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Review Article

A review on green hydrogen, the fuel source of the future

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Abstract

In 2018, a large-scale social movement emerged calling for the implementation of stringent measures to lessen the consequences of climate change in Europe and other parts of the globe. This movement is becoming more widespread as a result of both rapid global warming and widespread catastrophic weather events. The idea of the integrated hydrogen economy is that hydrogen serves as a primary fuel for transportation and, at the same time, in industrial applications, as well as energy production. While they started out by supporting fuel cell cars (FCEVs), a number of nations, including Australia, China, member states of the European Union, and Japan, are now creating long-term policies for the hydrogen economy. These nations have also expanded their efforts beyond the transportation sector. Spacecraft have been using hydrogen as a fuel since the 1960s, when it was first recognized as such. The Apollo ship's issues were caused by hydrogen seeping out of the fuel cells that drive the vehicle. In automobile engines, hydrogen is burned in place of gasoline, or it is combined with oxygen in fuel cells. Although both of these sorts of technology are now in use—to generate electricity and power automobiles—the second type has drawn more attention than the first in an effort to accelerate the shift to clean energy. What then is hydrogen? It is odorless, colorless, and non-toxic. Air is fourteen times more plentiful than water and is available in endless amounts everywhere; the only issue is that it is rarely found for free. It must therefore be extracted from other elements in order to be obtained. It is frequently paired with other molecules, whether they are water and oil in their liquid forms or natural gas in its gaseous condition.

Keywords: hydrogen, natural gas, fuel source.

Introduction

Everyone can now clearly see that finding fossil fuel substitutes is increasingly necessary, particularly in light of the growing costs and variety of once-familiar fuels. The increase in transportation costs caused a wave of strikes among many different parties, including producers, truck drivers, and consumers. However, scientists had a greater vision. With the assistance of the governments of developed and developing nations, which offered them every kind of support, they dedicated themselves to research and experimentation in the hunt for alternative energy sources. The outcomes were quite pleasing. The energy of tides and sea waves was employed as kinetic energy that could be transformed into energy, while solar energy was used to generate electricity and heat water. electrical power [1,2]. The utilization of hydrogen as an energy source has emerged as a novel concept, attracting enormous interest and hopes due to its status as the most abundant, safest, and cleanest element in the universe. However, the issue still stands: Given the abundance of clean and renewable energy sources, why is there still a need for fossil fuels and oil?

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The reason for this is that these new technologies are still quite expensive and are not a good replacement for conventional fuels. As we can see, most of them require electrical energy. While electricity is commonly utilized, it does not yet contain fossil fuels, particularly essential ones like managing transportation modes with electricity. The majority of effective energy sources are dependent on certain meteorological factors, such as the sun's brightness for solar energy, one's proximity to the coast for tidal energy, and the abundance of wind on farms for the usage of wind turbines. Following a number of tests and analyses, researchers determined that hydrogen was the most appropriate energy source to replace other fuel sources (Figure.1) [3,4].

Forms of renewable energy

There are many different types of energies and applications for them, particularly renewable energies, which are those found in nature that never run out, regardless of how much of them are used. Because of this, they are the most environmentally friendly and clean energy source available. The high cost of the components required to transform these resources into electrical energy makes it challenging to extract energy from them, though [6,7].

Forms of these energies

1- **Solar energy:** Cells that absorb solar radiation, transform it into electrical energy, and store it in lead cells are how the sun's energy is used to create electricity (figure.2). For subsequent use, these cells are positioned in sizable regions that receive constant sunlight, such as those close to the equator [8,9].

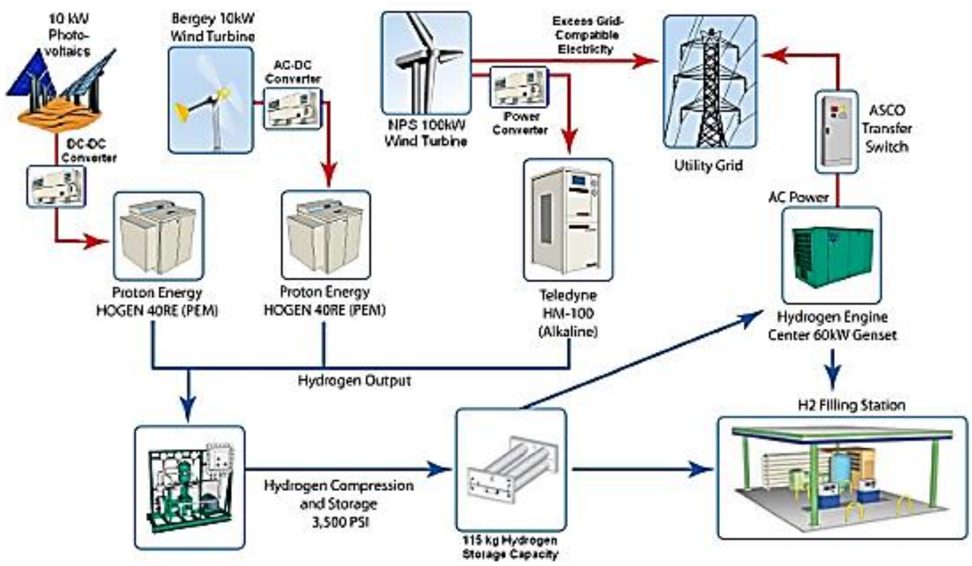


Figure 1: Overall Wind 2H2 system diagram [5]

Figure.2 The presence of hydrogen in the sun[10]

2- Wind energy: In this type of energy (figure.3), the wind is used as a source of energy production by converting it into electricity using turbines and storing it in a lead accumulator. These turbines are placed in large areas exposed to the winds and where weather fluctuations occur permanently. The optimal use of these energies has been made in Germany in a wind farm. One unit in this area provides enough energy for fifty thousand people [11,12].

3- Tidal energy: It is the energy (figure.4)that is produced by the effect of the gravity of the moon and the sun on the sea, which leads to water moving towards the beach and receding towards the sea, which leads to the generation of electricity through turbines, one of the lost energies in most countries of the world, as humans can exploit these energies through generators that produce and store energy. In lead batteries [13,14].

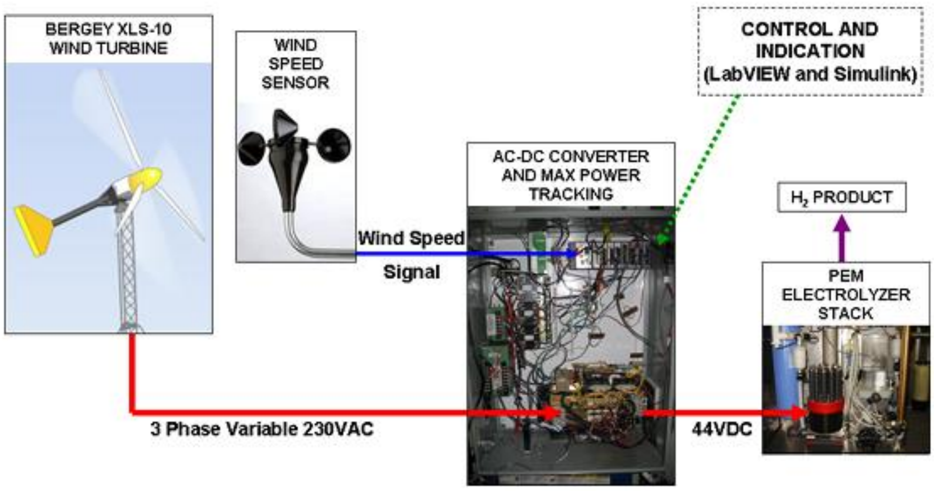


Figure.3 Enhanced wind-to-hydrogen system [5]

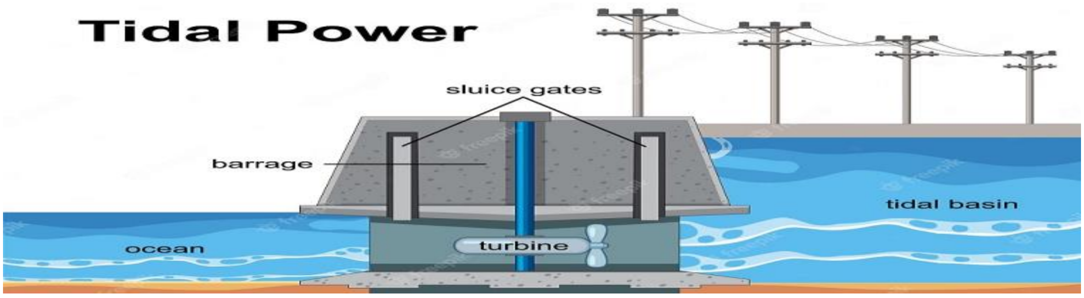


Figure 4 Tidal energy [15]

Non-renewable energies

These are energies that take millions of years to form, and they do not exist in abundance, but we depend on them in most areas of our lives. They include oil, gas, coal, and other resources as well [16,17]. These materials are:

1- **Oil:** It is a non-renewable resource with a greenish-black color (figure.5). It is used by humans in various fields, the most important of which is fuel for cars and means of transportation. Despite the difficulty of its formation, it is the result of the decomposition of dead plants over millions of years, and other factors such as its high prices. Humans tend to use it abundantly to meet their increasing needs and low prices. Compared to alternative and expensive energy means [18,19].

2- **Natural gas:** There are two forms of natural gas: the first is wet gas, where this gas is found with oil in special fields, and the second is where gas is found alone in its fields. These fields are found in abundance in Algeria and the Maghreb countries, and people depend on natural gas a lot in their daily lives, including heating, cooking, and other things. Household necessities (Figure 6) [21,22].

3- **Coal:** It is a type of non-renewable energy (figure.7). It is the result of the accumulation of organic materials on top of each other over millions of years under extreme conditions of high temperature and high pressure. This type of energy has few uses compared to other types of energy, so most of its uses are in heating and personal purposes [23,24].

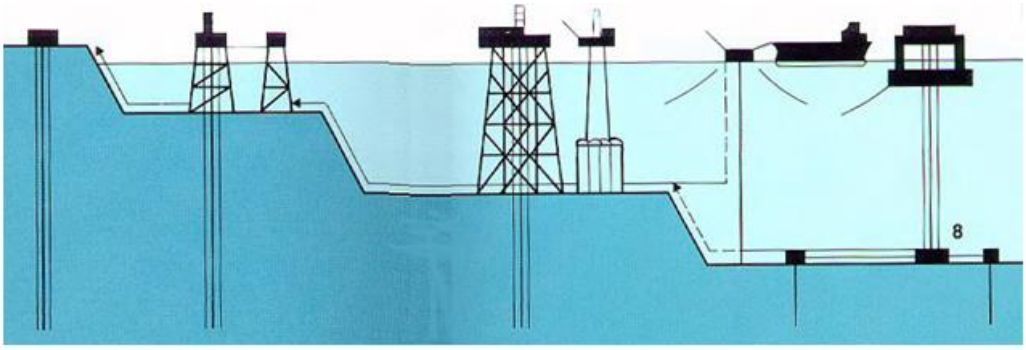


Figure 5: Oil production [20]

Figure.6 Natural gas [20]

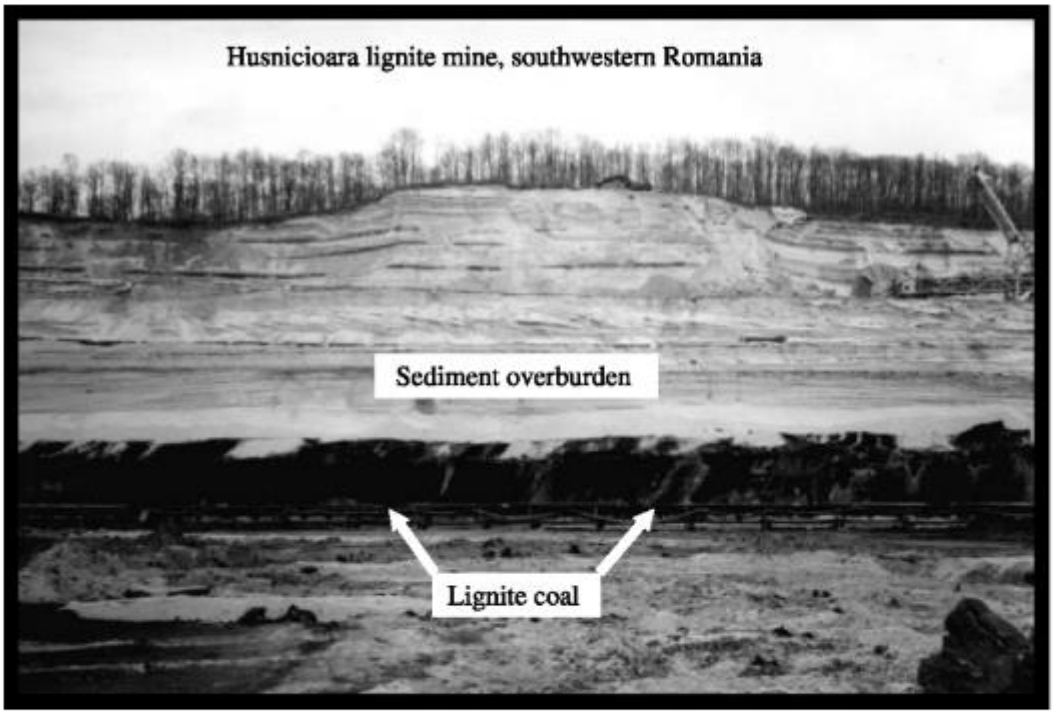


Figure 7 Photograph of a low rank coal bed (lignite of Pliocene age) from southwestern Romania [25]

Hydrogen production by solar cells

The Electrolyzer: The analyzer is just a piece of gear that analyzes water into its basic components. It is a critical component in fuel cell systems linked to solar cells, so-called ("hydrogen-sun") platforms. The devices were converting electrical energy generated by solar cells into hydrogen gas. These include high-pressure and high-temperature analyzers as well as low-temperature, low-pressure, and solid- media & liquid-media analyzers. The preferred operating conditions in hydro solar generation systems are low to medium pressure, lower temperature, and a liquid medium. It is compared with high-pressure, high-temperature, or solid-media analyzers, as they are inexpensive and simple to handle and available [26].

As a quick comparison between the solid electrolyte (PEM) medium and the liquid medium, we find that the electrolyte with the solid medium (PEM) (Membrane Exchange Proton) can be used in hydrosolar systems to avoid the use of caustic media. One of its advantages is that it does not require continuous monitoring, as in liquid electrolytes. However, the disadvantages of PEM analyzers are their high price, and they cannot provide any information about the analysis stage, like liquid analyzers, in which we can monitor the liquid level. In general, dealing with a PEM analyzer is considered almost free of any risks or errors, and its biggest problem remains replacing its parts when their validity period expires [27].

Examples include membrane plow -out or catalyst degeneration. Both problems are costly because we need to replace these parts.

Principles of the Electrolyzer

The simple alkaline media analyzer, which is utilized in Shams hydrogen systems, is such an elemental building block that separates water into its fundamental constituent parts, oxygen and hydrogen. This can be done by applying a low voltage, relatively high DC current through a simple medium or solution, such as potassium hydroxide (KOH) and distilled water. During the analysis, a flow of continuous electric current is applied, which flows in one direction only, and this is essential for understanding the principle of operation of the analyzer. But so, we can't use AC (Current Alternating) on the electrochemical analysis chemical dynamics unless we evaluate it. The DC that powers the analyzer can come from various renewable sources, such as wind or solar cells, or even small generators grounded in geothermal energy. It can also be generated from non-renewable sources, e.g., dry batteries, or by rectification of regular alternating current [28].

The analyzer consists of two electrodes, usually made of pure nickel or an alloy of nickel-iron (alloy iron nickel), stainless steel 313 (Monel), or Raney Nickel. The electrodes are connected to a direct-current power supply as follows: one of the electrodes is connected to the negative electrode, and the other is connected to the positive electrode. The two electrodes were dipped in a potassium hydroxide solution in hermetic containers containing two collecting tubes to capture the resulting gas. At the negative electrode, hydrogen gas is formed, and at the positive electrode, oxygen gas [29].

There are several ways to determine the amount of hydrogen or oxygen generated in the analyzer, the most important of which are [30]:

1- The ratio of potassium hydroxide (KOH) to water in the medium inside the analyzer.

2- The surface area of the poles.

3- The distance between the poles.

4- The amount of direct current from the supply source.

A high ratio of potassium hydroxide to water increases the production (but only up to 22.1%). This means that upon exceeding this ratio, the amount of gas that will eventually be generated is determined because the hydroxide concentration will produce an impediment to compete against gas formation. That is, as gas generation increases with increased effective electrode area, the larger area must be driven by a higher current to fully exploit the additional area. It can be said that there is a quasi-relationship of hydrogen generation with the current density, since the amount of generated hydrogen gas is directly proportional to the fed current on electrodes surface (amperes per Area unit), which value is an inherent parameter for the shop and given by analyzers usually available at market in optimal working conditions [31].

Connecting solar electrical systems with accumulators and an analyzer

Solar electrical systems connected to the savings system give a higher potential than the current, as the solar panels release a current ranging from 2 to 15 amperes, which is the short circuit current, and a voltage ranging from 13 to 18 volts, which is the open circuit voltage. Solar systems connected to accumulators are usually designed with a 12-volt output in order to charge the 2-volt accumulators and are suitable for powering a group of analyzers connected in series. That is, if we have a group of solar collectors, each of which has a voltage of 15 volts at a current of 15 amps, then by means of two solar collectors connected in series, we can operate 3 analyzers at a voltage of 1 volt for each analyzer and a current of 25 amps[32] (Figure 8).

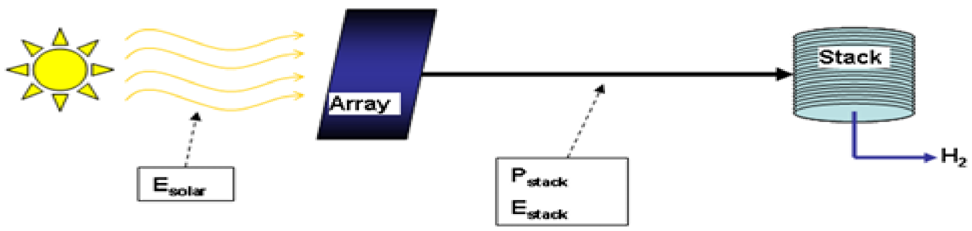


Figure 8 System efficiency illustration for direct connect configuration [5]

Methods

Hydrogen production methods

Displacement methods

This process relies on removing hydrogen from compounds by substituting elements higher up in the electrochemical series. The following items are included in the category of displacement methods. Only stronger elements from the electrochemical series can cause a metal to remove hydrogen from an acid. Zinc metal, for instance, will displace hydrogen when added to hydrochloric acid, producing zinc chloride salt in addition to hydrogen gas. Although this process is a little pricey when it comes to the concentrated acid and the metal, it doesn't hurt the environment. Zinc can be swapped out for aluminum or even iron ore [33].

Zn + 2 HCl → ZnCl2 + H2

1. When a metal, like zinc or aluminum, interacts with an alkaline solution, the basic hydrogen is replaced by the metal. The most popular and effective of these solutions is one containing potassium hydroxide (KOH) and sodium hydroxide (NaOH), where the reaction occurs gradually. Initially, the hydroxide is dissolved in water while being stirred for a brief while. We observe that the water's temperature has noticeably increased. Next, in order to help the reaction along, we add aluminum, which needs to be in the form of flakes. As the aluminum dissolves in the water and forms the sodium aluminate complex in the solution, we observe the color of the solution shifting to gray in a matter of seconds, in accordance with the equation:

$$Al + 2NaOH \rightarrow NaAlO_2 + H_2 + Na$$

$$Zn + 2\ NaOH \rightarrow Na_2ZnO_2 + H_2$$

2-A metal that replaces hydrogen with water. This process is comparable to the displacement reaction in that both involve a metal reacting with a molecule to cause one of its elements to be displaced. When it comes to water, an exothermic reaction occurs when a metal like magnesium or sodium interacts with the water. Together with hydrogen, metal hydroxide is also produced by this reaction. Given that metals are regarded as non-renewable energy sources and that using them excessively would lead to new problems that we can avoid, this approach is a little pricey.

Thermal decomposition

This process, which breaks bonds between atoms in compounds like hydrocarbons or hydrogenated coals, is what makes this approach work. The bonds between any of its compounds—methane, ethane, propane, butane, pentane, hexane, etc.—will disintegrate into carbon and hydrogen when a heat source is directed towards any of them. By conducting chemical reactions between natural gas and water vapor and exposing it to other stimulating factors, nearly half of the hydrogen produced worldwide is extracted from natural gas. In the process, the hydrogen atom is ultimately separated from carbon dioxide, which is a major contributor to Earth's rising temperature, also known as the greenhouse effect. Methane gas is produced when natural gas is processed. Since methane gas is made up of one carbon atom and four hydrogen atoms, it is the lightest and shortest hydrocarbon known to science. In addition, it generates compounds with larger molecular weights and heavier gaseous hydrocarbons like propane (C3H8) and ethylene chloride (C2H6). Then, as a byproduct, all of these substances are gathered and referred to as liquefied natural gas. Here, a variety of hydrocarbons, most notably the most basic kind of methane gas, can be treated using the steam reforming method [34].

$$CH_4 \rightarrow C + 2\,H_2$$

$$C_2H_6 \rightarrow 2\,C + 3\,H_2$$

$$C_3H_8 \rightarrow 3\,C + 4\,H_2$$

This method's requirement for high temperatures makes it utterly ineffectual, which is one of its drawbacks.

Electrolysis

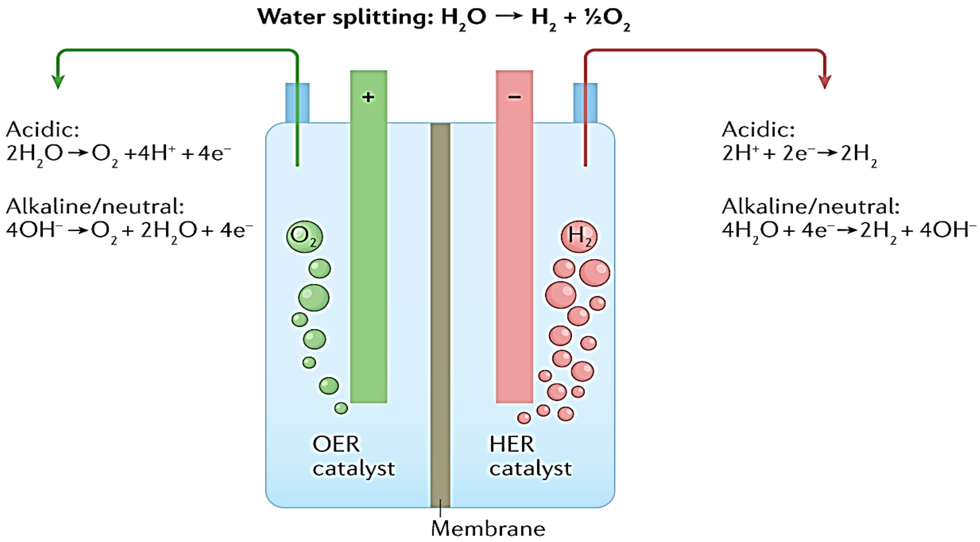
It is a procedure known as the cell that involves using an electric current to initiate a chemical reaction that doesn't happen on its own. The "electrolytic cell" in this instance (which transforms electrical energy into chemical energy). The electrode where the oxidation process takes place is referred to as the anode. Electrolytic cells are made up of electrodes in contact with a conductive medium and an external circuit. The cathode is the pole where electrolysis takes place. The primary purpose of the mostly inert electrodes in electrolytic cells is to allow electrons to enter and exit the cell. In electrolytic cells, the battery pushes electrons into the negatively charged electrode and draws them into the positively charged electrode. The most popular and somewhat inexpensive way to manufacture hydrogen is through the electrolysis of water, which doesn't pollute the environment while making hydrogen. This reaction demonstrates how to electrolyze water to make hydrogen [35].

$$4H_2O \rightarrow 4H^+ + 4OH^-$$

$$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$$

$$4H^+ + 4e^- \rightarrow 2H_2$$

$$2H_2O \rightarrow O_2 + 2H_2$$



Industrial methods for preparing hydrogen

Bosch method:

This method depends on converting coal into a gaseous state, which takes place in several steps [36]:

1- Introducing steam to the coke heated to 1200 C, and the endothermic reaction takes place according to the following equation:

$C+H_2O \rightarrow CO+H_2$

2- Then the temperature drops to about 855 C. The next step involves air (2O2 + N4), which reacts with carbon and leads to a second rise in temperature to about 1200 C. This is because it is an exothermic reaction according to the equation:

$CO+4N_2+O_2 \rightarrow 2CO+4N_2$

In the final step, water gas is treated with water vapor at C450 in the presence of an iron oxide intermediate as follows:

$CO+H_2+H_2O \rightarrow CO_2+2\ H_2$

We note that the reaction is reversible, so 2CO is treated with a hot solution or with water under high pressure. It reaches 50 bar, and thus we have hydrogen

Hydrogen production by steam–iron

In this method, hot water vapor is passed over the hot iron metal to the point of redness, and the iron is oxidized to form Magnetic iron oxide, which is a mixture of ferrous oxide and ferric oxide

$Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$

Since the reaction is reversible, a stream of water vapor must be passed continuously to shift the equilibrium towards the formation of hydrogen gas. As for the magnetic iron oxide, it can be reduced to iron by passing water gas over the hot oxide [37].

Hydrogen applications and uses

Perhaps the most prominent applications of hydrogen in our time are hydrogen fuel cells, as they include many applications that replace fossil fuels (oil and natural gas) and protect the world of pollution, which is increasing day after day, in addition to the military field, which has always exploited most of the modern discoveries, and the uses of hydrogen in the military field have become evident In particular, hydrogen bombs have a greater destructive power than an atomic bomb to detonate them, you only need to detonate a nuclear bomb near it [38].

In addition, there are some secondary uses for hydrogen [39-42]:

1-Large quantities of hydrogen are used in industry, especially in the production of ammonia by the Haber method, as well as in the hydrogenation of methanol. Hydrogen is also used in the hydroalkylation of oils and fats, hydrodesulfurization, and hydrocracking.

2-Hydraulic acid manufacturing, welding, and ore reduction.

3-It is used in rocket fuel.

4-It has a higher thermal conductivity than any other gas, and therefore it is used to cool motors in electrical generators in power stations.

5-Liquid hydrogen helps in low-refractory research, including studies of electrical superconductors.

6-Because it is fourteen times lighter than air, it has been widely used as a lifting agent in balloons and blimps. That was until the Heidenberg disaster convinced the public of the danger of using hydrogen for this purpose.

7-The hydrogen isotope deuterium (H-2) is used in nuclear fission applications as a moderator of neutrons to reduce their speed. It is also used in nuclear fusions. Deuterium compounds are used in chemistry and biology in studies of the reactions of isotopes.

8-Tritium (H-3), which is obtained in nuclear reactors, is used to make hydrogen bombs. It is also used to determine isotopes in biology and as a radiation source in optical paints.

Hydrogen fuel cells

The search for alternative sources of fossil fuels has become a problem of the modern era that has attracted the attention of many scientists and researchers, and has pushed them to many innovations in various fields. Although the world has not yet found a real solution to replace oil and its derivatives, fuel cells are considered a possible future alternative to oil. Despite some problems that have hindered scientists in developing it in a way that allows it to be used instead of fossil fuels, it has been greatly developed, especially in the recent period, and has been used in many life applications, as it has many advantages [43]. It is considered one of the most important applications of hydrogen used in our time**.** The mid-nineteenth century witnessed the invention of hydrogen fuel cell technology in England by Sir William Robert Grove. Due to the ineffectiveness of using hydrogen fuel cells in that period, this invention remained locked away for more than approximately 135 years, but hydrogen fuel cells returned again. To life in the 1960s, when General Electric developed cells that generate the necessary electrical energy for use in the famous spaceships Gemini and

Apollo, in addition to providing pure drinking water for astronauts. These were hydrogen fuel cells (Figure 9) in those two large vehicles. It was expensive, but it carried out its tasks without any errors and was able to provide electrical current as well as a source of pure drinking water in spacecraft [44].

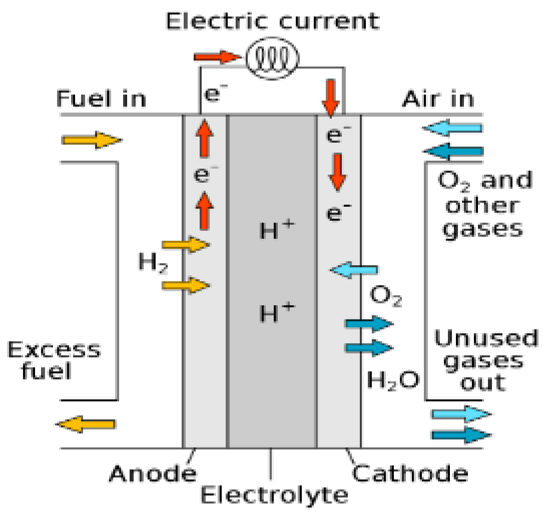


Figure 9 Basic Principle of Hydrogen Fuel Cells [45]

Fuel cell features

The advantages of fuel cells are [46,47]:

1-Its electrical efficiency is high.

2-It does not emit any pollutants harmful to the environment, and the percentage of gases during combustion is small compared to the traditional combustion process.

3-Low noise when operating (vibration-free, quiet).

4-It does not require much maintenance, and it lives for a long time.

5-It has a strong supply capacity, especially in air conditioning and heating.

6-The simplicity of the operating mechanism in the cell (the parts are fixed and immovable, and the simplicity of the speed gearbox).

7-Its performance ability is good (electrical current control).

Fuel cell applications

Fuel cells were initially used in space applications and then began to develop and spread more in military circles, where fuel cells were then relied upon as a backup source due to their high reliability. Currently, all car companies are marketing their new hybrid products that use fuel cells, in addition to the use of fuel cells, which has begun to spread in buses, trains, planes, and scooters [48,49].

Fuel cells have also spread to small applications such as cell phones, mobile computers, and others. The possibility of using fuel cells to fuel hospitals, banks, and ATMs is currently being studied [50].

Fixed applications

Currently, 2,555 fuel cell systems have been installed around the world in hospitals, hotels, offices, and schools, in addition to using fuel cells as electrical stations connected to the public electricity network to provide support for the network or independent electrical stations in areas that are difficult to connect to the network [51,52].

Fuel cell systems operate at 15% efficiency without noise and without air pollution. When using fuel cells in a cogeneration system that benefits from the resulting thermal energy, the efficiency can be raised to 85% [53].

Telecommunications

With the increased use of computers, the Internet, and communications networks (Figure.10), the need for a more reliable source of power has emerged. Fuel cells have proven to be 22.22% reliable. The savings can be replaced with fuel cells to supply a power of up to 5kW. They are silent and environmentally friendly and can be designed to be durable, meaning they can withstand weather conditions [54,55].

Figure 10: Transforming the World of Telecommunications [56]

Landfills/Wastewater Treatment Plants/Breweries

Fuel cells are currently installed in waste and water treatment plants all over the world, and this technology has proven its ability to reduce emissions, as it uses the methane gas produced from these sites as fuel. It has also been installed in several beer production factories, where untreated wine is passed through digesters that break down organic compounds and generate methane, which is a hydrogen-rich fuel [57].

Transportation

Cars: It is not surprising to find cars at the forefront of hydrogen cell applications, as they are one of the most widely used aspects of fossil fuels. We have shown in the past ten years that all car factories are working on developing new vehicles that often operate in a hybrid manner, as they are fed by hydrogen fuel cells, and It produces nothing but pure water as exhaust, in addition to the fact that some of them have currently been put on the commercial market, cars that are completely powered by fuel cells [58,59].

It must be noted that General Motors, Toyota, and Chrysler-Daimler, which constitute about 15% of the total investments in the field of cars in the world, support research and development of fuel cells, so that they are the environmentally friendly choice instead of fuel cells. Of internal combustion engines [60].

Among the results of the research is that Daimler introduced A-class cars equipped with fuel cells, and Toyota also presented two small cars that operate with fuel cells, in addition to Siemens producing a small tanker that uses the same technology. This is what encouraged Volkswagen (VW) to support research in the field of fuel cells as well, in addition to Hyundai launching the Hyundai 35ix, and the German industry has worked diligently in the field of hydrogen fuel cells, as demonstrated by BMW cars and Mercedes B-class cars that operate on hydrogen fuel [61].

Buses: During the past four years, more than 55 fuel cell buses have been used in Europe, North and South America, East Asia, and Australia. The high efficiency of fuel cells, in addition to the very low pollutants because hydrogen is produced from renewable sources, has greatly improved air quality, especially in areas that are considered among the most polluted areas in the world, such as China [62].

Bicycles: Despite their small size, many bicycles are considered air pollutants, as their exhaust gases are very polluting compared to their small size. It produces carbon monoxide and hydrocarbons in quantities similar to a diesel truck. Therefore, fuel cell bicycles are a suitable solution for countries such as India and Asia, where many residents use bicycles as a means of transportation [63].

Cranes and transportation mechanisms in factories: In addition to the advantage of reducing harmful gases emitted, cranes that operate on fuel cells are characterized by the fact that they require much less maintenance than machinery that operates on electricity, as they require periodic charging of their batteries and frequent replacement because they deteriorate quickly, as work in this field requires a quick stop and restart. It is repetitive, so fuel cells are considered to have excellent performance and constant electrical output, and in addition, they do not suffer from the voltage drop that occurs when accumulators are discharged [64].

Trains: Fuel cells are being developed for use in trains to get rid of the harmful gases they produce. A project is developing the largest means of transportation running on fuel cells in the world, which is a 1MW locomotive for military and commercial uses [65].

Planes: Interest is being given to fuel cell technology that fuels military aircraft due to its low noise, small size, and possibility of using it in the air. One of the largest companies developing this technology is Boeing. The figure shows a German plane flying on fuel cells above the city of Hamburg [66].

Marine vessels: Iceland has pledged to convert its extensive fishing fleet to use fuel cells as an auxiliary fuel source at the end of 2515 to pave the way for the transition of the entire fleet to operate on fuel cells as the primary source. Fuel cell engines are more efficient than combustion engines, in addition to their other advantage of reducing pollution [67].

Auxiliary electricity units: Advanced trucks carry many electrical appliances on board, such as heaters, air conditioners, computers, telephones, refrigerators, and microwaves. To operate these equipments when the truck is stationary without the engine running. The US Department of Energy measured the annual fuel and maintenance costs for a heavy truck at 1,855$. When using a fuel cell as an auxiliary power unit, it saves 375 million gallons of diesel fuel per year and one million tons of carbon dioxide per year [68].

Portable Equipment: Fuel cells can provide us with power where the electrical grid is not available. They are used in emergency situations and in military applications. They are more efficient than batteries, operate longer, and are lighter [69].

Small Equipment: Fuel cells are one of the most suitable sources of energy for small electronic devices small ones due to their small size and ability to generate a large amount of electrical energy for their small size. Fuel cells are currently used in cell phones, laptop computers, watches, and other small applications (figure.11). The chargers on the market now can charge a computer for approximately twenty hours and a cell phone for thirty days. It has also been used in smoke detectors, alarms, and surveillance cameras. Many of these devices are displayed annually at the Fuel Cell Exhibition held in Tokyo [70].

Figure.11 laptop computers [71]

Problems facing hydrogen cells

After learning about the advantages of fuel cells, you must be asking us about their lack of widespread use. The reason lies in many of the problems that have hindered the spread of this source of energy. We also learned that fuel cells use oxygen and hydrogen to produce electricity, and by securing these two gases, we can obtain a continuous source of energy. As for oxygen gas, it is obtained from the air, as the air is drawn into the cathode to obtain oxygen directly, but the real problem lies in hydrogen gas because of the difficulty of storing it and the scarcity of its free presence in nature. The cost of obtaining raw hydrogen gas is high, which makes oil superior to hydrogen cells in cost. What is required for a fuel cell to become economical is for its cost to be 255 times lower than it is now. Therefore, much research is currently directed to searching for a safe and cheap source of hydrogen gas that allows these cells to be disseminated and used on a larger scale [72,73].

Results

Global demand for hydrogen rose from 70 million tons to 115 million tons between 2000 and 2018. This is a 65% increase. 10 The chemical industry has historically used the majority of hydrogen to make fertilizers, process metals, and make food. The oil price crises of the 1970s and predictions of a sharp fall in oil supplies sparked interest in the use of hydrogen as a fuel for both individual and commercial vehicles. Fuel cell vehicle technology and commercialization took a while because, as we now know, oil supplies are not as finite as was formerly thought in the early 1980s, and prices have stayed relatively stable. As a result, pressure on technological innovation has decreased. However, fuel cell-powered compact and sports automobiles have been available for purchase since the early 2000s (see Box 1). Global industry companies launched the Hydrogen Council (see Box 2), which projects that by 2030, about 10% of cars sold in major industrialized countries may be hydrogen-powered fuel cell electric vehicles. Hyundai, a South Korean automaker, stated in 2018 that it would invest $6.7 billion to produce 0.5 million fuel cell vehicles by 2030. 12 By 2030, fuel cell electric vehicles are expected to account for 20% of all electric vehicles globally, according to German technology manufacturer Bosch. Thirteen Recently, the business and the Swedish startup Powercell formed a strategic alliance to start producing hydrogen fuel cells for heavy-duty commercial vehicles on a massive scale [66]. Leading international automakers Daimler, Toyota, Honda, and Renault have already constructed fuel cell vehicles that are prepared for release onto the market. These vehicles are still being tested on the road; prototypes have been developed by Ford, Tata Motors, and Indian Oil Corporation. In conclusion, although fuel cell cars have been sluggish to gain traction, they are now approaching the crucial point, as is the state of the necessary infrastructure, which includes hydrogen filling stations. In the transportation industry, fuel cell vehicles represent but one market segment. In 2018, Alstom's first hydrogen-powered trains went into regular operation in Germany. Since then, other areas have placed orders for hundreds more hydrogen trains. Currently, hydrogen-powered buses are being used on a modest but expanding basis in numerous locations across the globe. The fact that there is a rising need for hydrogen outside of the transportation industry is arguably the most significant factor. Major technology businesses like Siemens and General Electric, along with industrial enterprises, are already preparing their energy and industrial plant technologies, such as burners and stoves, for use with hydrogen-mixed fuel. Examples include non-catalytic oxidation techniques without a flame and hydrogen boiler designs (e.g., from Mitsubishi-Hitachi Power Systems) or generators that turn hydrogen into steam when water is injected into a stream for hydrogen/oxygen combustion. The demand for hydrogen worldwide could rise sharply as a result of all these projects [74].

Finally, new technologies are being developed that will allow the efficient use of hydrogen in traditional thermal power plants without requiring significant modifications by the middle of the 2020s, directly substituting fossil fuels like oil, gas, and coal. This has the potential to transform the world's electricity production system. Approximately 40% of the world's power was produced in 2018 using coal and oil, or 2,500 gigawatts of installed capacity. If 10% of the current installed capacity, or 250 gigawatts, or 250 major lignite-fired power plants, are converted to hydrogen fuel by 2030, there will be an additional demand for hydrogen ranging from 120 to 170 million tons per year. The future hydrogen market has enormous potential, especially when compared to the current annual usage of 70 million tons of hydrogen. As will be covered in more detail below, given the prospects for renewable energy in the Gulf, this offers the GCC countries excellent opportunities to diversify their economies and enter new markets for energy exports, as hydrogen is expected to outcompete oil in demand and replace coal. Hydrogen can be produced using a variety of technological methods that rely on electricity or fossil fuels. These include coal gasification, steam methane reforming in natural gas (SMR), and several types of electrolysis, such as proton exchange membrane (PEM) technology. While the last technique emits greenhouse gases when electricity is generated from renewable sources, the subsequent two technologies do not emit any emissions [75].

Conclusion

Positively, hydrogen fuel cells might eventually offer a totally sustainable and renewable energy source for both mobile and stationary applications. In order to do this, carbon-free hydrogen production and fuel cell manufacture must be encouraged, and the relevant policy framework must be established in order to precisely specify industrial applications. In order to lower the costs associated with collecting, storing, and delivering, further technological advancements are anticipated, and infrastructure spending is increasing to support this. In the future, hydrogen might hold the key to meeting our energy requirements. To get there, though, they will require funding and government support. Furthermore, hydrogen may end up serving as a backup energy source to meet global energy demands as fossil fuels become less plentiful. From what has become clear to us previously, we have found that hydrogen is still under experimentation for many financial and industrial reasons, but these obstacles are periodically studied by hundreds of scientists and in the most technical and advanced laboratories, as the pressures placed on governments and states have reached their greatest intensity with the expansion of the industrial revolution and the expansion of the human tide. In addition to several natural reasons, we must not forget that many transportation companies were proactive in this context to keep pace with the protests that affected many institutions due to the high transportation prices and the unacceptable high prices of goods and products, but unfortunately this technology is still far from our Arab countries because it is one of the main sources of fossil fuels, which is one of the obstacles that stand in the way of the spread of this project and others. The Arab countries do not have the capabilities. The main reason for such experiments is the weakness of funding for such projects, despite their extreme importance in contemporary life. We only hope that this technology will find a way to enter the Arab borders as it is spreading in European and Western countries.

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