicle. Conclusion is discussed finally.

**KEYWORDS:** BEV, HEV, FCEV, Energy Storage Unit, Emission Comparison, Policy Adoption

### INTRODUCTION

Robert Anderson of Scotland built first crude electric carriage vehicle that vehicle is powered by non rechargeable primary power cell, and in 1899 Henri Pieper developed the first petro –electric hybrid automobile in the world in 1898 Ferdinand Porsche build the hybrid car that charge its batteries from a small internal combustion engine. But in 1920-30 due to advancement in internal combustion technology they have gained popularity among consumers and ignoring the green house gas emissions from IC engines and completely eliminate the need of development of hybrid vehicle however in certain countries recognized the need of use of hybrid vehicle to control the emissions like in 1966 US government first bill recommending use of electric vehicle as a means of reducing air pollution all those year small level research going on but in recent years Hybrid vehicle gain the concentration globally due to concerning enormous amount of emission level annually. It is reported that vehicle emission accounts for 39.2% of total emission in 2007[3].The International Energy Agency (IEA) has mentioned that the fuel consumption and CO<sub>2</sub> emissions will roughly double between 2000and 2050.This make the hybrid vehicle as one of the best alternative of conventional vehicle that's why globally governments espousing policies that will boost the acceptance of hybrid vehicle among consumers and also there is lot of privately and government funded research is going on.

A hybrid vehicle contain multi propulsion system that help to provide the intended power commonly hybrid vehicle contain a small IC engine and a motor to propel the vehicle although Fuel Cell Electric Vehicle (FCEV) have different process to generate power. PHEV have a plug that can be connect to external power source to recharge the

batteries all the hybrid vehicle types briefly explain in this paper. These vehicle also accommodate some advance technology like regenerative braking, auto start/shut off, power splitter to optimize the fuel efficiency.

## CLASSIFICATION OF HYBRID VEHICLE

Hybrid vehicle classified basically on the basis of powertrain. Power configuration will decide what kind of hybrid vehicle it is:

### Parallel Hybrid

Parallel hybrid has an internal combustion engine in parallel to small electric motor which works on battery. Power can be drawn individually from engine or electric motor or together they are couple by a gearbox. Engine power can also be utilized to charge the battery's and in short journey engine can be turn off and can works on pure electric power in this case it act as pure electric vehicle.

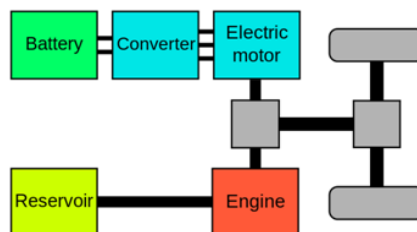


Figure 1: Parallel Hybrid Configuration

### Mild Hybrid

Mild hybrid is a vehicle in which electric motor cannot propel the vehicle on its own here internal combustion engine actually propel the vehicle. Electric motor execute duties only to aid IC engine. Electric motor also act as power booster providing ancillary power during acceleration, some mild hybrid have provision to recapture mechanical power during braking, also has a trait of auto start/stop . Mild hybrid assist in improve fuel efficiency because they are not using gas at certain points.

### Series-Parallel Hybrid

In series- parallel hybrid vehicle accommodate electric motor, internal combustion engine and a power splitter (set of sun and planet gear) the ratio of power using is 100% electric motor or 100% IC engine or severance of power between electric motor and IC engine ( like 40% electric motor & 60% IC engine). IC engine also work as generator charging the batteries. Power split hybrid are more efficient over all at lower speed series hybrid is more efficient and at higher speed parallel hybrid is efficient [1].

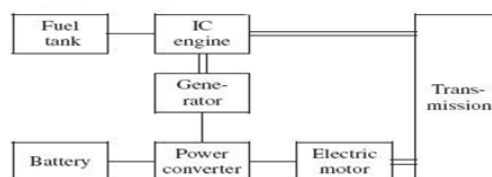


Figure 2: Series-Parallel Hybrid Vehicle Configuration

### Series Hybrid

In series hybrid the vehicle is propelled by electric motor there is no connection between the IC engine and wheels. A small IC engine is provided to recharge the battery pack when down usually series hybrid are equipped with larger battery pack and motor that's why sometime series hybrid is more expensive.

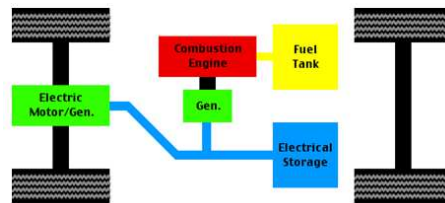


Figure 3: Series Hybrid Vehicle Configuration

### Plug-In Hybrids (PHEVS)

Plug in hybrid vehicle is a kind of hybrid vehicle which have a option to charge the batteries from external source by equipped a vehicle with a plug. PHEVs also have a IC engine which work as a backup sometime a generator to recharge a battery and sometime vehicle run on IC engine power. PHEVs increase the range of vehicle that why it's a gaining popularity now a days.

### Fuel Cell Electric Vehicle (FCEV)

Fuel cell is one of the most encouraging source of renewable energy also provide clean energy with very low sulphur and nitrogen oxide and carbon dioxide emission. It carries anode and cathode and an electrolyte for moment charges between on two sides. Electron move through external circuit from anode to cathode provide direct current this DC current is stored in battery and this energy is used while driving vehicle .Input are oxygen on cathodic side and hydrogen on anodic side and output is direct current (which get to stored in battery ) and water. Fuel cell are classified on the basis of electrolyte used in them some of most common fuel cell are:

#### Phosphoric Acid Fuel Cell (PAFC)

#### Molten Carbonate Fuel Cell (MCFC)

#### Solid Oxide Fuel Cell (SOFC)

#### Microbial Fuel Cell (MFC)

### ADVANCED TECHNOLOGY ADOPT BY HYBRID VEHICLES

The main focus of the hybrid vehicle is to make the vehicle more fuel efficient, optimize the use of fuel and battery energy and minimize the use of unaccounted waste energy and reduction in emission, this is the main focus of hybrid vehicle.

To accomplish this hybrid vehicle are equipped with undeniable new technologies like recapturing the energy by using regenerative braking[1], using power splitter to optimize the fuel efficiency and energy use between IC engine and battery energy .It literally increase the cost of vehicle here in this context cost is not a concerned parameter. Few advanced technology are discussed below:

### **Power Splitter**

It's a combination of sun, planet and ring gear and hold gasoline engine, generator and motor together. This gear set is tuned like that when car start electric motor supply power once vehicle reach a specified speed gasoline engine start supplying power that how power splitter optimize energy use. According to Toyota pirus power splitter sun gear connect the generator, ring gear connect the motor, planetary gear connect to IC engine. It empower the car to work like parallel and series hybrid. When there is a rapid acceleration the power splitter combined the power of both electric motor and gasoline, Power splitter also eliminate the need of traditional gearbox or transmission components [6].

### **Regenerative Braking**

Regenerative braking system is used to capture the kinetic energy from the vehicle which is misspend during the braking of a vehicle. Regenerative braking recapture the energy convert into electricity and send to battery to store. When the driver applies the brake the electric motor which run the vehicle comes into reverse mode and act as generator the tyre move reverse two operation happen together braking and capturing energy and converting into electricity by generator and stored in battery will be use later when require. It assist in emission reduction and improvement in fuel economy.

### **Automatic Start/Shutoff**

This feature in hybrid vehicle automatic stop the engine when the car comes to halt and promptly start the engine when the accelerator pedal is pressed. This feature help in fuel saving and also assist to control the emissions.

## **ENERGY STORAGE UNITS**

Energy storage units or simply battery play a very important part in hybrid and battery electric vehicle these are the units which has stored energy and dispense when needed almost all batteries used in vehicle are rechargeable. There are different –different kinds of battery used in vehicle depending upon the need like energy density, cycle life, self discharge rate, cost, different battery have different properties commonly used energy storage units in hybrid and electric vehicles are Lead Acid, Nickel-Metal Hydride (NiMH), Lithium Ion (Li-Ion) Batteries.

### **Lead Acid Battery**

A lead-Acid battery is oldest types of rechargeable batteries and is still in use. Instead of having low energy to weight ratio and low energy to volume their ability to supply high cascade of current [8] is remarkable. It has moderate rate of performance but also limited energy density due to hydrogen evolution in some designs have tendency of explosion [8].

### **Nickel–Metal Hydride Batteries (NIMH)**

It is also one of the most widely used batteries in hybrid vehicle due to its good energy density and specific power. Nickel Metal hydride batteries have more life cycle than Lead Acid batteries .Main challenges with NiMH batteries is heat generation when operating at high temperature and high self discharge rate.

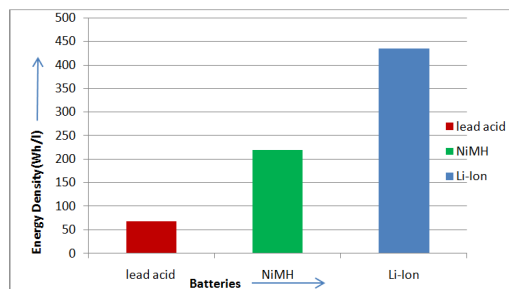
### **Lithium-Ion Batteries (LI-ION Battery)**

Li-Ion batteries have stunned automobile world due to its high energy density and very low self discharge rate provide energy for prolonged time .In Li-Ion batteries lithium ion move from negative electrode to positive electrode for discharge and opposite while charging [8].In last decade lithium ion batteries got a immense vogue due to very high

efficiency and high performance, rapid charge capability although these batteries have high initial cost and start wearing out at high temperature.

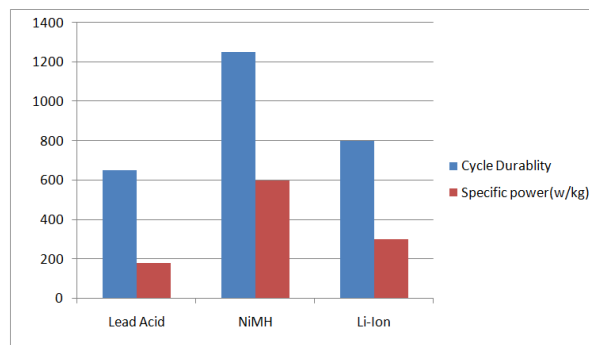
**Ultra capacitors**

Supercapacitors or ultracapacitor are homogenous in work .In general capacitor only contrast is that supercapacitor employ high surface area electrode material and thin electrolyte dielectrics[10]to attain higher capacitance than conventional capacitor. However that super capacitor have higher energy density and higher power density as compare to typical capacitor. Due to high power density means provide high power in very short span of time. Super capacitor assist hybrid vehicle during sudden acceleration by providing power swiftly also deploy power during peak load demand .



**Figure 4: Energy Density of Different Batteries**

The graph shown in figure 4 is the juxtaposition of the energy density of the different batteries which are typically used in Hybrid vehicle. In energy density graph the average is taken of every battery energy density because the energy density varies for every battery. The Li-ion battery have the highest energy density that’s why now a day’s Li-ion battery getting popularity among the hybrid car manufactures due to its long span of energy supplying capability.

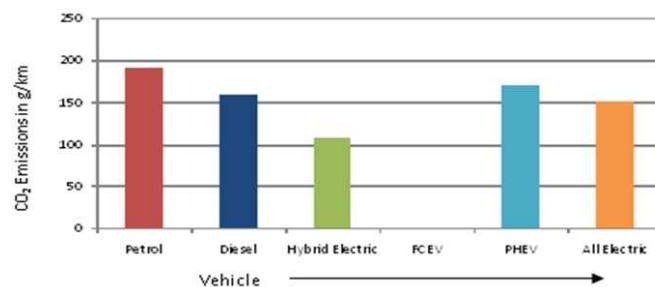


**Figure 5: Cycle Durability and Specific Power Comparison of Batteries Used in Hybrid Vehicle**

The bar chart shown in figure 3 explicitly compare the cycle durability and specific power of the different storage units used in hybrid vehicle .Cycle durability basically decide the expected life of a battery it denotes that before losing capacity of bestowing power how many charge and discharge cycle a battery can undergo. And specific power tells the capacity of battery to deliver a maximum power in very short period of time. Lithium Ion batteries get the attention of all the hybrid vehicle provider due to its high energy density and moderate life cycle and moderate specific power and low maintenance.

## EMISSION CONTROL FROM HYBRID VEHICLE

Green house gas emission is distressing worldwide as in 2013 the transport sector contribution to emission globally is 21.9% .Transport sector plays a utmost role in world wide emission so it's become of everybody major objective to control emission from vehicle because it's leading towards global warming, health hazards and several many other troubles. The primary concerned of every country is to control CO<sub>2</sub> emission the transport sector emit 23.7 % of total CO<sub>2</sub> emission [14].So many countries worldwide have adopted certain norms to control CO<sub>2</sub> emissions like In Europe newly registered vehicle by 2015 should not emit 130 gm/Km and by 2021 it will be 98gm/Km CO<sub>2</sub> emission [14].One of the best surrogate to reduce emission is electric and hybrid vehicles, these vehicle customarily have low or zero emissions as compared to conventional vehicles and many countries encouraging the use of a BEV, HEV, PHEV, FCEV very enthusiastically by providing privileges to the owner. FCEV is more or less twice as high as the efficiency of a conventional petrol internal combustion engine [18]. The average emission from a conventional vehicle is about 191gm/km (vehicle: Megnic Scenic) which is very high as compared to hybrid electric 51lbCO<sub>2</sub>/ 100 mile driven[15]. It is clearly seen that hybrid vehicle has less emission as compared to conventional vehicle that why these vehicle are the best alternative to diminish carbon emissions.



**Figure 6: Comparison of CO<sub>2</sub> Emission of Different Fuel Using in Vehicle**

The appraisal of all electric vehicle emission is on the basis of well-to-wheel emissions there are also tail pipe emission from PHEV but over all emissions is lower as compare to conventional vehicle. Distinctly hybrid vehicle has less emission as compare to petrol or diesel operated vehicle so there is utmost requirement of adopting hybrid vehicle to reduce carbon footprint globally.

## POLICY INDUCEMENT FOR HYBRID VEHICLE PROMOTION

In the last decade the so many countries adopted a plenty of policy for the adoption of hybrid vehicle which help these hybrid vehicle to be easily accessible by the people .Due to expensive battery packs the sales price of EV is exorbitant than those of conventional vehicle [21] so people can't meet the expense because of that government of several countries introduce a policy for the easily adoption of hybrid vehicle. Most of the policies are divided into two parts - For consumer and For Manufacturers [23]. Policies that is generally adopted by governments are:

### Financial Incentive

For consumer like Tax scaling down ,Direct Subsidy, free road tax and for manufacturers like cutback in road sales tax like in Belgium individual receive a 30% subsidy of the price of EV in Denmark BEV are exempt from registration tax until 2015 [23].

### **Rebates**

German government providing subsidies of 5000 euro for EV buyers, hybrid vehicle consumer not liable to pay annual tax in Denmark.

### **Local Benefits**

Norway and German government confer EVs free access to use ferries also providing free parking for EVs.

### **Support of Technology**

The price of the hybrid vehicle is in infancy stage although expensive also fewer hybrid vehicles can be propelled only for short range so technical advancement is necessary for hybrid vehicle, Germany did research funding in lithium ion alliance project to make battery more efficient [21], USA doing research in light vehicle technology [23].

### **Charging Infrastructure**

Charging infrastructure for BEV, PHEV is very necessary for long distance using of hybrid vehicle for promoting this UK government initiated PIP (Plug in places) programme from 2009 onward, Rotterdam electric programme install free charging point for first 1000 EV owners.

## **CONCLUSIONS**

Hybrid vehicles are definitely the vehicles of the future but still they are facing the problem such as expensiveness of vehicle, limited range of driving due to low energy density batteries, government of the different countries adopted policies to attract the consumer by providing subsidies, rebates for commercialization of these vehicles. This paper clearly presents the CO<sub>2</sub> emission comparison and hybrid vehicles clearly have low emission as compared to conventional vehicles. This clearly implies why there is a need to adopt hybrid vehicles, there is a lot of funding in the research field to make hybrid vehicles cost, battery range up to expectation of consumers, new technologies like power splitter, regenerative braking make them very efficient and eco friendly by providing optimized operating range. Hybrid vehicle acceptance should have to stimulate globally to truncate greenhouse gas emission for habitat and social welfare.

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