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A Comprehensive Examination of the Progression of Hybrid Vehicle Technology

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Abstract

Hybrid vehicles are vehicles that use more than one power source to propel themselves. They can combine different types of engines, such as internal combustion engines, electric motors, fuel cells, or solar panels, to achieve better fuel efficiency, lower emissions, and improved performance. Hybrid vehicle technology has evolved over the years, from the early experiments in the 19th and 20th centuries, to the mass production of hybrid cars and trucks in the 21st century. This paper provides a comprehensive review of the evolution of hybrid vehicle technology, covering the historical development, the current state of the art, and the future trends and challenges. The paper also discusses the benefits and drawbacks of hybrid vehicles, as well as the environmental and economic impacts of their adoption. The paper aims to provide a useful reference for researchers, engineers, policymakers, and consumers who are interested in hybrid vehicle technology and its applications.

Keywords – Combustion Engine, Hybrid Vehicles, Electric Motors.

1. Introduction

Hybrid cars are a combined traditional internal combustion engine with an electric propulsion system. This was developed since the transportation sector contributes to the widespread carbon emissions (Ong et al, 2023). The advancements have reached a level where the vehicles are being built on the grounds of being eco-friendlier, safer and money saver on long term basis. Hybrid cars are one such innovation (Asim et al, 2020). With the advancement in 21st Century, there has been increase in usage of Oil and Gas leading to problems like Global Warming, climate change, shortage of crude oil, etc. As, the world went through 20th Century, there happened many advancements for making this technology efficient and cost-effective. Due, to which it became the commercial success and its use in the day-to-day period increased (Prajapati et al, 2014). Electric vehicles may play an important role in reducing CO_2 emissions in the long term. However currently they are facing two main problems. Firstly, batteries for an adequate driving range are bulky, heavy and expensive. Secondly, the CO_2 emissions of electric vehicles directly connected to the electricity generation (Ott et al, 2013).

1.1 Background

The economic and managerial literature dealing with hybrid vehicles is still very poor, basically, limited to enthusiastic press, coverage for newly launched models or surveys on cost efficiency. Most academic publications emphasize scientific and technical issues, such as power train modelling and control, braking systems with regenerative devices, energy storage, energy management systems, propulsion systems, electric engines, vehicles simulation, vehicles design, etc. Most key articles limit their scope to technical efficiency (Chanaron & Teske, 2007).

1.2 History

The first ever REV was built in 1898, and there were several automotive companies who were selling REV s in the early 1900s. The production of HEV s did not last the course of time due to significant problems with them. Henry Ford initiated the mass production of combustion enginevehic1es; making them widely available and affordable within the $455 to $911 price range (H» 375€ to 750€ with prices taken from the current American dollar to Euro conversion rate). In contrast, the price of the less efficient EV s continued to rise. During 1912, an electric roadster sold for $1,732 (1,425€), whilst gasoline car sold for $547 (450€) as illustrated by About Inventors. Another problem was the requirement for a smooth coordination between the engine and the motor, which was not possible due to the use of only mechanical controls. Since these early attempts, there has been a rise in the concern for global warming, a continual rise in fuel prices, and the threat of oil reserves drying up altogether. This handled to interest in more efficient and environmentally means of transport again, particularly in the area of HEV. With advances in battery technologies and onboard computer systems, the option of a plausible HEV has become reality, and a number of models from the likes of Honda (Civic and Insight) and Toyota (Prius) have been available now since 2000 (Sanchez-Repila & Poxon, 2006).

2. Environmental Impact

The growing effect of global warming is being made all the worse with CO_2 emissions from vehic1es. In fact, $C0_2$ is the primary greenhouse gas which increases global temperature. The emissions of $C0_2$ from vehic1es are a huge concern, and there have been a number of research efforts which have gone on in order to fully begin to understand the full extent of the problem (Sánchez-Repila & Poxon, 2006). World health organization listed air pollution as the world's most consequential environmental health risk, resulting in estimated deaths per year, around 6 million along with countless cases of diseases related to cardio and respiratory system. Michal and his mates mention in their article, that a huge part of contribution to air pollution is caused by road transport and even static traffic. Over the years, with increasing population leading to rise in vehicles, a major shift towards hybrid and electric cars is taking place for a greener, cleaner and better environment (Asima et al, 2020).

3. Technology and Innovation:

Hybrid cars attempt to get the perfect blend of a more advanced internal combustion (IC) along with a very economical electric motor (Asim et al, 2020). A hybrid electric vehicle is a type of hybrid vehicle which combines a conventional internal combustion engine propulsion system with an electric propulsion system. Or in a technical way, a Hybrid Electric Vehicle is a type of technology which indulges both mechanical drive train and electric vehicle.

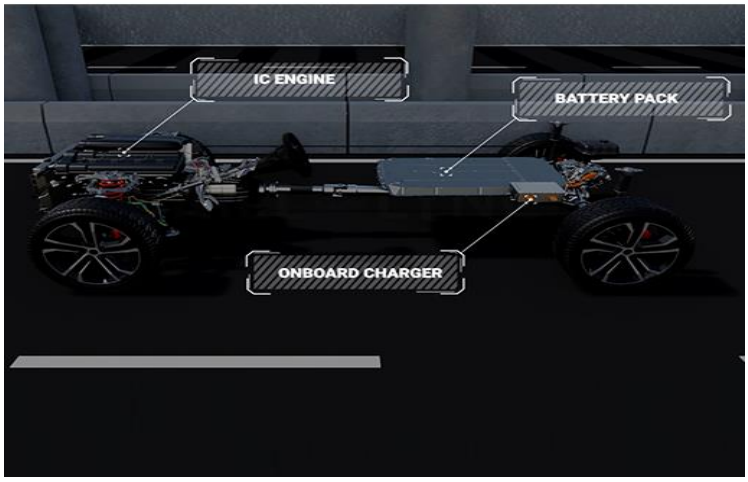


Fig 1. Model of Hybrid Electric Vehicle (Navin Baskar, 2023).

3.1 Hybrid System

A mechanical drive consists of the Fuel tank (containing conventional fuels like petrol/diesel/CNG), the combustion Engine, the gear box and transmission to the wheels showing in Fig 2.

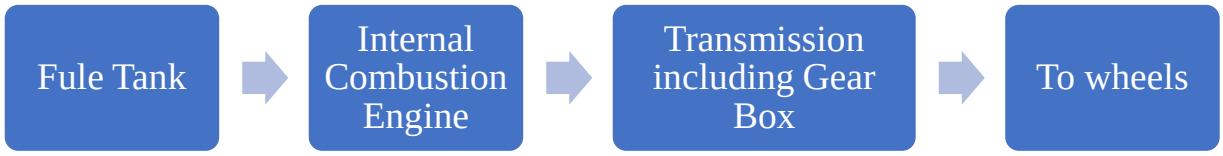


Fig 2. Flow of energy within a mechanical drive train (Prajapati et al, 2014).

An electric drive consists of the Battery, an electric motor and Power Electronics for control as shown in Fig 3.

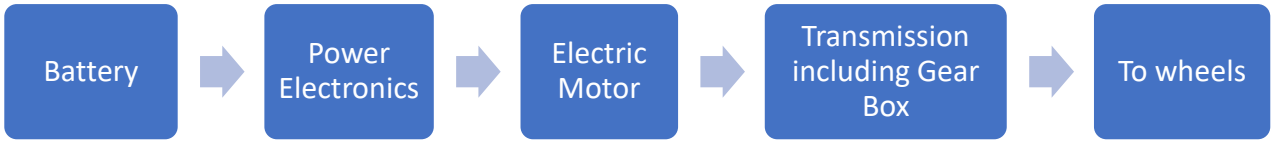
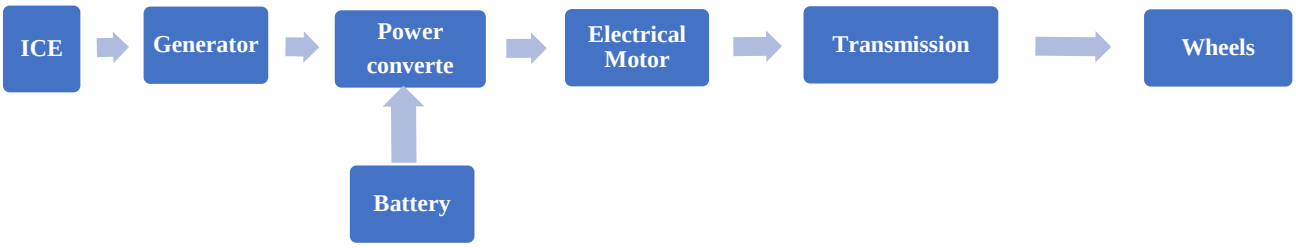


Fig 3. Flow of energy within a electric drive train (Prajapati et al, 2014).

The use of Ultracapacitors has a high potential in the Hybrid Electric Vehicles. They have the advantages of being a more robust power device when compared to batteries (Lithium Ion and Nickel Metal Hydride), as an example during regenerative braking which is considered as high powered event (Prajapati et al, 2014).



3.2 Regenerative Braking

This technology captures the energy from braking and recharges the vehicle's battery. This helps to reduce the amount of energy lost during braking, which in turn helps to improve fuel efficiency (Navin Baskar, 2023). Regenerative Braking is the process of converting energy that is wasted when the vehicle slows down into energy that is stored into the battery bay with the aid of the electric motor (DoE U.S., 2014). This is one of the methods that is used to charge the battery. Every time the car applies breaks or comes to a halt, it releases kinetic energy. This energy is released usually by the breaks and turning of the wheels. The system then acquires this energy, and transforms it into electrical energy and sends it back to the batteries pack, where this is now stored for future utilization. In this way, it never completely runs out of charge. Although hybrid cars use this system of braking, the effectiveness of this braking system ultimately depends on the way the driver drives their vehicle. The most effective utilization of this system is by driving at constant speed and braking when necessary for maximum effectiveness (Asim et al, 2020).

4. Types of Hybrid Vehicles

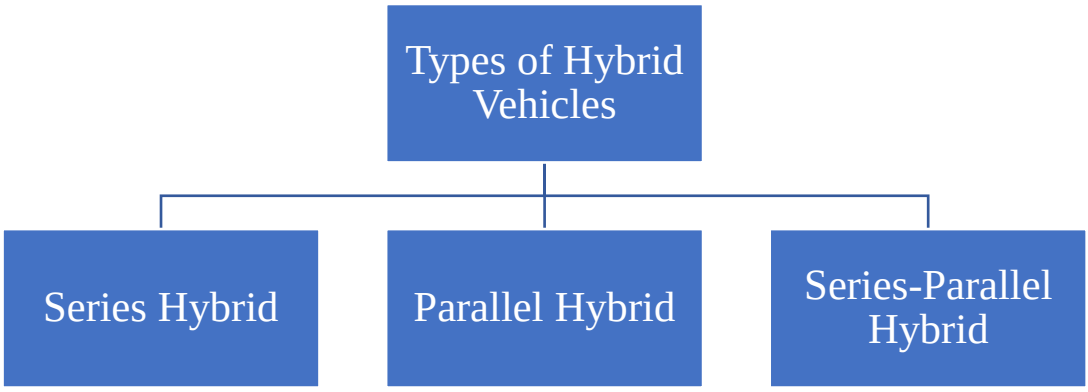


Table 1. Classification of Hybrid Electric Vehicles

4.1 Series Hybrid

Fig 4. Series Hybrid Structure (Prajapati et al, 2014).

The electric motor is in charge here. The gas engine or a generator plays the role of recharging the battery packs of the motor. Since it runs majorly on the motor, such cars are better for driving shorter distances within the cities with more stops. The engine is usually held back to be used only for situations that actually require the car to run more efficiently. This makes the engine smaller and the built of motors bigger since it's the major source. The bigger the size of the

motor, the larger the battery it needs, hence adding all together, ends up being more expensive than a parallel hybrid. Example: The BMW i3 (Asim et al, 2020). As shown in Fig. the traction power is delivered by the electric motor, while the internal combustion electric motor. The excess power is then stored in the battery pack. The Internal Combustion Engine is decoupled from the driven wheels and can be operated mostly in the maximum efficiency region. The major shortcomings of the series hybrid drive train configurations are the high power installed in each component and the request of a generator. In fact, the energy form the Internal Combustion Engine is converted twice before to drive the wheels. Thus, the system is more expensive than the parallel one (Prajapati et al, 2014).

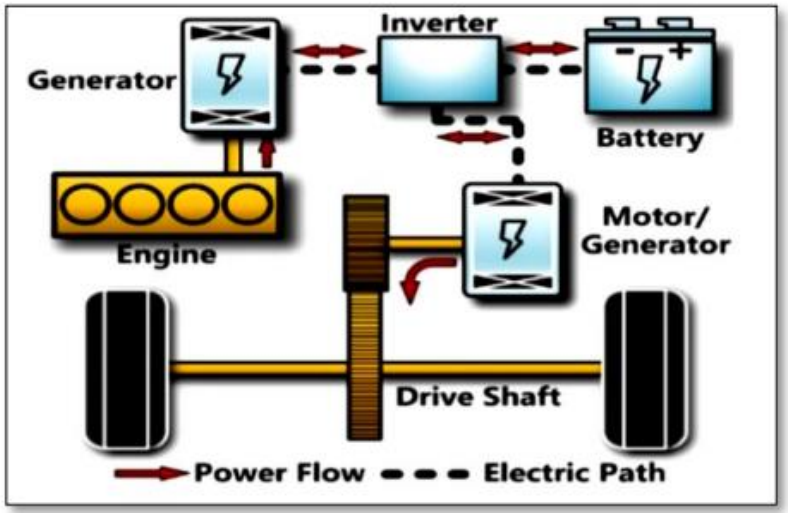


Fig 5. Configuration of series HEV (Elkelawy et al, 2022).

4.2 Parallel Hybrid

Here, both the IC engine and the motor are allowed to work together to power the car. The engine is never switched off here, and it keeps contributing to the car's progress. The gas is provided to the engine by the fuel tank and the batteries are charged using generators. At low power, the motor can also be converted to a generator to supply power. This makes the size of battery pack smaller. This saves more fuel and is more preferable for faraway travels. Example: LaFerrari (Asim et al, 2020).

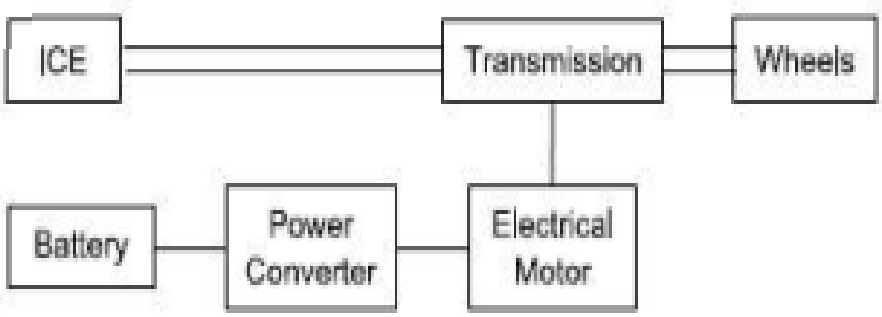


Fig 6. Parallel Hybrid Structure (Prajapati et al, 2014).

As shown in Fig. there is direct mechanical connection between power unit and the wheels. In addition, this layout has an electric taction motor that drives the wheels and can recuperate a share of the braking energy, in order to change the batteries or help Internal Combustion Engine during acceleration conditions. In fact, Internal Combustion Engine and electric motor and coupled by a mechanical device. Then the electrical machine can be designed with a reduced configurations depending on the structure of the mechanical electrical motor. There can be a torque-coupling with a single shaft or two shaft configurations, a speed-coupling with planetary gear unit, a merge of both previous coupling (Prajapati et al, 2014).

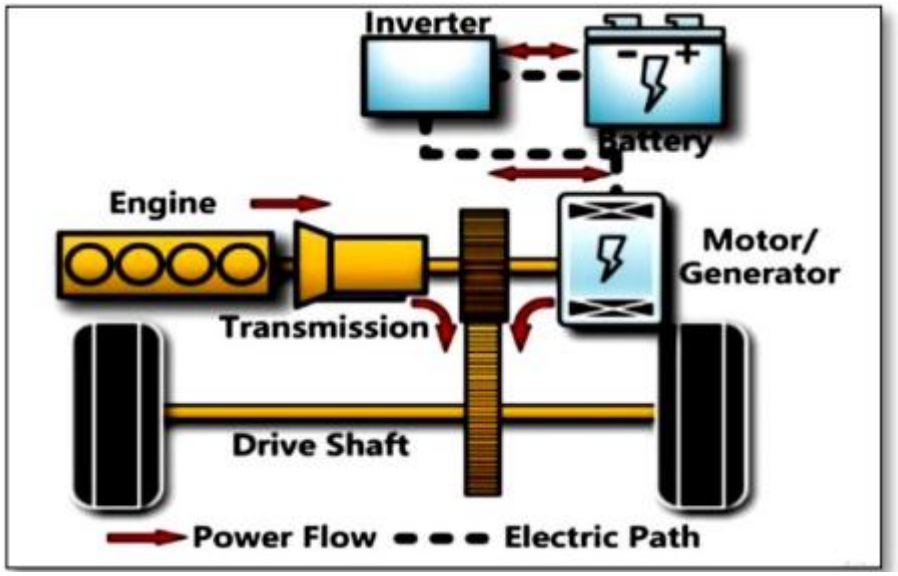


Fig 7. Configuration of parallel HEV (Elkelawy et al, 2022).

4.3 Series-Parallel Hybrid

In this version of the hybrid, as the name suggests, it mixes the power of both the above-mentioned types. This allows the IC engine to take up the role of powering the vehicle completely or even let the motor be in charge fully and disconnect itself. With such options, the vehicle can operate at high efficiency, but at lower speeds it is usually the motor's job. This means a battery pack of bigger size and more work to manage the dual system. This category has a better performance and saves much more fuel than the alone series and parallel.

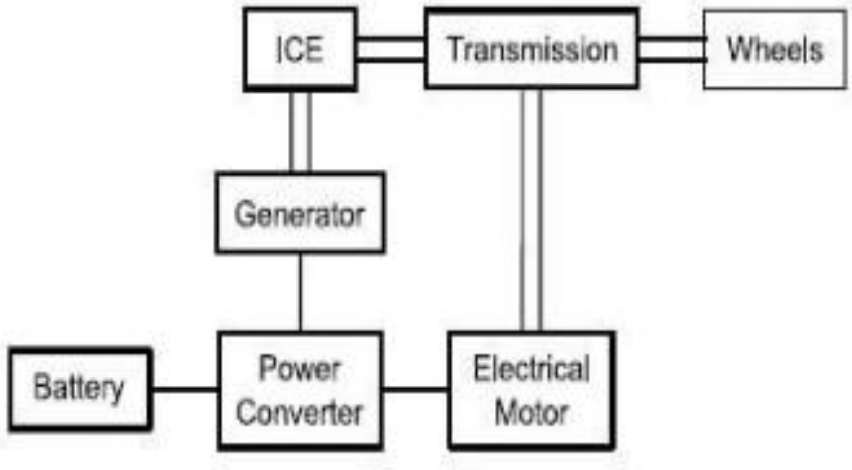


Fig 8. Series-Parallel Hybrid Structure (Prajapati et al, 2014).

As shown in Fig. the series layout and the parallel layout are merged together in order to have both advantages. In particular the ICE is able to supply the electrical motor or charge the battery thanks to a generator (Prajapati et al, 2014).

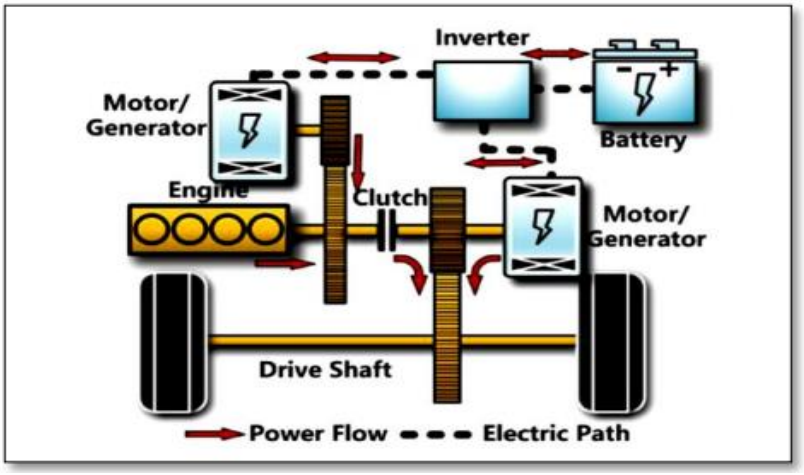


Fig 9. Configuration of series-parallel hybrid powertrain (Elkelawy et al, 2022).

5. Future Prospects

As technology continues to evolve, we can expect to see more hybrid electric vehicles on the roads in the near future. The future of hybrid electric vehicles is exciting, and we can look forward to a cleaner, greener, and more sustainable future. The future of transportation is rapidly changing, and hybrid electric vehicles are at the forefront of that change. As technological advances continue to make hybrid electric vehicles more efficient and sustainable, they are becoming increasingly popular as a viable alternative to traditional gasoline-powered cars. So put your seat belts on, and let's explore the current and potential future of hybrid electric vehicles, including the advances in technology and sustainability that make them an attractive option (Navin Baskar, 2023).

6. Advantages

Here are some of the most significant benefits of owning a hybrid electric vehicle:

- Eco-Friendly: One of the most significant features of hybrid electric vehicles over gasoline-powered automobiles is that this runs smoother and get higher gas mileage, making them more eco-friendly. A hybrid electric vehicle has two engines: a gasoline engine and an electric motor, which reduces fuel consumption and saves electricity.
- Economic Benefits: Many credits and incentives are ready to support hybrid electric vehicles becoming more competitive. Less money expended on petrol results in lower annual tax bills and exemption from congestion charges.
- Less Reliance on Fossil Fuels: Since hybrid electric vehicles are cleaner and use less fuel, they emit fewer pollutants and are less reliant on fossil fuels. It also assists in the lowering of oil prices on the domestic market.
- Regenerative Braking System: As you apply the brakes in a hybrid electric car, it helps to recharge the tank. An internal mechanism kicks in, storing the energy emitted and using it to charge the battery, minimizing the amount of time and the need to recharge the battery on a regular basis.

- Lightweight Materials: Hybrid electric vehicles are built of lighter materials, consuming less energy to work. The engine is also smaller in size and lighter, resulting in significant energy savings.
- Higher resale value: As the price of fuel continues to rise, more and more people are opting for hybrid electric vehicles. As a result, these green vehicles have begun to command and resale prices that are higher than average. So, if you're frustrated with your car, you can always sell it for a higher price to customers who are looking for it (Iqbal. 2022).

7. Disadvantages

Expensive and can cost up to a few thousand more than regular gasoline cars. Battery power and charging might be an issue sometimes. Cases reported showing that even leaving a light switch on for a night can drain the battery. The silent moving of the car can also be a disadvantage, with cases being reported that some pedestrians had no idea about a car approaching, which can prove to be dangerous (Asim, 2020). The development of HEVs has been a major step forward in the automotive industry. However, the technology is still in its infancy, and many challenges are yet to be addressed to make HEVs more viable and sustainable (Navin Baskar, 2023).

- Cost of the Technology: While the cost of the components has decreased in recent years, the overall cost of a hybrid electric vehicle is still significantly higher than that of a traditional gasoline-powered vehicle. This makes it difficult for many people to purchase a HEVs as the upfront cost can be prohibitive.
- Repair and Maintenance: The technology is still relatively new, meaning there may be limited options for repair and maintenance. Hybrid electric vehicles rely on batteries to store energy, which must be replaced periodically.

This can be costly and time-consuming, making it difficult for drivers to keep their vehicles running efficiently (Navin Baskar, 2023).

Types of Hybrid Cars	Advantages	Disadvantages
Series	Efficient operation of the ICE. Good performance at low speeds. Simpler control of the ICE	Many components. Band performance at high speeds. Low efficiency.
Parallel	No necessity of electric generator. ICE reduced size.	Control of the ICE is more complex.
Mixed	Great flexibility & High efficiency.	Very complex architecture involving many components.

Table 2. Summaries table of advantages and disadvantages of Hybrid Cars (Leon, 2021)

8. Summary

The main objective of this research is to analyse Hybrid-Electric Vehicles (HEV) and their components and justify how these vehicles are less harmful than gasoline cars to the environment. This is done by analysing and conspicuously explaining how an HEV works, its characteristics, and the components that differentiate it between traditional gasolines. The result after testing the vehicles and researching and understanding its components is that HEV does is indeed less harmful to the environment due to it consuming less gasoline and because the components; mainly the battery and motor, are naturally built to be less impactful to the environment. This research also aims to encourage

consumers into buying HEV. If the number of total hybrid vehicles increases and the total number of gasoline vehicle decrease, the total amount of pollution caused by vehicles would drastically decrease due to the total consumption of gasoline decreasing as large amounts of gasoline will not be needed to fulfil the needs of hybrid vehicles. This ultimately reduces environmental pollution caused by vehicles. Along with the reduction of pollution, the amount of money saved of fuel refilling could be turn out to be helpful for most of the individuals, who are struggling with balancing their budget.

All the above topics, which have been studied analytically, concludes that hybrid vehicles prove to be eco-friendlier and safer for the environment than the IC engine vehicles. With increasing production of hybrid variants, batteries are being planned and designed in way that extends its life as well as provides the ability of recycling. This overall, turns to be safer, healthier and a money saver package, saving you a fine amount spent on fuel. An investigation into other vitality sources, for example, power devices and sustainable powers make the future look more splendid for hybrid vehicles.

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