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Hydrogen Fuel as a Viable Energy Source, the Indian Scenario

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Abstract: This research paper aims to explore the potential of hydrogen fuel as a viable energy source for cars, e bikes, many machinery things as well as the associated challenges and opportunities. It examines the current state of hydrogen fuel technology, its advantages and disadvantages, and the prospects for its adoption in the automotive sector. Additionally, the paper will discuss the safety, environmental, and economic aspects of using hydrogen fuel in cars, as well as the infrastructure and research and development requirements. The paper will also analyse the potential of hydrogen fuel to reduce greenhouse gas effects its emissions and improve air quality, as well as the risks associated with its use and also its further prospects for research. This includes an investigation into the safety, cost, and logistical considerations of using hydrogen fuel, as well as the potential for its use in existing vehicles. Additionally, the paper will provide insights into the future of hydrogen fuel in the automotive industry, with a focus on its potential to reduce carbon emissions and improve air quality. It will also explore existing initiatives and research in the development of hydrogen fuel technology, as well as the potential for new technological advancements to further reduce emissions and create a more sustainable automotive sector. The paper will draw on current research and literature to provide a comprehensive overview of the potential of hydrogen fuel in the automotive sector, as well as a detailed examination of the associated challenges and opportunities.

Keywords: Hydrogen fuel, Clean energy, Hydrogen Fuel cells, Renewable Energy.

I. INTRODUCTION

Hydrogen fuel is gaining increasing attention as a clean and sustainable alternative to traditional fossil fuels. As a chemical element, hydrogen has the potential to be used in a range of applications, including fuel cells, vehicles, heating systems, and energy storage, among others. When hydrogen is burned or used in a fuel cell, the only by product is water, making it a clean and emission-free source of energy. One significant advantage of hydrogen fuel cells is their high efficiency compared to traditional combustion engines. Fuel cells are more than twice as efficient as gasoline engines, and the energy produced can be used more effectively in a range of applications. Fuel cells can be used to power anything from small portable devices to larger vehicles and buildings. Hydrogen, as a fuel source, is also considered to be more sustainable than fossil fuels, as it can be produced from a variety of resources, including water, natural gas, and biogas from organic waste. Despite its many benefits, there are several challenges to expanding the use of hydrogen as a fuel source. One challenge is the limited availability of hydrogen fuelling stations, which makes hydrogen-powered vehicles less practical for long-range travel. However, steps are being taken to address this challenge, with governments and private companies investing in the development of hydrogen infrastructure. Another challenge is the cost of producing and transporting hydrogen. While the cost of producing hydrogen has decreased in recent years, it is still more expensive than other fuels. The production of hydrogen also requires energy, which can be derived from fossil fuels or renewable sources. Additionally, transporting hydrogen can be challenging and potentially hazardous, as it requires specialized containers and infrastructure.

Overall, hydrogen fuel represents a promising alternative to traditional fossil fuels, offering a clean and efficient energy source with a range of potential applications. While there are challenges to expanding its use, efforts are being made to address these challenges and improve the infrastructure required to support hydrogen as a fuel source. With continued investment and development, hydrogen has the potential to become a key fuel of the 21st century, offering a sustainable and emissions-free energy source for a wide range of applications [1,2].

II. MATERIALS

Although the development of infrastructure is a key issue that has to be tackled, hydrogen fuel cell vehicles have the potential to address both the environmental and oil dependence challenges in transportation. By transporting charged hydrogen ions through an electrolyte membrane to create current, fuel cell cars transform chemical energy into electrical energy. It is anticipated that as infrastructure for producing hydrogen is constructed, the market would grow dramatically. The market for hydrogen fuel cell vehicles (HFCV) is anticipated to grow as government funding for HFC vehicle development rises.

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The industry's growth is projected to be accelerated by rising petrol prices globally. The adoption of hydrogen is fuelled by a rise in environmental awareness caused by air pollution, as well as a rise in traffic and greenhouse gas emissions. The market demand for hydrogen fuel cell vehicles (HFCV) has increased as a result of a rise in the number of R&D efforts for hydrogen fuel cell technologies. In addition, a rise in the use of reimbursement procedures in the automation sector is favourably impacting market growth. Several nations have created various policies to handle environmental concerns. For instance, in order to reach its goal of 1.5 million zero-emission vehicles by 2025, the American state of California committed funds to the construction of hydrogen filling stations. Such programmes aid in market expansion. Market expansion is projected to be fuelled by key industry players' increasing innovations and improvements. For instance, the three publicly available hydrogen vehicles as of 2019 are the Honda Clarity, Toyota Mirai, and Hyundai ix35 FCEV.Electrical shock and fuel flammability are the two main risks associated with hydrogen and fuel cell cars. By electrochemically converting oxygen (O_2) and hydrogen (H_2) from the air around them into water (H20) and electrical energy, fuel cells provide vehicle propulsion. The vehicle's electric motors are then employed to propel it forward, and current electrically operated features like the radio, lighting, and air conditioning are additionally powered by electricity. Some fuel cell car motors operate at voltages higher than 350V. Electric shock is a serious risk when currents are this high; 50V is a high enough voltage to stop a person's heart. Another problem is that hydrogen is flammable. In comparison to other fuels, hydrogen has a relatively wide range of flammability in air, ranging from 4% to 75% (gasoline is to 7.6%). The energy required to start hydrogen combustion is substantially lower than that necessary to start other common fuels (for example, a little spark will ignite it) when the ideal combustion environment is present (a 29% hydrogen-to-air volume ratio). But compared to petrol vapour and air, hydrogen is around 57 times and 14 times lighter, respectively. It follows that if it's released into the open, it usually rises quickly and disperses. This is advantageous for safety in the outdoors. Additionally, because hydrogen burns with a flame that is practically invisible, it is harder to spot and put out. Therefore, hydrogen leakage could be a problem, especially if vehicles are kept in enclosed places where hydrogen can accumulate in roof gaps. At standard atmospheric pressure, hydrogen disperses swiftly due to its small molecule size. As a result, larger pressures (up to 10,000 pounds of force per square inch) must be maintained. Due to the extremely high turbulent flow rate of hydrogen, significant concentrations of hydrogen can form close to the vehicle in the event of a pressure vessel rupture. Even though hydrogen disperses quickly, this emission will cause a combustible mix to form for a short period in the open. A vehicle powered by a hydrogen fuel cell emits only water. The hydrogen itself doesn't 'burn', instead a chemical reaction between hydrogen and oxygen creates electricity, which drives the motor Fig 1[3,4].

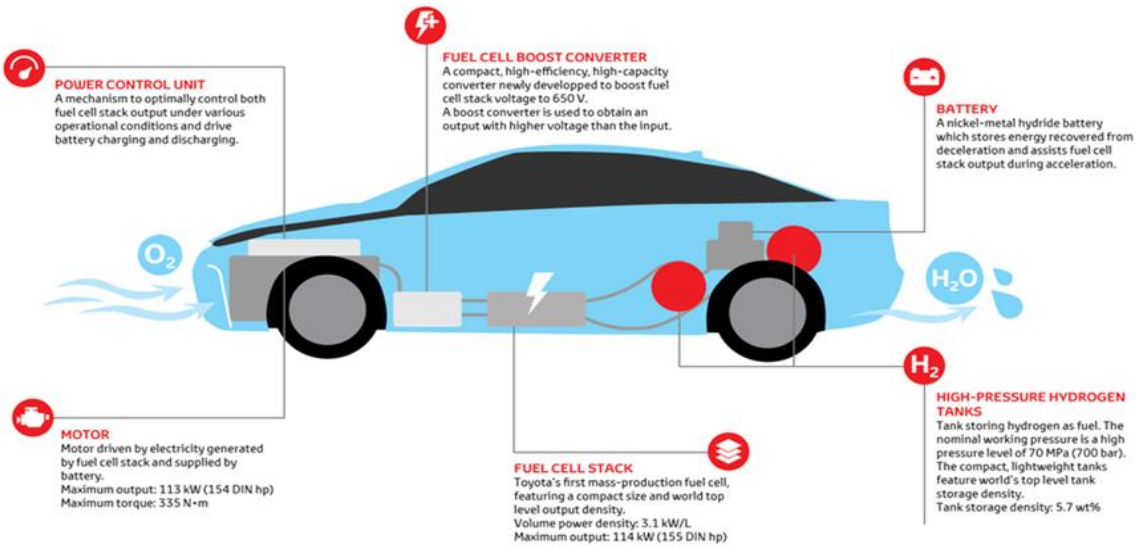

Fig. 1 Steps in functioning of hydrogen car (Courtesy: carmagazine.co.uk)

III. CURRENT REVIEWS

Because of its low impact on the environment and adaptability, hydrogen fuel is becoming more and more recognised as a promising clean energy source. A variety of industry-led and continuing research projects are now working to enhance the creation, storage, and application of hydrogen fuel. By 2050, the world's need for hydrogen generated only through low-carbon pathways might increase more than 10 times, according to "The Global Hydrogen Review" by the International Energy Agency (IEA). Numerous home energy sources, including grid electricity and renewable energy sources like wind, solar, and hydropower, can be used to create hydrogen. Hydrogen fuel is considered as a promising renewable energy source more and more due to its versatility and minimal environmental impact. Currently, a number of industry-led and ongoing research programmes are trying to improve the production, application, and storage of hydrogen fuel.

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According to "The Global Hydrogen Review" by the International Energy Agency (IEA), by 2050, there may be a more than 10-fold increase in the global demand for hydrogen produced solely through low-carbon pathways. Hydrogen can be produced using a variety of home energy sources, including grid electricity and renewable energy sources including wind, solar, and hydropower. "Renewable energy hydrogen fuel cell energy systems: A critical review" presents a critical review of integrating hydrogen fuel cells with batteries and the control system with renewable energy. The paper suggests that the combination of renewable energy, fuel cells, and batteries may be a promising approach to achieve sustainable energy storage and utilization. "Hydrogen as an energy carrier and main fuel" is another paper that reviews the current development and usage of hydrogen in various sectors, including transportation and energy storage. It concludes that hydrogen fuel cells are a promising technology for powering transportation, particularly in heavy-duty vehicles like buses and trucks. However, the paper also notes that there are still technical and economic challenges that need to be addressed. "Current state of steam reforming" is another paper that reviews the current state of steam reforming, one of the most common methods of hydrogen production. The paper notes that there are ongoing efforts to improve the efficiency of steam reforming. According to a survey, global annual sales of hydrogen fuel cars will be increasing year by year, as we can see in the below figure2. [5, 6]

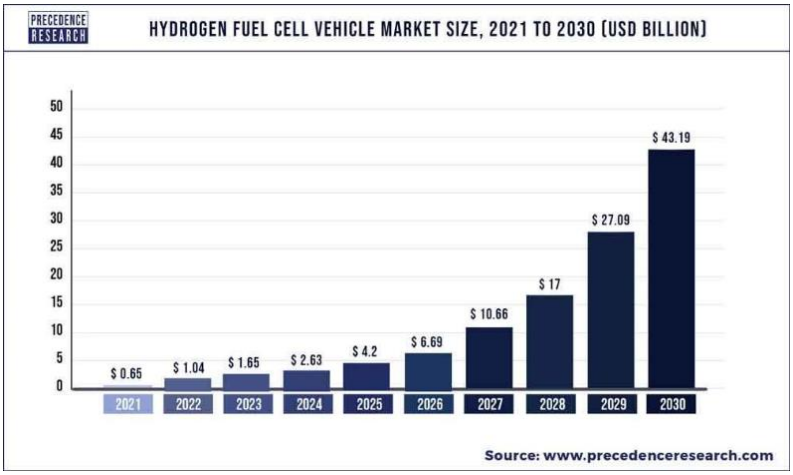

Fig. 2 Global Annual Sales of Hydrogen Cars

News Report

13 March 2023, New York, NY GLOBEE NEWSWIRE: An updated market study titled "Hydrogen Fuel Cell Vehicle (HFCV) Market Share, Size, Trends, Industry Analysis Report, By Technology (Proton Exchange Membrane Fuel Cell, Alkaline Fuel Cell, Solid Oxide Fuel Cell); By Vehicle Type (Commercial Vehicle, Passenger Car); By Region; Segment Forecast, 2023 - 2032" has been added to Polaris Market Research's database. According to the most recent research analysis, the global hydrogen fuel cell vehicle (HFCV) market size/share is forecast to reach a revenue of around USD 62.88 billion by 2022, with an estimated value of USD 1.51 billion. with a CAGR of almost 45.2% between 2023 and 2032, by 2032. March 14, 2023 (The Express wire) "Hydrogen Fuel Cell Vehicles Market" - Global [Recent Market Research 110 Pages]: A crucial tool for companies of all sizes, 2023 offers thorough data on current trends, market size, recent advancements, and fresh prospects. This research provides an overview of the hydrogen fuel cell vehicle market together with historical and forecasted data on prices, revenue, demand, and supply. It also includes a growth analysis. The Hydrogen Fuel Cell Vehicles market research offers in-depth perceptions into market segments by type (Proton Exchange Membrane Fuel Cell, Alkaline Fuel Cell, Solid Oxide Fuel Cell), applications (Commercial Vehicles, Passenger Cars), and market size. The paper looks into a number of important elements influencing future product advancements and overall growth prospects. [7, 8].

IV. INDIAN SCENARIO

In keeping with India's lofty environmental goals, Prime Minister Narendra Modi wants to make his country energy independent by 2047, with green hydrogen serving as a significant replacement for fossil fuels. The National Hydrogen Mission, which aims to manufacture hydrogen using renewable energy sources, was announced in the Budget Speech for FY 2021–22 in order to stay up with multinational corporations. When the programme was unveiled, Green Hydrogen was positioned as the key to India's energy security and combating global warming. India’s hydrogen demand was estimated by TERI to be 6 million Tonnes (MT) annually in 2020. However, research has indicated that there is a huge potential for development in this field. The price of hydrogen is anticipated to decrease by 50% by 2030. By 2050, there will be a 5-fold increase in hydrogen demand, reaching 28 MT, with 80 percent of that demand anticipated to be environmentally friendly. A lot of Indian businesses have already begun advertising their intentions to dabble in the green energy market. Reliance Industries Ltd. (RIL), the largest oil and gas corporation in India, recently revealed its aspirations to go green. The business has disclosed its goals to achieve net zero carbon emissions by 2035. In order to

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construct a 5000-acre green energy complex in Jamnagar, Gujarat, RIL aims to invest INR 600 billion. A green hydrogen electrolyser plant will be housed in the facility. The Public Sector Undertaking (PSU) GAIL (India) has announced a tender to buy an electrolyser. One of the largest facilities announced thus far, a 10 MW facility, is being finalised, and locations are being considered. GAIL has advanced and has even begun experimenting with blending hydrogen into natural gas in one of the cities. In a similar vein, NTPC has also expressed interest in commercially producing green hydrogen. They have announced a 5 MW plant and stated their intention to achieve the same from their 4.75 GW park in the Rann of Kutch.The company is now operating a pilot in its Vindhyanchal division. Additionally, the business intends to build a green hydrogen refuelling station in Leh, Ladakh, and will begin operating 5 hydrogen buses there. Expressions of Interest (EOI) for ten hydrogen fuel cell buses and vehicles have been requested. Another PSU, Indian Oil Corporation Limited (IOCL), has declared its intention to investigate the green hydrogen market. At their Mathura refinery in Uttar Pradesh, they recently announced plans to build a green hydrogen facility with a daily capacity of roughly 160,000 barrels. The Kochi international airport's solar facility will be used to power IOCL's ambitions to put up a hydrogen production facility there. Another Indian company seeking to enter the green hydrogen market is Larsen and Tourbo (L&T). Their most recent report states that they have a goal to attain net zero emissions by 2040. They are constructing a green hydrogen plant at their Hazira facility in addition to looking into the possibilities of producing electrolysers there. Hydrogen will be used in refineries owned by both Hindustan Petroleum Corporation Limited (HPCL) and Bharat Petroleum Corporation Limited (BPCL). In addition, Solar Energy Corporation Limited (SECI) plans to release a request for proposals for the construction of green hydrogen facilities powered by renewable energy sources. Ohmium International has sent its first ever electrolyser unit to the United States, establishing India as a major hub for the production of green hydrogen. India's first green hydrogen electrolyser Gigafactory, Ohmium's Bengaluru plant, where the electrolyser was made.India has taken a ground-breaking approach to the green hydrogen industry. The industry currently has a high cost of production, but because to rising demand, improved technology, and strong government support, it will soon achieve economies of scale that will lower the cost. India's Make in India drive and its net zero emission ambitions are in line with the sector, which offers a tonne of room for investment and growth. [7,8]

V. CONCLUSION

Hydrogen fuel has been a topic of interest in recent years, with the potential to become a clean and sustainable energy source for various sectors, including transportation, power generation, and industrial processes. While traditional fossil fuel-based supply activities decline, the expertise of the oil and natural gas industry fits well with the advancement of hydrogen technologies. Hydrogen has the advantage of being the lightest element and can be used in fuel cells to generate electricity with water as the only by product. It has the potential to be a key element in the transition to a low-carbon economy, especially since it can be produced from a variety of sources including water, biomass, and natural gas, making it a versatile fuel option.

In the transportation sector, hydrogen fuel cells are being developed for applications such as cars, trucks, and buses. Fuel cells offer several advantages over traditional combustion engines, including greater efficiency, low emissions, and quiet operation. However, hydrogen infrastructure deployment remains a challenge, and the costs associated with hydrogen fuel cells have yet to become fully competitive with traditional combustion engines. On the other hand, utilizing hydrogen as a fuel in an internal combustion engine (ICE) or fuel cell (FC) propelled vehicles is a promising direction for the future.Hydrogen is also being explored as a potential solution to decarbonize the power sector [2]. Hydrogen can be used as a fuel in gas turbines, which can generate electricity with lower emissions than traditional fossil fuel-based power plants. Additionally, hydrogen can be used to store excess renewable energy generated from wind and solar power, allowing it to be used when the renewable sources are not generating enough power. The industrial sector, especially the chemical industry, could also benefit from the use of hydrogen as a feedstock or fuel. In the chemical industry, hydrogen can be used in various processes, including the production of ammonia, hydrogen peroxide, and methanol. The versatility of hydrogen as a feedstock or fuel is a testament to its ability to help achieve decarbonization goals in numerous sectors. The cost of hydrogen is still a challenge that needs to be addressed. The cost of production, storage, and distribution of hydrogen is a limiting factor in its widespread adoption. Blue hydrogen, produced from natural gas with carbon capture and storage (CCS), is currently the most cost-competitive option, but it still requires more comprehensive deployment initiatives. In conclusion, hydrogen fuel has the potential to be a significant contributor to the transition towards a sustainable future. It can be used in various sectors, including transportation, power generation, and industrial processes.

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