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الهيدروجين الأخضر: التحديات والفرص في عمليات إنتاج الصلب في مصنع الحديد والصلب (مصراتة)

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Green Hydrogen: Challenges and Opportunities steel production processes at the iron and steel plant (Misurata)

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الملخص
ستكون الطاقة الخضراء القضية الرئيسية في هذا القرن الـ 22 بسبب التأثير السيئ لانبعاثات ثاني أكسيد الكربون الناتجة عن حرق الوقود الأحفوري. ويلعب الباحثون دورًا مهمًا في إيجاد مجموعة متنوعة من الطرق للتخلص من المشاكل المرتبطة بالبيئة. وتوفر الطاقة الخضراء أفضل الحلول للحد من تأثير الغازات المسببة للاحتباس الحراري على البيئة. وتُصنّف الطاقة الخضراء على أنها آمنة ومستدامة وغير مكلفة وعديمة الانبعاثات. أحد أفضل أشكال الطاقة الخضراء هو الهيدروجين الأخضر بسبب عدم تلويثه للبيئة. ويُعد توافر الموارد المائية من أشعة الشمس وتقنيات الإنتاج من المقومات الرائعة لإنتاج وقود الهيدروجين الأخضر. تقترح هذه الورقة البحثية الخيار المحتمل لإزالة الكربون من عمليات إنتاج الحديد والصلب في مصنع الحديد والصلب (مصراتة)، مع التركيز على استخدام الهيدروجين الأخضر. وهي تمثل عمليات إنتاج الهيدروجين وأهمية الكربون في صناعة الحديد والصلب، وكذلك آثار التحول إلى الهيدروجين الأخضر في هذا القطاع الصناعي.

الكلمات المفتاحية: الطاقات المتجددة، صناعة الصلب، الهيدروجين الأخضر، انبعاثات ثاني أكسيد الكربون.

Abstract
Green energy will be the major issue in this 22-century due to the bad impact of CO_2 emissions that come from the burning of fossil fuels. The researchers are playing an important role in finding a variety of ways to get rid of environment-associated issues. Green energy provides the best solution to reduce the influence of greenhouse gases on the environment. Green energy is classified as safe, sustainable, inexpensiveness and zero-emission. One of the best forms of green energy is green hydrogen due to no pollution to the environment. The availability of water resources sunlight and production techniques are great assets for us to produce green hydrogen fuel. This paper proposes the potential option for decarbonization of iron and steel production processes at the iron and steel plant (Misurata), with an emphasis on the use of green hydrogen. It represents hydrogen production processes and the significance of carbon in the iron and steel industry, as well as the effects of switching to green hydrogen in this industrial sector.

Keywords: Renewable energies, Steel industry, Green hydrogen, CO_2 emissions.

1. Introduction

The area of Libya is roughly 1,759,540 square kilometers. There are 83,200 km of highways connecting it, 47,590 km of which are paved. In addition, there are more than 140 airstrips and airports dispersed throughout Libyan communities. The transportation sector is anticipated to utilize the most fuel, approximately 5,545,000 tons yearly, with 5,483,760 cars on the road. The transportation sector consumes approximately 17,262 Terajoules (TJ) of electricity annually. It is estimated that this business will produce 18,246 million tons of CO2 a year.

Libya's economy was based on the production of oil and natural gas, so it is difficult to alter its structure. With the right investment and training, the state can use sustainable, renewable energy to expand its existing revenue base. Libya can fully satisfy its electricity requirements, power the general grid, charge EVs, and export a sizeable amount of electricity to its neighbors in southern Europe by utilizing the renewable energy sources that are available in this oil-rich country. Libya has the potential to become a global leader in renewable energy.

It has a very high daily solar radiation rate, around 8.1 kWh/m2/day in the southern region and 7.1 kWh/m2/day on the flat coastal plain. According to a study published in the Journal of Renewable Energy, Libya could produce more than five times as much PV system if it employed a PV system to gather just 0.1% of the Earth's mass. Libya uses a PV to cover just 0.1% of its land. Figure. 1, would be generated if Libya produced even 0.1% of the Earth's mass from solar energy [1, 6].

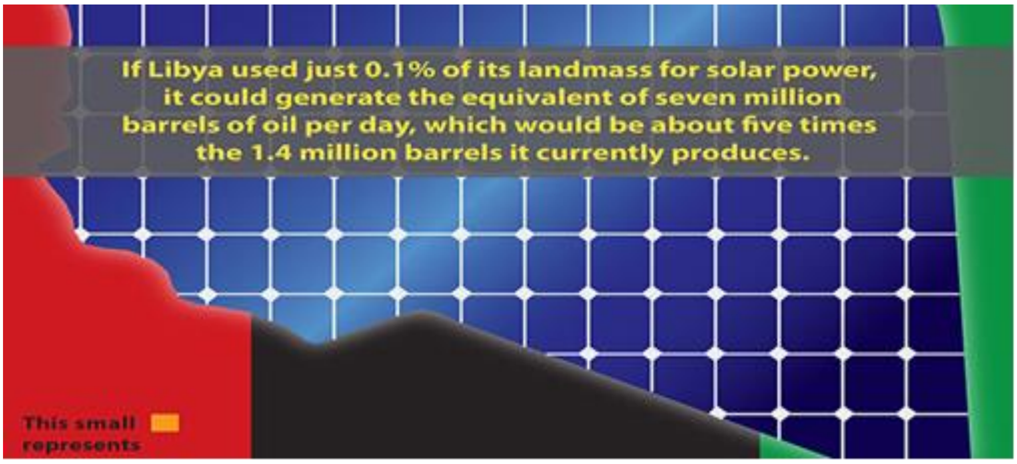

Figure 1 If Libya uses a PV to cover just 0.1% of its land.

Many countries have paid more attention to renewable energy (RE) sources in recent years due to the adverse environmental effects of burning fossil fuels. The reduction of gas emissions becomes important with the increase of fossil fuel sources in the industrial sector[7, 8]. Most of the gas emissions are because of the fourth industrial revolution that led to a rise the global income levels and improved the quality of human life. The UN climate change conference forces yearly all the countries to achieve net-zero emissions by 2050. The world power generation consumes approximately 74% of fossil fuels and produces around 31.5 Giga-tons emissions[9]. Renewable energies become cheaper due to the development of existing techniques compared to fossil fuel plants. The strong support of hydrogen production technologies will drop the use of coal and crude oil to 36.7% and 40.5% respectively by 2030 [10]. Transportation sectors release about one-fifth of the total global emitted Carbon dioxide (CO_2) due to fossil fuel consumption [11].

Consequently, transition to the alternative fuel-powered engines in the transportation system is vital in the world's future energy scenario. In this regard, hydrogen-powered engines are considered promising technologies for vehicles' energy supply. The production of iron and steel with current technologies requires large amounts of coal, where producing 1 ton of steel releases about 1.85 tons of CO_2 on average, as emissions into the atmosphere. Steel production typically happens in two steps: First, iron ore is turned into iron, e.g. in blast furnaces, and then, in a second step, the iron is turned into steel, e.g. through the basic oxygen converter process. Both steps are very energy intensive and are responsible for CO_2 emissions in quite different ways. They both require huge amounts of energy to process the materials at high temperatures. If this energy is derived from fossil fuels, these furnaces are thus responsible for large CO_2 emissions [12].

2. Problem Statement

The strength and versatility of iron and steel have led to their use in countless sectors. However, the production of these materials has significant environmental impacts. As of 2017, the iron and steel industry produces 7-9% of the total global emissions. The carbon emissions are directly related to iron ore reduction. The ever-increasing demand for electric power, the rapid rate of consumption of fossil fuels, and environmental concerns require highly efficient and environmentally friendly energy conversion technologies. Alternatives to fossil fuels are wind energy, hydro energy, wave energy, solar energy, and energy from renewable fuels like biomass, waste gas, and alcohol.

New production processes are exploring the use of hydrogen gas instead of coke. Hydrogen similarly reacts with iron oxide to carbon monoxide, but instead of producing carbon dioxide, the only by-product is water vapor. When hydrogen used in this process is derived from renewable or decarbonized sources itself, the steel-making process can become completely emission-free, creating 'green steel'[13-15].

The steel industry in Libya is considered relatively acceptable compared to the conditions of the industrial sector, and improvement in some industrial processes for this sector remains essential. This paper explores the proposal to decarbonize iron and steel production processes, with an emphasis on the use of green hydrogen as an alternative to fossil coal.

3. **Hydrogen Production Processes**

Hydrogen has the chemical symbol of (H), and the first element listed in the periodic table, and is the most abundant, lightest, and simplest element in nature. Hydrogen can be classified as non-toxic, tasteless, colorless, and odorless. Green hydrogen is an existing form of clean energy that has been paid full attention globally due to its advantages such as a promising fuel, the possibility of using it as a carrier of energy, storage in energy cells, and net-zero emission. Green hydrogen can be produced at a high level of purity around 99.9% which makes it ideal for utilization in various industrial processes. Several ways have been employed to obtain hydrogen from renewable energy sources with the use of electrical electrolysis as the most thriving. Recently, many studies have evaluated the production of green hydrogen in terms of economics, technologies, and environment. These studies encourage many countries around the world to take vital steps to produce and utilize green hydrogen, for example, China, the European Union, South Korea, North America, and Malaysia.

Renewable and non-renewable energy sources (see Figure. 2), can be used to obtain hydrogen that depends on the production technique and raw materials. The hydrogen has been classified into various types according to the technological pathways and production route including gray hydrogen, blue hydrogen, and green hydrogen.

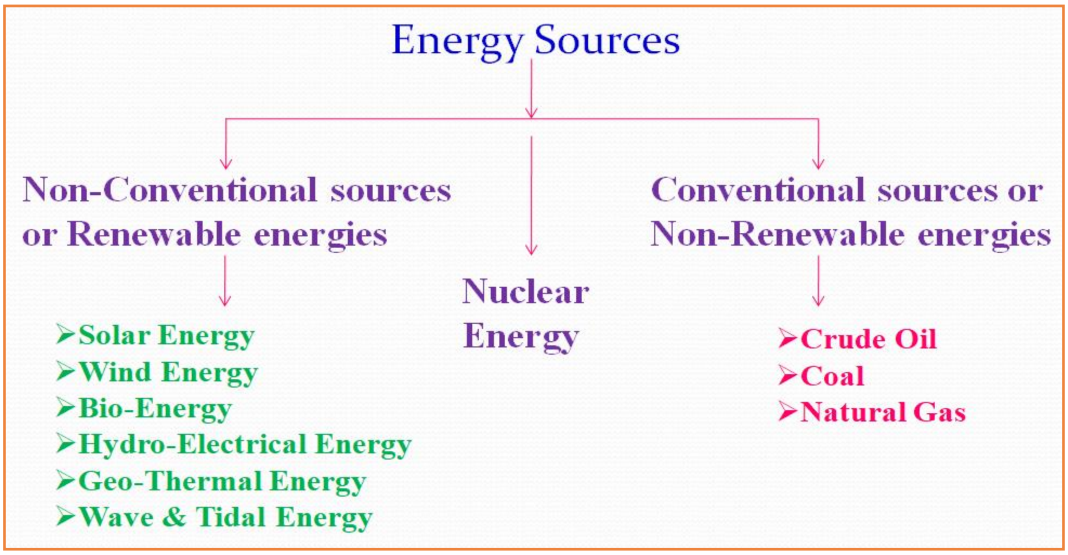

Figure 2: Shows energy sources.

3.1 Gray hydrogen

Gray hydrogen can be produced from fossil fuels using natural gas and coal (see Figure. 3) but contributes significantly to global warming due to the emitting of CO_2 into the atmosphere. Gray hydrogen from natural gas or methane is produced through various chemical reaction processes such as steam methane reforming (SMR), partial oxidation (POX), and auto-thermal reforming (ATR)[16]. Blue hydrogen is usually produced from the production of grey hydrogen with a carbon capture and storage system to avoid the emitting of CO_2 emissions from the production process.

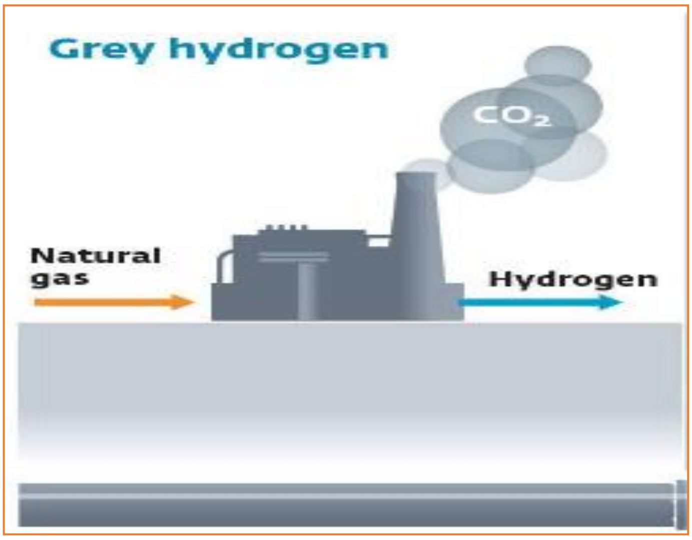

Figure 3. Shows the grey hydrogen production process.

3.2 Blue hydrogen

Blue hydrogen is mainly produced from fossil fuel sources. Blue hydrogen can be obtained through the production of gray hydrogen with a carbon capture and storage system which means the CO_2 is not released into the atmosphere[17]. Steam methane reforming (SMR) is one of the common methods to obtain blue hydrogen by using natural gas [see Figure. 4], the process begins with converting methane to hydrogen and carbon dioxide (CO_2) by using heat, steam, and pressure or gray hydrogen, meanwhile capturing the carbon dioxide[18].

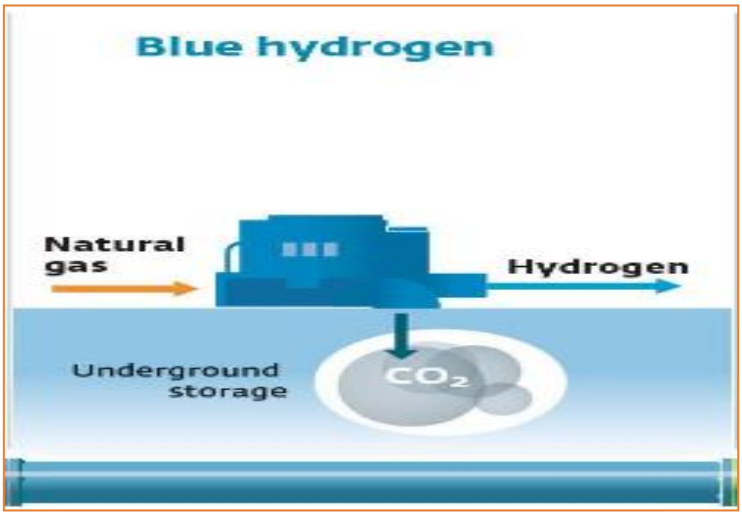

Figure 4: shows the blue hydrogen production process.

3.3 Green hydrogen

Gray hydrogen is classified as a clean and green energy and is usually produced through electrolysis using renewable energy sources. The green hydrogen-free carbon emission route and the route of production do not require a carbon and storage system. Green hydrogen is an ideal product to be used for environmentally friendly applications such as power generation, shipping, green industries, trucks, cars, trains, and steel production. The production of green hydrogen is obtained normally from the connection of water electrolysis directly to renewable energy sources to achieve a zero-carbon footprint[19].

The main purpose of using a water electrolyzer is to convert the electrical power obtained from renewable energy sources to splitting high-purity hydrogen from the water molecule (see Figure. 5). Green hydrogen is expected to replace fossil fuel sources due to the negative environmental impacts.

However, the production of green hydrogen is more expensive in comparison with gray and blue hydrogen due to many reasons such as the high cost of electricity generated from renewable energy sources, electrolyzers, and conversion losses [19, 20]. The cost of producing green hydrogen is expected to go down due to the reduction in prices of renewable energy technologies in the coming years. Varieties of renewable energy sources can be used to produce green hydrogen including solar energy, wind energy, hydropower energy, and geothermal energy [21, 22].

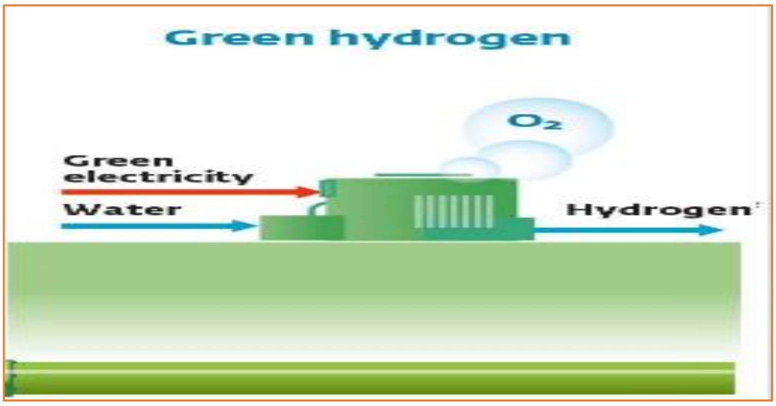

Figure 5: Shows the green hydrogen process.

4. Green Hydrogen applications

Green hydrogen has a wide range of applications, it can be used to decarbonize energy, in fuel cells to generate electricity, power, and heat [23]. The common applications of green hydrogen can be classified into three main categories: -

A. Green industries including ammonia production, steel production, synthesis gas, hydro-cracking, and hydrogenation.

B. Power and heat generation including power generation for the grid, power buffering, H_2 adding to natural gas, heat/power for buildings, and heat/power for industry.

C. Transport includes fuel cell forklifts, H_2-powered vehicles, H_2-powered trains, H_2-powered aircraft, and H_2-powered shipping.

5. **Global Green Hydrogen Investment**

The investment in green hydrogen has been paid more attention in recent years (see Figure. 6), due to the increase in global demand in a wide range of engineering applications. The **green** hydrogen fuel provides multitrillion-dollar market opportunities[24].

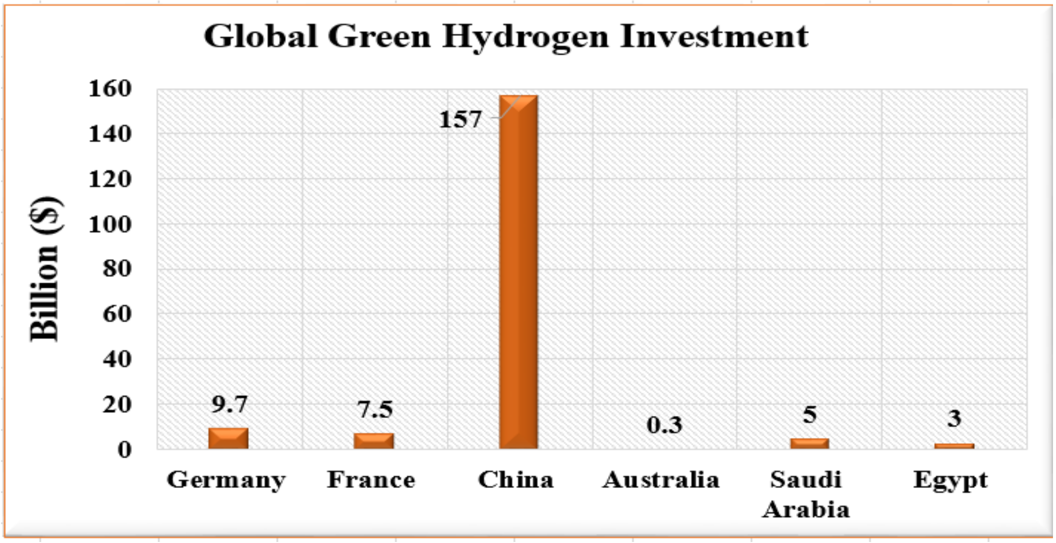

Figure 6: Global green hydrogen investment.

6. Conclusion

Green hydrogen is expected to play an important role in the reduction of gas emissions and achieving climate change targets. Green hydrogen is ideal to be used as an energy carrier. Various routes are commonly employed to obtain hydrogen from energy sources including renewable and non-renewable energy. The most common technique to obtain green hydrogen is renewable energies associated with water electrolysis that is classified as environmentally friendly, meanwhile with high cost and energy losses. The fossil fuel-associated hydrogen production techniques are cheaper in comparison with renewable energies associated with water electrolysis, but disadvantaged by high emissions of CO_2. Green hydrogen provides a wide range of advantages including decarbonizes energy, a key to a more environmentally friendly mobility ecosystem, hydrogen fuel-Tech provides high-performance refueling concepts and technologies, short-time of refueling, easy storage and transmission in liquid or gaseous form, and advanced technologies make green hydrogen more efficient, more effective, more profitable, and, with greater sustainability. Green hydrogen can be exploited in many daily applications such as steel industries, power generation, transportation, green industries, utility, and the built environment.

7. Recommendations

1. Decrease the usage of fossil fuel-associated hydrogen production techniques.
2. Reduction the gas emissions by utilizing more environmentally friendly pathways to produce hydrogen.
3. Increase the utilization of green hydrogen to meet the demand of all sectors such as power generation, green industries, and transport.
4. Set the roadmap to meet the requirements of decarburization by 2050.
5. The government plays an important role in overcoming the challenges of producing and utilizing green hydrogen.

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