International Journal
of
Automobile Engineering

E-ISSN: 2707-8213
P-ISSN: 2707-8205
IJAE 2024; 5(2): 08-14
www.mechanicaljournals.com/ijae
Received: 14-05-2024
Accepted: 14-06-2024

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Revolutionizing mobility: Decoding EVs and HFCVs

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Abstract

In recent years, the rise in carbon emissions and the widespread effects of global warming have brought new energy vehicles into the spotlight. Electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs), both producing zero tailpipe emissions, are seen as promising alternatives. This paper examines the working, structural characteristics, and safety designs of EVs and HFCVs, comparing their carbon emissions, charging infrastructure, energy efficiency, and safety features. The analysis reveals that both EVs and HFCVs significantly reduce carbon emissions and enhance safety compared to traditional vehicles, with EVs showing greater emission reductions. Moreover, EVs are advancing more rapidly in terms of charging infrastructure compared to hydrogen energy vehicles. However, HFCVs exhibit lower energy efficiency than EVs. In terms of safety, both types surpass conventional vehicles, though EVs are more prone to overheating and fire hazards due to battery design issues. Current research suggests that EV technology and its supporting infrastructure are more comprehensive, cost- effective, and efficient in reducing carbon emissions. With continued investment in the development of new energy vehicles and potential advancements in hydrogen energy production, the future for HFCVs appears promising. The paper also expresses optimism for innovative solutions that could accelerate the growth of hydrogen energy vehicles.

Keywords: Electric vehicles (EVs), Hydrogen Fuel Cell Vehicles (HFCVs), New Energy

Introduction

The demand for energy has evolved due to global technological advancements and heightened environmental awareness. There is a significant shift from traditional fossil fuels to cleaner energy sources, driven by the urgent need to address global warming, one of the most pressing environmental issues today. CO_2 emissions constitute a major portion of greenhouse gases, with the transportation sector alone contributing approximately 14% to the global CO_2 emissions. To mitigate these emissions, nations worldwide are transitioning from petrol, diesel-powered engines to cleaner alternatives, such as hydrogen-powered and electric vehicles. These vehicles are anticipated to become the dominant form of private transportation, replacing traditional gasoline and diesel engines. The growing adoption of electric and hydrogen fuel cell vehicles has underscored the importance of research in this field. Extensive literature reviews have been conducted, focusing on the basic principles, energy efficiency, environmental impact, and economic benefits of these new energy vehicles. This article aims to provide a comprehensive overview of the operating principles and safety concerns associated with both electric and hydrogen-powered vehicles. It also compares the advantages and disadvantages of each vehicle type, identifying areas that require further investigation and development. The emergence of hybrid energy vehicles, which seek to balance the benefits and drawbacks of both technologies, highlights the ongoing innovation in this sector. This article aspires to enhance understanding and promote the advancement of new energy vehicles by summarizing the fundamental concepts and current research findings. The primary objective of this paper is to elucidate the working principles of electric and hydrogen fuel cell vehicles, assess their safety risks, and compare their current statuses. Initially, the paper delves into the structure of electric vehicles, detailing the types of Electric Vehicles. It then explains the operating mechanism of hydrogen fuel cell vehicles, which utilize hydrogen as a primary energy source, and examines their associated safety factors. Finally, the paper compares the two vehicle types across four key dimensions: charging experience and convenience, environmental impact, safety, and energy efficiency. The comparison aims to outline the strengths and weaknesses of each vehicle type, providing a foundation for future improvements in electric and hydrogen fuel cell vehicle technologies.

Literature Review

R. Hannappel studied about human-made gases such as CO_2, drive global warming, with transportation contributing 14% of emissions. Countries target a 2 °C limit by 2100, shifting to electric engines and improving infrastructure, battery tech, vehicle range, and hydrogen production [1]. J. Duan, X. Tang, H. Dai, Y. Yang, W. Wu, X. Wei, and Y. Huang studied the structural features, safety, carbon emissions, charging infrastructure, and efficiency of electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs). Results show EVs are more developed with lower costs and greater emission reductions, though they face safety concerns regarding battery structure-related heating issues [2]. R. Rapier studied the escalating carbon emissions and the necessity to achieve net-zero levels for environmental sustainability, focusing on the pivotal role of green hydrogen generation amidst challenges in storage and logistics. Through DEMATEL analysis, insights were provided for policymakers and stakeholders to address these complexities effectively [3]. E. Helmers and P. Marx studied on electric vehicles energy efficiency and environmental impact compared to internal combustion engine vehicles, emphasizing the significant advantages of battery electric cars (BEVs). The research highlights BEVs as a sustainable mobility solution, particularly in small-size models, with potential for substantial emissions reductions through conversion from combustion to electric [4]. A. Albatayneh, M. N. Assaf, D. Alterman, and M. Jaradat studied EVs' energy efficiency versus ICEVs and CNGVs, emphasizing well-to-wheel efficiency. Results show EVs powered by natural gas have highest efficiency; renewables can further boost efficiency to 40-70% [5]. Lindsey, R. and Dahlman, L. highlighted climate change's threat due to natural and human factors, impacting human welfare, ecosystems, and various sectors like agriculture. Drastic temperature changes, rising greenhouse gas emissions, and sea level rise are major concerns, with potential delays in the onset of a new ice age. Comprehensive scenarios outline the multifaceted impacts on all living species [6]. S. Mekhilef, R. Saidur displayed fuel cells' benefits for rural areas, comparing various technologies and hydrogen fuel cell vehicles (FCVs) with internal combustion engine vehicles (ICEVs), highlighting their simple design, reliability, efficiency, and minimal environmental impact for comprehensive reference in fuel cell power generation reviews [7]. E. Sherman examined the growing interest in new energy vehicles amidst rising carbon emissions. The paper compares electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs), highlighting EVs' faster infrastructure development and superior efficiency, although both show improved emissions and safety over traditional vehicles [8].

Electric Vehicles

Structure and Working Principle

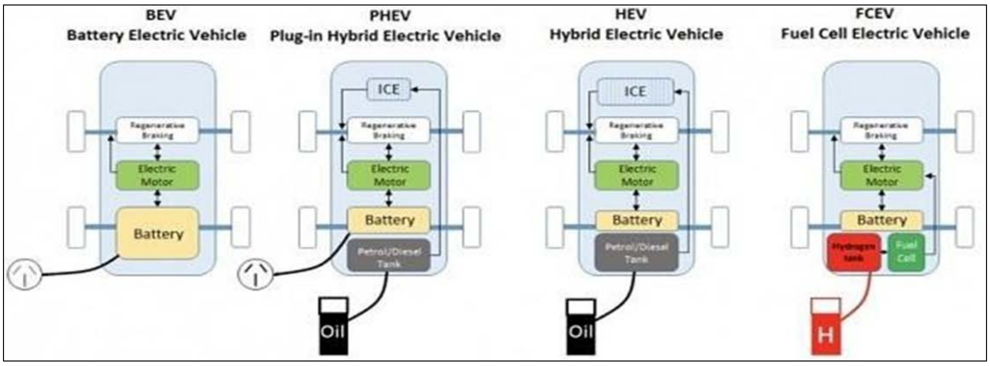

Fig 1: Types of Electric Vehicles

BEV

A Battery Electric Vehicle (BEV), also known as an All-Electric Vehicle (AEV), operates solely on an electric drive train and a battery, without the need for an Internal Combustion Engine (ICE). The vehicle's energy is stored in a substantial battery pack, which is charged by connecting to an electrical grid. This stored energy is then used to power one or more electric motors that propel the vehicle. The key components of a BEV include the electric motor, inverter, battery, control module, and drive train. In terms of operation, the power from the DC battery is converted to AC for the electric motor. The vehicle's speed is regulated by the controller, which adjusts the frequency of the AC power from the inverter to the motor based on the signal from the accelerator pedal. The motor, in turn, rotates the wheels through a gear mechanism. Interestingly, when the vehicle decelerates or the brakes are applied, the motor functions as an alternator, generating power that is fed back into the battery.

HEV

Referred to as a standard or parallel hybrid, is a unique blend of an Internal Combustion Engine and an electric motor. In this type of vehicle, the ICE derives its energy from fuel (such as gasoline), while the electric motor is powered by electricity stored in batteries. The gasoline engine and electric motor work in tandem to rotate the transmission, propelling the wheels. What sets HEVs apart from BEVs and PHEVs is the charging mechanism for the batteries. In an HEV, the batteries can only be charged by the ICE, the motion of the wheels, or a combination of both. There is no external charging port, meaning the battery cannot be recharged from an external source like the electricity grid. The components of an HEV include the engine, electric motor, battery pack with controller & inverter, fuel tank, and control module. In terms of operation, an HEV has a fuel tank that supplies gasoline to the engine, much like a conventional car. It also has a set of batteries that power an electric motor.

PHEV

They usually start in all-electric mode, operating on electricity until their battery pack is depleted. Some models switch to hybrid mode when they reach highway cruising speed, typically above 60 or 70 miles per hour. Once the battery is depleted, the engine takes over, and the vehicle operates as a conventional, non-plug-in hybrid. In addition to plugging into an external electric power source, PHEV batteries can be charged by the internal combustion engine or through regenerative braking. During braking, the electric motor acts as a generator, harnessing the energy to charge the battery. The electric motor supplements the engine's power, allowing for the use of smaller engines, thereby increasing the vehicle's fuel efficiency without compromising performance.

FCEV

Fuel Cell Electric Vehicles, alternatively known as fuel cell vehicles (FCVs) or Zero Emission Vehicles, represent a category of electric vehicles that utilize 'fuel cell technology' to produce the necessary electricity for propulsion. In these vehicles, the fuel's chemical energy is directly transformed into electrical energy. The primary components of an FCEV include the electric motor, fuel-cell stack, hydrogen storage tank, and a battery equipped with a converter and controller. The operational principle of a 'fuel cell' electric vehicle differs from that of a 'plug-in' electric vehicle. This is primarily because an FCEV generates the required electricity onboard the vehicle itself.

Protection System

To safeguard passengers from potential electric shock during collisions, high-voltage components are strategically positioned outside the passenger compartment, typically beneath the front & rear seats. The vehicle's zone body structure acts as a protective shield for the battery pack, absorbing impact forces from both the front and rear. The robust cabin design shields the mid-section of the vehicle on both sides. In the event of a side impact, most of the energy is absorbed by the vehicle's floors & structural members. To mitigate damage to the battery pack resulting from framework deformation during a collision, the impact energy is redirected to the floors through separate members, effectively isolating it from the entire body sill. A high-strength battery frame surrounds the battery pack, providing an additional layer of protection.

Lithium-ion Batteries: Lithium-ion batteries are the most preferred choice in the electric vehicle industry due to their high energy and power densities. These batteries maintain performance across a wide temperature range. They consist of separators and electrodes, facilitating the movement of lithium ions between the anode and cathode.

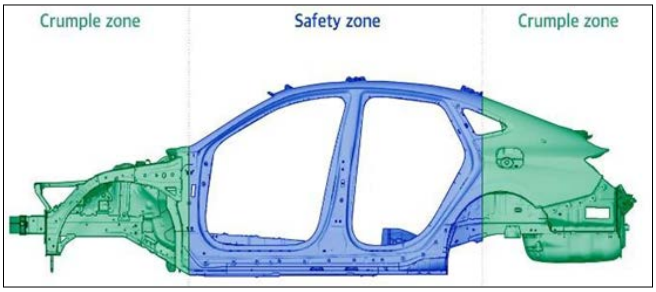

Fig 3: EV Body

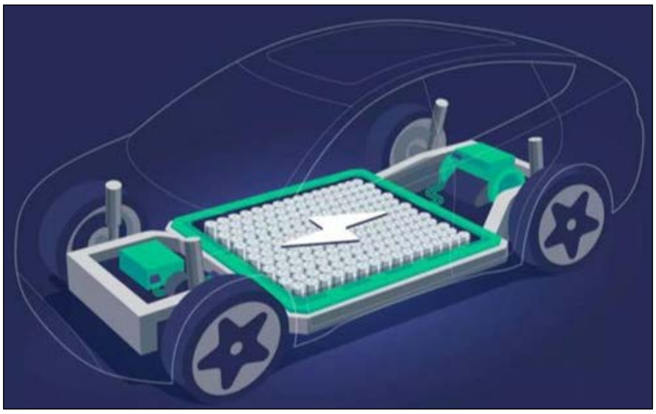

Fig 4: EV Battery Safety Design

Cathode

In the electric vehicle industry, three primary cathode materials are commonly used: LFP, LMO, and $LiMO_2$ (where M represents Ni, Co, Mn, and Al). LFP exhibits excellent thermal stability and cost-effectiveness due to the strong covalent bond between phosphorus (P) and oxygen (O) in its PO_4^{3-} octahedral structure. However, LFP has a low volume energy density and theoretical specific capacity. On the other hand, LMO has better manufacturing properties but suffers from low energy density and poor cycling stability due to manganese (Mn) dissolution during charging and discharging. To enhance cell performance, pure $LiNiO_2$ is modified by replacing Ni with Mn, Co, or Al to form a more stable lattice structure.

Anode

The materials used as anode in lithium-ion batteries can be classified to three types. The advantages and disadvantages are summarised in Table 1. (I) carbon-based material such as graphite and lithium titanium oxide; (II) Conversion reaction anode; (III) Alloying type materials.

Table 1. Advantages and disadvantages of four common types of Lithium-ion battery

Materials	Advantage	Disadvantage
Graphite	Low cost, High electrical conductivity, Low potential plateau	Low volume expansion
LTO	High-rate charge/discharge, long lifespan	High lithiation/ delithation plateau, low specific capacity
MX (M=transition metal and X=O, F, H)	High specific capacity	Poor electronic capacity, low-rate performance
IV and V group and its oxides, sulphides, or phosphates	High discharge capacity	Poor lifespan and serious pulverization

Safety Issues

Safety concerns related to lithium-ion batteries arise at both the materials and cell levels. The core issue causing these safety risks is the exothermic reactions that occur within the batteries. Generally, these exothermic reactions include: (I) excessive lithium extraction from the anode resulting in irreversible structural changes, oxygen release, and organic solvent oxidation; (II) the formation of lithium dendrites on the anode, which react with the electrolyte, generating significant amounts of gas and heat, potentially penetrating the separator and causing internal short circuits; (III) the melting of polyethylene (PE)-based separators at temperatures above 130 °C; (IV) the decomposition of the electrolyte at high temperatures (>200 °C) and pressures (approximately 4.6V) due to the low flash and boiling points of carbonate organic solvents, leading to substantial heat generation. Electric vehicles, which incorporate numerous batteries connected in series and parallel, rely on these circuits to form a high-energy, high-power battery system essential for their operation.

This battery system can encounter various triggering conditions such as collisions, overcharging, over discharging, and water immersion. Lithium-ion batteries are particularly sensitive to temperature and voltage variations. Both extreme high and low temperatures can cause faults. A continuous temperature rise can lead to the decomposition of the solid electrolyte interface (SEI) and electrode materials, exacerbating side reactions. Conversely, low temperatures can result in lithium plating on the negative electrode and degraded performance, potentially causing serious issues like circuit shorts. Overcharging is particularly problematic as it causes the positive material to collapse, intensifying side reactions and generating significant heat, which rapidly increases the temperature. Data indicate that overcharging is one of the primary causes of electric vehicle failures. Over discharge, which occurs when the battery voltage drops below the minimum threshold, degrades lithium battery performance, and can lead to severe safety problems such as internal short circuits.

Hydrogen Fuel Cell Vehicles (HFCV)

Structure of hydrogen fuel cells (HFC)

A fuel cell is an energy conversion device that generates electricity by combining fuel (usually hydrogen) with oxygen. Unlike a typical electrolysis reaction, the energy output of a Hydrogen Fuel Cell (HFC) is derived from the energy released when hydrogen and oxygen combine to form water.

This fundamental chemical reaction in an HFC can be represented as follows:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) + Electric\ Power + Heat$$

Fuel cells, like other cells, have a basic structure that includes a cathode (Where reduction occurs), an anode (where oxidation occurs), an electrolyte (which maintains balance between the two sides of the cell), and an external circuit (Which harnesses the generated energy to power devices). In a hydrogen fuel cell, hydrogen undergoes oxidation to form hydrogen protons and electrons at the anode. The electrons generated traverse the external circuit, creating a current that can be harnessed for power. Subsequently, oxygen is reduced into oxygen ions at the cathode. The oxidation and reduction reactions can be represented as follows:

Oxidation: $2H_2(g) \rightarrow 4H^+ + 4e^-$ Reduction : $O_2(g) + 4e^- + 4H^+ \rightarrow 2H_2O(l)$

There are various types of HFCs, but they all share the same primary reaction. The distinguishing factor is the type of electrolyte used in the cell. Factors such as operating temperature, fuel purity requirements, cell cost, reaction byproducts, etc., determine the specific applications of these cells. For instance, Alkaline fuel cells, which are known for their stability and potential to produce pure water as a byproduct, are utilized in space missions. Phosphoric acid fuel cells, which have a low fuel purity requirement, are employed in large power plants or for on-site stationary applications. Proton Exchange Membrane Fuel Cells (PEMFCs), known for their moderate operating temperature and high-power output, are commonly used in hydrogen-powered vehicles.

Proton exchange membrane fuel cell (PEMFC)

In a Proton Exchange Membrane Fuel Cell (PEMFC), the electrolyte is a hydrogen proton produced from the oxidation reaction at the anode. The fuel, hydrogen, is catalysed by platinum and oxidized into hydrogen protons and electrons at the anode. These protons then traverse a proton exchange membrane situated between the anode and cathode. Subsequently, the protons combine with electrons and air. The PEMFC does not produce tailpipe emissions as the only byproduct is pure water. The electrons generated at the anode are harnessed in the external circuit.

The structure of a PEMFC, as depicted in Figure 4, includes a Membrane Electrode Assembly (MEA). Within this assembly, there is a porous layer, two catalyst layers, and most importantly, a proton exchange membrane. The catalyst layer, which contains platinum or other newly developed catalyst materials (recently developed alternatives to reduce the use of noble metals), accelerates the reduction and oxidation reaction rates. The porous gas diffusion layer ensures pressure balance between the anode and cathode, enabling uniform fuel consumption. It also dissipates heat and provides sufficient mechanical strength to accommodate the expansion of the proton exchange membrane. The proton exchange membrane facilitates the passage of hydrogen protons from the anode to the cathode while preventing electron passage, thereby directing electrons through the external circuit where the energy is harnessed. PEMFCs are ideal for transportation applications due to their moderate operating temperature. They operate at temperatures between 60 to 100℃, slightly above environmental temperature. Additionally, they are lightweight as they do not contain solid or liquid electrolytes, thus adding no extra weight to the vehicle. They are also cost-effective compared to other types of hydrogen fuel cells and have a longer lifespan. The efficiency of a PEMFC is primarily dependent on temperature. As per collision theory, the rate of chemical reactions (efficiency) increases with temperature. However, PEMFCs cannot operate at temperatures above 100℃ as the membrane only functions under wet conditions. The electrical efficiency is approximately 40%, and the output power can reach up to 250kW, comparable to the power generated by internal combustion engines (around 500kW).

A significant limitation of PEMFCs is the potential for carbon monoxide contamination, which reduces efficiency. The catalyst platinum reacts with carbon monoxide to form a layer that covers the catalyst layer. This reduces the available surface for the hydrogen redox reaction as carbon monoxide continues to accumulate on the surface. The surface is covered by carbon monoxide through one reaction, while carbon monoxide is removed through oxidation in another. These reactions compete and affect efficiency, depending on the conditions.

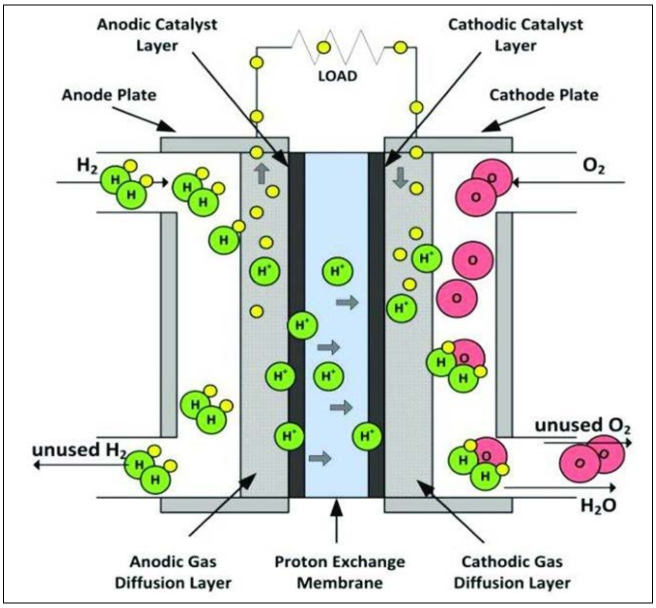

Fig 4: Proton exchange membrane fuel cell (PEMFC)

Hydrogen Fuel Cell Vehicle Safety

Hydrogen is commonly perceived as a highly explosive substance and potential bomb material. However, Hydrogen Fuel Cell Vehicles (HFCVs) are safer than generally believed. Indeed, hydrogen is highly explosive, capable of detonating when the ratio of hydrogen to air is between 4% and 75%, a range wider than most other fuels. Furthermore, hydrogen's low ignition energy of 0.017MJ implies a risk of ignition and explosion if mishandled. Yet, these same properties make hydrogen an excellent alternative fuel. Its low boiling point and high latent heat of combustion render hydrogen a clean fuel, provided safety precautions are meticulously observed. Recent studies have affirmed the safety of HFCVs. Firstly, there have been no severe accidents resulting from hydrogen leakage from the tank. Hydrogen, being the lightest gas in nature, vaporizes rapidly at room temperature and pressure and rises above the air, thereby minimizing potential fire hazards. Secondly, modern HFCVs are equipped with onboard sensors that monitor hydrogen leakage, the disparity between consumption and outflow rate, and the internal temperature and pressure of the tank. In the event of any unsafe situation, the valve automatically shuts off, ensuring the safety of the driver. Consequently, the safety of HFCVs is assured.

Analogy

Eco-friendly

Climate change is a pressing global concern. The continuous release of greenhouse gases has led to an increase in global temperatures by 0.08° Celsius every decade, with the rate of warming doubling since 1981. New energy vehicles are anticipated to reduce emissions and help control this temperature rise. Carbon dioxide, a major contributor to global warming, is significantly reduced in electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs) which have zero tailpipe emissions. This is a stark contrast to traditional cars that burn gasoline and emit harmful gases like carbon monoxide, hydrocarbons, and nitrogen oxides. However, the concept of zero-emission is misleading for both EVs and HFCVs as emissions can occur during fuel generation.

For EVs, emissions are produced during electricity generation. Studies indicate that in developed countries like the United States, natural gas, and coal, which emit greenhouse gases, make up 60.1% of the electricity source. Consequently, an electric vehicle contributes to about 4,000 pounds of carbon dioxide pollution annually. This means that EVs produce about 33% of the carbon dioxide compared to conventional cars. Although this is significantly less than the 12,000 pounds produced by gasoline cars, it is still far from zero emission. In countries that primarily rely on non-renewable energy sources, EVs can produce even more emissions than conventional vehicles.

For HFCVs, emissions are produced during hydrogen production. Currently, there are three main methods to produce hydrogen. One method is the steam methane reforming process (SMR), which converts methane (natural gas) into carbon dioxide and water vapor. The other two methods involve electrolysis of water and direct sourcing of methane from landfills and sewage. Presently, over 95% of hydrogen is produced through SMR, a process that emits a high amount of carbon. According to Praxair, a leading hydrogen fuel production company, 21.9 metric tons of carbon dioxide is produced per million cubic feet of hydrogen in practice. This equates to 9.3kg of CO_2 emission per 1 kg of hydrogen. In comparison, producing 1 gallon of gasoline (3.78 litters) results in 9.1kg of CO_2.

Assuming an HFCV consumes 0.55kg of hydrogen per 100 kilometres, around 5.15 kg of CO_2 is produced per 100 kilometres. Meanwhile, assuming 0.5 litres of gasoline per 100 kilometres for conventional cars, around 12 kg of CO_2 is produced per 100 km. This suggests that HFCVs produce only half of the CO_2 compared to conventional cars. Comparing the data, EVs currently produce fewer greenhouse gas emissions than HFCVs, but more than zero-emission due to fuel production. HFCVs produce half of the CO_2, while EVs only produce 33% of CO_2, compared to gasoline cars. EVs' performance in reducing carbon emissions is around 30% better than HFCVs. In conclusion, both EVs and HFCVs are more environmentally friendly than internal combustion vehicles (ICVs).

Charging Infrastructure

The associated refuelling facilities are still in an early stage. Therefore, there is a huge difference in the number of the electric charging station and hydrogen refuelling station. For example, according to a statistic from February 2, 2024, there are 12,146 public charging stations to support the electric vehicles in India. There are only 2 hydrogen refuelling station available in the India (specifically Gurugram and Faridabad). Figure 3 is made from the data available at The Ministry of Heavy Industries (MHI) who have been making consistent efforts for facilitating the promotion of electric vehicles in India. It clearly shows the huge disparity in the number of charging stations between the two types of stations. The number of both types of charging stations is bound to increase in the future, but so far, electric vehicles have a definite advantage in terms of charging convenience. The charging time of an electric vehicle depends on the battery capacity and charging efficiency. Most current electric vehicles require between half an hour and twelve hours to recharge. Hydrogen cars are charged in a similar way to conventional cars, simply by filling the tank through a designated hydrogen dispenser at a public refuelling station. Only five minutes or less is needed for it to complete the process. In this aspect of charging time, electric cars have a big disadvantage.

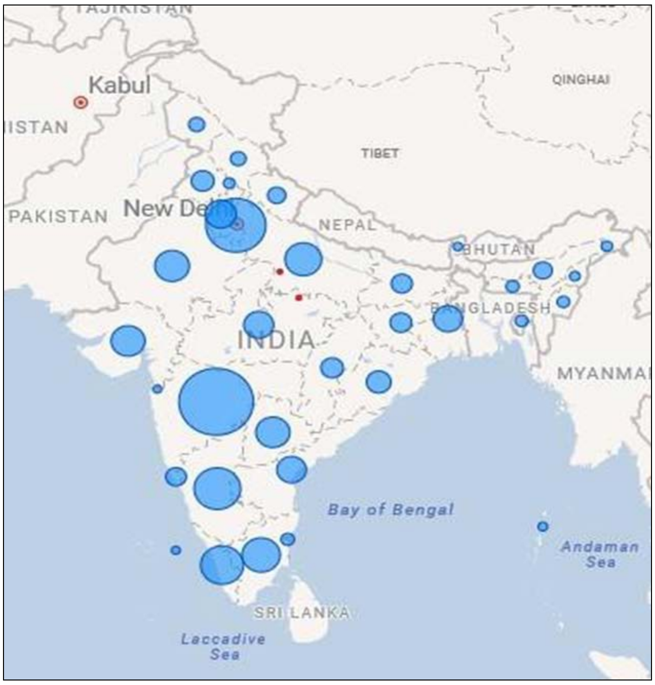

Fig 5: Distribution of electric charging station

Energy Efficiency

Electric motors are known for their superior energy efficiency compared to internal combustion engine vehicles. The energy conversion process in an internal combustion engine is rather inefficient, with only about 10% to 25% of the energy being utilized to drive the vehicle. The rest, a staggering 75% to 90%, is dissipated as heat. On the other hand, electric motors exhibit an impressive efficiency of up to 90%, a stark contrast to their internal combustion counterparts. However, to gain a comprehensive understanding of the energy efficiency of both types of engines, it’s crucial to consider the well-to-wheel (WTW) efficiency, which considers both the well to tank efficiency and the tank to wheels efficiency.

Studies have shown that the WTW efficiency of hydrogen-powered internal combustion vehicles can vary between 6.8% and 29.2%, depending on the methods used for hydrogen production and transformation. Similarly, the WTW efficiency of electric vehicles is largely dependent on the energy sources used to charge the batteries. Electric vehicles charged by fossil fuel-powered plants have a WTW efficiency ranging from 12% to 22%, which is comparable to that of hydrogen-powered vehicles. However, when electric vehicles are powered by renewable energy sources, their overall energy efficiency sees a significant boost, with the WTW efficiency ranging between 39% and 72%. This highlights the potential of renewable energy in enhancing the energy efficiency of electric vehicles.

Safety Comparison

Safety is a significant factor when discussing alternative fuel vehicles. Recent research indicates that both electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs) have a better safety record than vehicles powered by internal combustion engines (ICEs). In 2022, the Insurance Institute for Highway Safety (IIHS) in the United States conducted safety tests on a variety of vehicles, including ICEs and EVs. Interestingly, the safety scores of most EVs surpassed those of the ICEs. The Tesla Model 3 even set a record in the IIHS safety scores. The superior safety of EVs can be attributed to several factors.

Firstly, the gasoline fuel in an ICE vehicle poses a potential risk, making the vehicle akin to a small “time bomb”. Although the battery pack in an EV can also catch fire, it is not as volatile as liquid gasoline. Secondly, the absence of an engine at the front of an EV enhances its performance in front crash simulations. Furthermore, the low centre of gravity of EVs reduces the likelihood of rollovers. However, lithium-ion batteries used in EVs are prone to thermal runaway. A lithium-ion battery pack consists of several individual cells. If one cell short-circuits, it heats up and can affect the other cells.

If this heat becomes self-sustaining, leading to a cycle of heat transforming into energy and vice versa, the cell undergoes thermal runaway, which can easily cause the battery to ignite. Many EV fires are triggered by a short circuit within the battery. Although there are systems in place to regulate the temperature of individual cells, their effectiveness during accidents is not guaranteed. HFCVs, on the other hand, are also safer than ICEs. Hydrogen, being the lightest gas in the atmosphere, disperses quickly in the event of a fuel leak. A study conducted by the University of Miami in 2008 compared fuel leaks in hydrogen and gasoline vehicles.

The results showed that, within three seconds of ignition, the flame from high-pressure hydrogen shot upwards, while the heavier gasoline ignited from the bottom of the car. After one minute, the hydrogen-fuelled car was largely unaffected, having only burned the leaked hydrogen, while the gasoline car had turned into a large fireball and was completely burned out.

Additionally, the fuel tanks of hydrogen vehicles are designed to withstand significant pressure from both inside and outside during an accident. Tanks made of carbon fibre can theoretically withstand pressure less than 10,000 psi (six times atmospheric pressure). In conclusion, both EVs and HFCVs are safer than traditional gasoline vehicles. However, EVs are more susceptible to thermal runaways, leading to potentially more severe accidents than HFCVs.

Fig 6: Combustion comparison test of hydrogen fuel cell vehicle and gasoline vehicle (left: 3s; right: 1min)

Conclusion

The transportation sector, responsible for a quarter of global emissions, has seen a significant shift towards new energy vehicles, particularly electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs). These vehicles play a crucial role in reducing energy consumption and emissions. This article provides a comparative analysis of EVs and HFCVs, focusing on aspects such as carbon emissions, charging infrastructure, driving experience, and safety. The study reveals that EVs outperform HFCVs by nearly 30% in terms of energy conservation and emission reduction. In India, the charging infrastructure for EVs is more developed than that for HFCVs, with over 12,146 charging points for EVs compared to only 02 hydrogen gas stations. When it comes to energy efficiency, HFCVs lag with less than 30% efficiency, while EVs boast an efficiency of around 30% to 70%. In terms of safety, HFCVs are less prone to fire following an accident due to the volatile nature and lightweight properties of hydrogen gas. On the other hand, EVs are susceptible to overheating and catching fire, leading to severe accidents. However, both EVs and HFCVs offer better safety than traditional vehicles. Currently, EVs hold a clear advantage. However, the future holds promise for both EVs and HFCVs, with potential power reforms, increased infrastructure investment, and the development of low-carbon hydrogen production methods, such as water electrolysis. This suggests that both electric vehicles and hydrogen fuel cell vehicles have significant potential for further development.

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