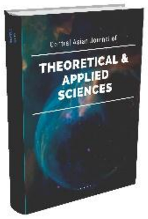

CENTRAL ASIAN JOURNAL OF THEORETICAL AND APPLIED SCIENCES

Volume: 03 Issue: 08 | Aug 2022 ISSN: 2660-5317
https://cajotas.centralasianstudies.org

Hydrogen Energy: An Alternative Fuel for the Future

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Received 24th Jun 2022, Accepted 13th Jul 2022, Online 5th Aug 2022

Annotation: *Hydrogen is an energy carrier that can transform our fossil-fuel dependent economy into a hydrogen economy, which can provide an emissions-free transportation fuel. Literature reviews and independent research were the main methods of research. Hydrogen storage and transport are issues of intense research due to hydrogen's characteristic low density. Hydrogen is the fuel of the future. As an avid researcher of alternative fuels and an ambitious chemistry student, this researcher understands the importance of a shift to a hydrogen economy. Hydrogen is an energy carrier that can be used in internal combustion engines or fuel cells producing virtually no greenhouse gas emissions when combusted with oxygen. The only significant emission is water vapor. Hydrogen production and storage is currently undergoing extensive research. A solar-hydrogen system can provide the means of a totally emissions-free method of producing hydrogen. Although steam reformation of methane is currently the major route to hydrogen production, the emissions involved can also be controlled much more efficiently than our current system of transportation fuel. Much work is in progress to initiate a shift from a fossil-fuel economy to a hydrogen economy.*

Keywords: *hydrogen, fuel, future, energy, production, transportation, fossil, economy, alternative, carrier.*

Introduction

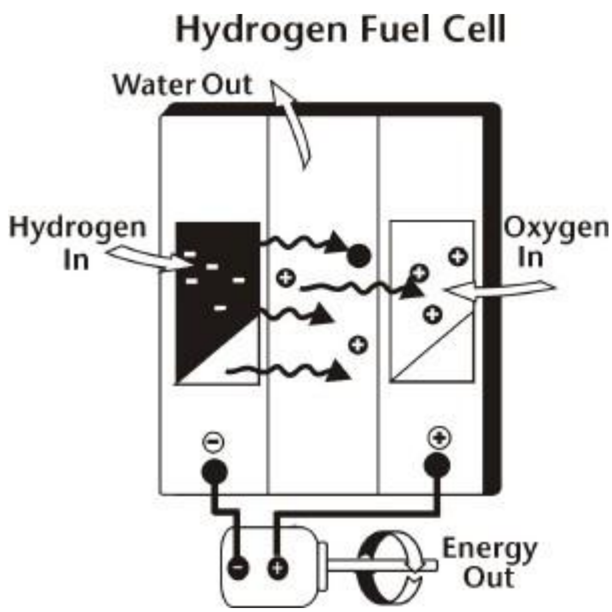
Hydrogen can be considered as a clean energy carrier, similar to electricity. Hydrogen can be produced from various domestic resources such as renewable energy and nuclear energy. In the long-term, hydrogen will simultaneously reduce the dependence on foreign oil and the emission of greenhouse gases and other pollutants. Hydrogen can be considered as the simplest element in existence. Hydrogen is also one of the most abundant elements in the earth's crust. However, hydrogen as a gas is not found naturally on Earth and must be manufactured. This is because hydrogen gas is lighter than air and rises into the atmosphere as a result. Natural hydrogen is always associated with other elements in compound form such as water, coal and petroleum.Hydrogen has the highest energy content of any common fuel by weight. On the other hand, hydrogen has the lowest energy content by volume. It is the lightest element, and it is a gas at normal temperature and pressure.[1,2]

Hydrogen is considered as a secondary source of energy, commonly referred to as an energy carrier. Energy carriers are used to move, store and deliver energy in a form that can be easily used. Electricity is the most well-known example of an energy carrier. Hydrogen as an important energy carrier in the future has a number of advantages. For example, a large volume of hydrogen can be easily stored in a number of different ways, including underground hydrogen storage, compressed hydrogen in tanks, or through chemical compounds that release hydrogen after heating.Hydrogen is also considered as a high efficiency, low polluting fuel that can be used for transportation, heating, and power generation in places where it is difficult to use electricity. In some instances, it is cheaper to ship hydrogen by pipeline than sending electricity over long distances by wire. Since hydrogen does not exist on Earth as a gas, it must be separated from other compounds. Two of the most common methods used for the production of hydrogen are electrolysis or water splitting and steam reforming.[3,4]

Steam reforming is currently the least expensive method for producing hydrogen, but building the plants for the process is expensive. It is used in industries to separate hydrogen atoms from carbon atoms in methane. Unfortunately, because methane is a fossil fuel, the process of steam reforming results in greenhouse gas emissions, which is linked to global warming. The other method for the production of hydrogen is electrolysis. Electrolysis involves passing an electric current through water to separate water into its basic elements, hydrogen and oxygen. Hydrogen is then collected at the negatively charged cathode and oxygen at the positive anode. Hydrogen produced by electrolysis is extremely pure, and results in no emissions since electricity from renewable energy sources can be used. Unfortunately, electrolysis is currently a very expensive process, but costs may fall if the cost of electricity to carry out the procedure also falls. There are also several experimental methods of producing hydrogen such as photo-electrolysis and biomass gasification. Scientists have also discovered that some algae and bacteria produce hydrogen under certain conditions, using sunlight as their energy source. Currently, hydrogen is mainly used as a fuel in the NASA space program. Liquid hydrogen is used to propel space shuttle and other rockets, while hydrogen fuel cells power the electrical systems of the shuttle. The hydrogen fuel cell is also used to produce pure water for the shuttle crew. Hydrogen is also used in agriculture to create fertilizers, and to make cyclohexane and methanol, substances used in the production of plastics and pharmaceuticals. Oil-refining processes also make use of hydrogen gas.[5,6]

Discussion

Fuel cells directly convert the chemical energy in hydrogen to electricity, with pure water and heat as the only by-products. Hydrogen-powered fuel cells are not only pollution-free, but a two- to three-fold increase in the efficiency can be experienced when compared to traditional combustion technologies.



Hydrogen Fuel Cell (Image source U.S. Dept. of Energy)

Fuel cells can power almost any portable devices that normally use batteries. Fuel cells can also power transportation such as vehicles, trucks, buses, and marine vessels, as well as provide auxiliary power to traditional transportation technologies. Hydrogen can play a particularly important role in the future by replacing the imported petroleum we currently use in our cars and trucks. In the future, hydrogen will join electricity as an important energy carrier, since it can be made safely from renewable energy sources and is virtually non-polluting. It will also be used as a fuel for ‘zero-emissions’ vehicles, to heat homes and offices, to produce electricity, and to fuel aircraft. Hydrogen has great potential as a way to reduce reliance on imported energy sources such as oil. But, before hydrogen can play a bigger energy role and become a widely used alternative to gasoline, many new facilities and systems must be built.

Future hydrogen energy infrastructure: The hydrogen is produced through a wind electrolysis system. The hydrogen is compressed up to pipeline pressure, and then fed into a transmission pipeline. The pipeline transports the hydrogen to a compressed gas terminal where the hydrogen is loaded into compressed gas tube trailers. A truck delivers the tube trailers to a forecourt station where the hydrogen is further compressed, stored, and dispensed to fuel cell vehicles.[7,8]

Hydrogen technology is still at a very nascent stage in the country, and there is limited infrastructure and scale of hydrogen dispensing units available. This makes the acquisition and total cost of ownership for FCEVs higher. Most hydrogen production methods deployed today rely on fossil fuels. The government incentives and localisation of core aggregates are likely to reduce costs and improve the overall economics of FCEV. The newly introduced National Hydrogen Energy Mission Programme aims to bring open access to renewable energy and increase the production of green hydrogen. With these positive steps, one can expect a decisive move towards a sustainable future of mobility, with hydrogen fuel cell technology playing a predominant role across segments, in public transport, commercial vehicles, and passenger vehicles.

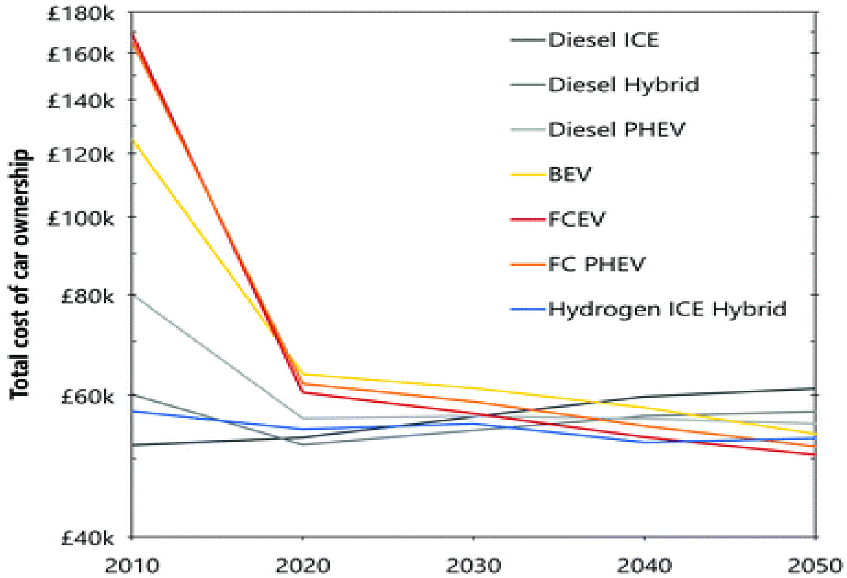
Hydrogen too produces energy when burnt like all other fuels. What makes it environment-friendly fuel is that the by-products of burning hydrogen are water and water vapour. Being an energy carrier, it can store or deliver a huge amount of energy. Presently, it is used in petroleum refining and fertilizer production and transportation is also creating a new market for it. Hydrogen can be used in fuel cells to generate electricity and heat. Further, it has the potential to produce energy for use in diverse applications like backup power, portable power etc.Presently, less than 1 per cent of hydrogen produced is green hydrogen. According to the International Renewable Energy Agency (IRENA), hydrogen will make up 12% of the energy mix by 2050. It was further suggested that about 66% of this hydrogen used should come from water, not natural gas. It is comparatively highly efficient and has a lower carbon footprint.[9,10]

To produce ammonia and methanol in industrial sectors including refineries and fertilisers, over 6 million tonnes of hydrogen is consumed by India every year. By 2050, hydrogen consumption is expected to rise by 28 million tonnes. It is projected that India's hydrogen demand will increase five-fold by 2050, with 80% of it being green. It is well known that green hydrogen is sustainable and environment-friendly but it is costly too. The cost factor restrains the Indian plan to adapt green hydrogen on a larger scale. Also, only a few companies in India manufacture electrolysers, used for the generation of green hydrogen. As per the Energy and Resources Institute (TERI), it costs $5-$6 per kg to produce green hydrogen. This is expensive for industries like steel and fertilizers to adopt the fuel and at least $2 per kg might help in improving the scenario. Reducing prices is not possible till India ramp up its electrolysers manufacturing. The government of India launched the National Hydrogen Energy Mission (NHEM) in 2021-22 to work in the sector. In 2022-23, the Ministry of Power announced a Green Hydrogen Policy (GHP) and welcomed Industry participants. The policy offers the establishment of manufacturing zones for production, connectivity to the ISTS (Inter-State Transmission System) and free transmission for 25 years with few underlined exceptions. By 2030, a target of 5 million tonnes per annum (MTPA) of green hydrogen production is set under the policy.

Results

Hydrogen technologies have experienced cycles of excessive expectations followed by disillusion. Nonetheless, a growing body of evidence suggests these technologies form an attractive option for the deep decarbonisation of global energy systems, and that recent improvements in their cost and performance point towards economic viability as well. This paper is a comprehensive review of the potential role that hydrogen could play in the provision of electricity, heat, industry, transport and energy storage in a low-carbon energy system, and an assessment of the status of hydrogen in being able to fulfil that potential. The picture that emerges is one of qualified promise: hydrogen is well established in certain niches such as forklift trucks, while mainstream applications are now forthcoming. Hydrogen vehicles are available commercially in several countries, and 225 000 fuel cell home heating systems have been sold. This represents a step change from the situation of only five years ago. This review shows that challenges around cost and performance remain, and considerable improvements are still required for hydrogen to become truly competitive. But such competitiveness in the medium-term future no longer seems an unrealistic prospect, which fully justifies the growing interest and policy support for these technologies around the world.[11]

Conventional internal combustion engines can be modified to run on pure hydrogen (‘HICEs’) and could see early deployment as they are substantially cheaper than fuel cells. However, hydrogen combustion is less efficient than a fuel cell and releases NO_x, hence is not expected to play a significant long-term role in transport. Hydrogen can be blended with natural gas (‘hythane’) or diesel in dual-fuel vehicles; or it is possible to switch between both in bi-fuel powertrains. This allows the use of existing infrastructure, but these are not zero-emission and could eventually be displaced by lower-carbon options. Deep decarbonisation of transport must focus on private cars, which account for around half of the global transport sector . FCEVs are currently expensive, but several analyses suggest cost reductions from mass-production could see their total cost of ownership (TCO) converging with other principal powertrains by 2030.



Total cost of ownership for major powertrains. Hydrogen, electric and fossil-fuelled vehicle lifetime costs are expected to converge by 2030.Ships-Marine applications hold promise for hydrogen deployment, with fuel cells already being trialled for propulsion in a handful of projects including ferries

Aeroplanes-Aviation is one of the hardest sectors to decarbonise, and reducing emissions from aircraft propulsion has seen little progress. In 2016 the International Civil Aviation Organization agreed to cap aviation emissions at 2020 levels, but primarily through carbon offsetting rather than low-emission fuels.Other aviation-based sectors are more promising-Fuel cells have been tested for aircraft auxiliary power units and for taxiing aircraft to/from airport terminals.

Hydrogen energy resource is a new renewable energy resource. At present, it is in the beginning phase of research and advancement. MNRE additionally financed research ventures on various parts of hydrogen vitality innovation improvement. Bringing down the expense of hydrogen energy in India incorporates a difficult task. The improvement in production rates from various strategies, advancement of stockpiling capacity and productivity improvement of various kinds of power device for the practical framework are still required. The specific guidelines are required to examine, improve, and exhibit exercises in different hydrogen energy-based energy advancements. [12]

Conclusions

Hydrogen energy development continues to be an important research, development, and demonstration pathway for major economies around the world. With respect to hydrogen energy products and services, the focus is on FCVs, FCBs, and industrial equipment like forklifts. However, addressing the needs for lower cost and better performing hydrogen energy infrastructure for these products is also an important priority. While progress has been made in areas such as hydrogen production, storage, delivery, codes and standards, and customer acceptance, cost and other targets necessary for commercialization and market scale-up have not been reached.

Recently, following the global economic downturn and increases in the production of petroleum and natural gas due to advances in drilling techniques, many questions have been raised about the prospects of long-term market success for hydrogen energy systems.

Infrastructure development costs remain an important concern. It is important to ask questions and focus ongoing research, development, and demonstration activities on the key barriers so that the most important technical targets are addressed and hopefully reached in a timely and cost-effective manner.

Nevertheless, one of the lessons learned in energy markets over the last several decades is the variability and uncertainty associated with the price and availability of various types of fossil and bio-based fuels. Not only does hydrogen energy offer the potential for near limitless supplies and clean conversion to electricity using fuel cells, it also provides risk management advantages as it can be derived from many locally-supplied sources, including water. These advantages continue to make hydrogen energy a valuable investment opportunity in the energy portfolio of many countries around the world.[13]

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