HYDROGEN, FUEL CELL & ENERGY STORAGE

Prospects and challenges for the production and use of green hydrogen as a promising energy in Libya

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Abstract

The world's ever-increasing energy demand has led to the diversification of energy sources, especially renewable energy. Libya is currently entirely dependent on non-renewable energy sources. Therefore, the presence of a clean and renewable energy source has become one of its foundations for sustainable development. It is, therefore, necessary to search for an alternative energy source to oil and gas, the only energy source in Libya. This study examines the challenges and prospects of the potential of green hydrogen production in Libya and its use for future implementation. It also provides an overview of the benefits of switching to green hydrogen technology. Green hydrogen production will offer an alternative energy source in Libya. It will be a better alternative to the currently available energy sources as it is a sustainable and environmentally friendly energy. The study confirms that Libya is one of the most promising countries for producing large quantities of green hydrogen for several reasons. The most important point is the availability of solar energy. Libya has high solar radiation (3,000 to 3,500 hours of sunshine per year), a hot and dry climate, and large uninhabited areas, 88% of which are covered by deserts. In addition, wind energy and thermal energy are potentially available in Libya. Furthermore, Libya is positioned strategically close to the European market.

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1 Introduction

Hydrogen is the best potential candidate to deliver economically reasonable, socially beneficial, and energetically efficient answers to problems associated with the ever-increasing world energy demand and climate change [1]. Nowadays, the commercial process of hydrogen production is based on fossil fuels, and although these fuels are not renewable, they draw the roadmap of hydrogen applications to the year 2050 [2].

As governments worldwide have strengthened their commitment to decarburization, their search for solutions to achieve net-zero emissions has renewed interest in clean hydrogen (green hydrogen) [3]. So, sustainable and scalable energy sources that provide high energy density are urgently needed as alternatives to secure the energy supply and lessen the environmental impact of the current state-of-the-art non-renewable energy sources [4].

Libya is a rentier country that depends entirely on oil for its economy, energy, and electricity production. Most of the energy supply in the country, about 97%, comes from non-renewable sources, leaving only 3% from renewable sources (Figure 1), with solar energy being the only renewable energy source used in Libya [5].

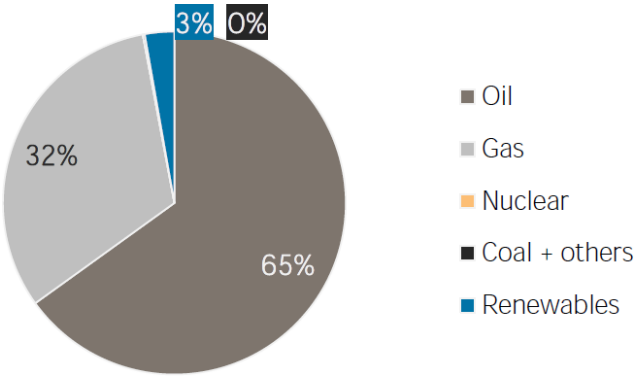

Fig. 1. Libya's total energy supply in 2020 [5].

Unfortunately, most of these sources are non-renewable and depleted sources. Therefore, it is necessary to search for an alternative and renewable energy source to avoid any economic crises in the future. However, finding an alternative renewable energy source that does not affect the environment is necessary to achieve sustainable development in Libya. Green hydrogen is one of the most important and promising alternative sources, for reasons discussed later in the paper.

Green hydrogen is considered one of the most promising technologies for energy generation, transportation, and storage. In this paper, the prospects of green hydrogen production potential in Libya are investigated, along with its usage for future implementation. Additionally, an overview of the benefits of shifting to green hydrogen technology is presented.

2 Problem statement

Given the global consumption of oil and natural gas, oil production will reach its peak by the end of this century, and then production will begin to decline because it is a non-renewable energy. In addition, the emissions from this energy cause global warming, which in turn has led to uncountable environmental problems around the world, such as climate change, increased rates of earth temperatures, acid rain, the expansion of the ozone hole, and pollution. New clean energy sources, such as green hydrogen, can be a better solution to these problems.

3 The green hydrogen

Hydrogen is a chemical element with the symbol H and atomic number 1. With a standard atomic weight of 1.008, hydrogen is the lightest element on the periodic table. Its monatomic form (H) is the most abundant chemical substance in the universe, constituting roughly 75% of all baryonic mass [6]. It is the tenth most abundant element in the earth's crust and can be found in combination with other elements. Hydrogen is scarce on the earth's surface (0.14%) and found only in trace amounts (0.07%) in the atmosphere. As hydrogen gas is lighter than air, it is not available freely on the Earth [7].

Hydrogen energy has attracted interest in most of the world, and many previous studies and research have indicated that hydrogen energy could replace fossil fuels [8]. According to previous studies such as Ewan and Allen [9], Zhang et al. [10], Parthasarathy and Narayanan [11], and the World Nuclear Association [12], most of the current production comes from the oil industry, accounting for 96%. This 96% comprises 50% natural gas, 30% liquid hydrocarbons, and 16% coal, with only 4% coming from renewable sources such as water, biomass, sunlight, and wind.

Green hydrogen has a number of uses (Figure 2). It can be used directly as an energy carrier and chemical input in multiple end-use applications. It can also be combined with a sustainable carbon source or nitrogen to produce derivative compounds such as methanol or ammonia, which can be used as feedstock for chemical production (e.g., plastics and fertilizers) or as sustainable fuels [13].

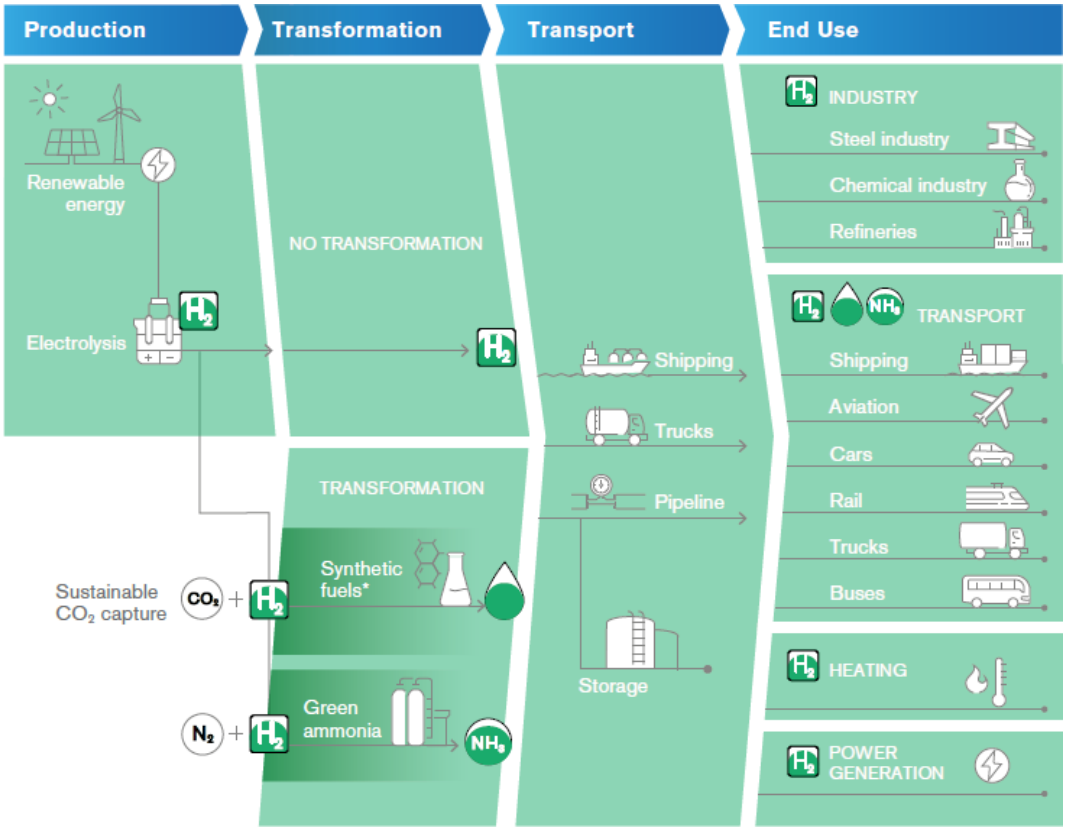

Fig. 2. Green hydrogen production, conversion, and end use across the energy system [13].

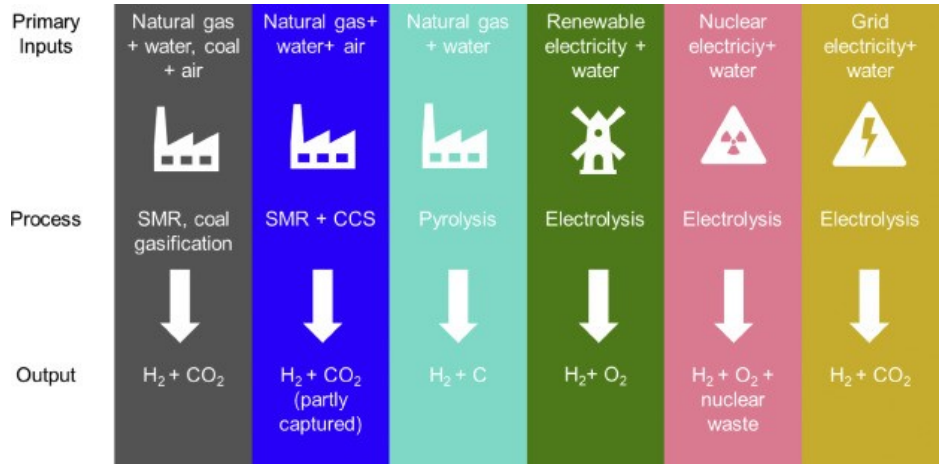

Fig. 3. Hydrogen production pathways and colors [14].

3.1 Types of hydrogen energy

Generally, hydrogen energy is classified based on the levels of carbon emissions, production method, and kind of energy used (Figure 3). The various hydrogen production methods produce varying levels of carbon emissions, and the level of these emissions determines the type of produced hydrogen:

Grey hydrogen Grey Hydrogen is hydrogen produced using fossil fuels such as natural gas or coal gasification without Carbon Capture, Utilization, and Stor-

age (CCUS). The major disadvantage of grey hydrogen is associated with significant CO_2 emissions generated during production [14]. Unfortunately, this accounts for roughly 96% of the hydrogen produced worldwide today [15].

Blue hydrogen Blue hydrogen is produced via natural gas or biogas reforming processes with CO_2 emissions but using CCUS technologies for a neutral carbon system [16].

Turquoise hydrogen Turquoise hydrogen is produced by the pyrolysis process of natural gas (methane) and water, resulting in hydrogen and carbon [17].

Green hydrogen Green hydrogen is produced via a water electrolysis process powered by clean and renewable energy sources [16]. This kind of hydrogen is considered sustainable energy because it is generated using renewable energy sources such as solar or wind and meets low-carbon emission standards (Figure 4).

Purple hydrogen Purple hydrogen is obtained by electrolysis through an atomic current. The results of this method are hydrogen and oxygen, and there are no carbon emissions. However, the biggest concern is its dangerous nuclear waste [18].

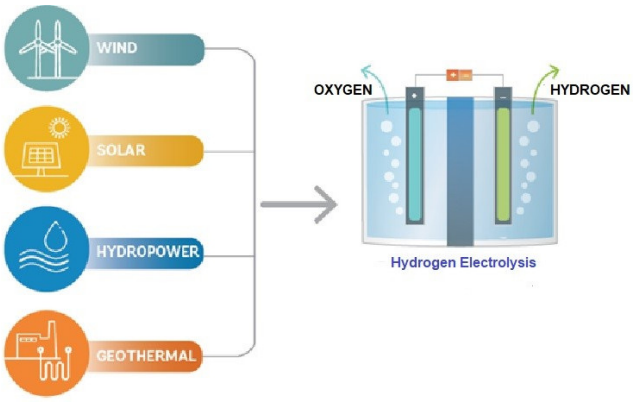

Fig. 4. Green hydrogen production [19].

4 Results and discussion

4.1 Prospects for the production and use of green hydrogen as a promising energy in Libya

As mentioned previously, Libya relies entirely on non-renewable and unclean energy sources. Therefore, it is necessary to search for an alternative energy source that must be renewable and not harmful to the environment. One of the most important of these sources is green hydrogen, which has become a priority for many countries, especially neighboring countries such as Egypt, Algeria, and Morocco. Apart from oil and gas, Libya has several other valuable resources to become a global leader in low-cost green hydrogen production and export, and acting now can secure its rightful place in this emerging new global economy. The most important reasons are:

- Abundant clean renewable energy sources to produce low-cost green hydrogen,
- Large uninhabited areas,
- Strategic location.

4.1.1 Clean energy sources

Libya is considered the most promising country in North Africa for energy production from renewable sources such as the sun and wind. Some of the advantages of solar and wind energy in Libya are described as follows:

- **Solar energy.** Libya has long hours of sunlight; it receives between 3000 and 3500 hours of sunshine each year [20]. This large solar radiation potential, in addition to the vast and uninhabited areas, can be used to produce clean energy, which in turn provides a good opportunity to produce green hydrogen at relatively low prices.
- **Wind energy.** In addition to solar energy, Libya has vast areas that are characterized by high-speed winds. The average wind speed in Libya is above 2.9 m/s, indicating the clear potential for wind energy utilization [8]. These sites can be used to produce clean and sustainable energy. This produced energy is also considered a potential energy source for green hydrogen production in Libya.

Libya's location in a high-centered radiation area and its long coastal line on the Mediterranean make it one of the countries with a very high potential for solar and wind energies [21]. Its wind and solar energy could provide a clean, renewable energy source, a good reason for encouraging investments in the green hydrogen project to achieve energy sustainability in Libya.

Figure 5 illustrates the future costs of hydrogen production using renewable electricity around the world, using future cost assumptions. Here, it can be seen that renewable hydrogen may be produced in Libya in the long term in a cost range of 1.8-2.0 US$/kg$H_2$ [22].

4.1.2 Large uninhabited areas

Libya is characterized by its spatial expansion, with an area of about 1,774,440 square kilometers. The unin-

habited area in Libya accounts for 88 percent of the total area. With its high rate of solar radiation and high winds, this large area can be best exploited to produce clean and cheap energy sources, which will be the most essential factor in the success of green hydrogen production in Libya.

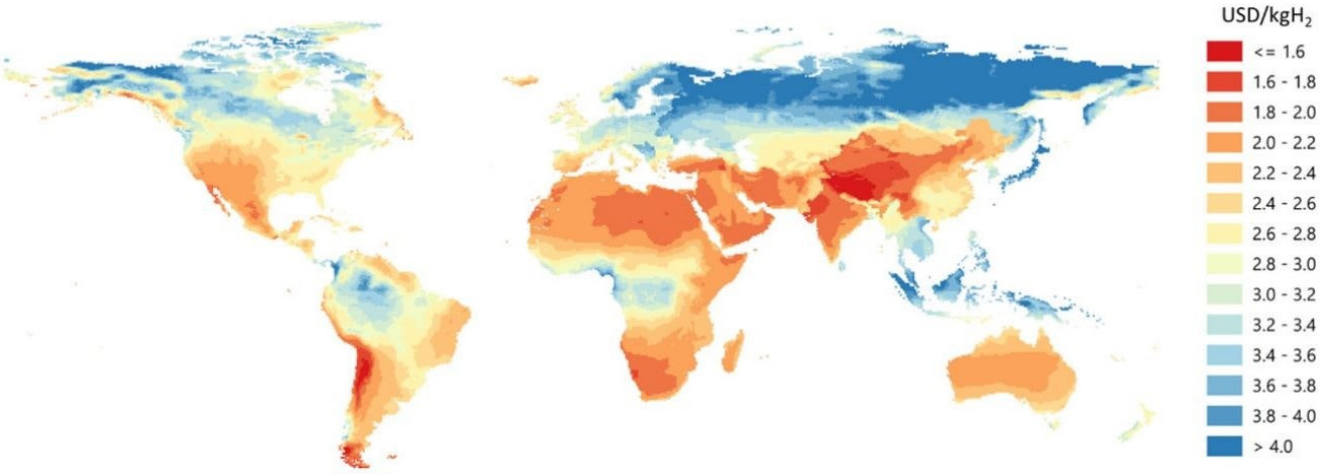

Fig. 5. Hydrogen costs from hybrid solar and onshore wind systems in the long term [22].

4.1.3 Strategic location

Libya's location on the Mediterranean Sea is important. It occupies about 1900 km on the southern shore of the Mediterranean Sea, which is overlooked by several Western European countries, most importantly Italy, France, Spain, and Greece, not to mention islands that lie in this sea, the most important of which are the two islands of Cyprus and Malta. Its geographical location makes it a strategic location for the production and export of green hydrogen.

4.2 Problems and challenges of transitioning towards hydrogen energy in Libya

Unlike the case for renewable energy two decades ago, the introduction of green hydrogen into the energy system in Libya faces many complex and difficult challenges. The barriers and challenges include:

Laws and regulations Libya, predominantly an oil and gas-producing nation, has many policies and regulations that favor this trade. Unfortunately, this works against the development of the renewable energy sector. In order to promote the renewable energy sector, the regulation laws and policies on energy need to be evaluated, and new policies that favor the renewable energy industry must be developed [23].

Storage and transportation facilities Green hydrogen energy faces major challenges in storage and transportation facilities, which play a significant role in the competitiveness of hydrogen. The costs of transmission and distribution could be three times as large as the cost of hydrogen production [23].

Production methods and technology Technological development in the green hydrogen energy industry is still in its juvenile stage, which explains the existence of myriad technical challenges. This poor technological development in the industry makes it difficult for people to risk investing in it.

Applications Many applications have been activated but on a very limited scale (including the transportation sector, some heavy industries, and centralized and distributed power generation), but other applications are still in the development stage.

Cost of production The cost of green hydrogen energy production using renewable sources exceeds other non-renewable alternatives, making investors choose the latter.

5 Conclusions

- Hydrogen provides long-term opportunities for economic growth and diversification. Green hydrogen production will diversify Libya's economy.

- It is important to note that hydrogen can be produced from renewable sources, such as solar and wind energies, which are available almost everywhere in Libya.
- Libya is considered the most promising country in North Africa for green hydrogen production for many reasons, such as the availability of renewable energy sources and vast uninhabited areas for its production, in addition to being close to the European market, which reduces the cost of transportation.
- There are some obstacles and challenges that must be overcome in order for Libya to become a leading country in the production and export of green hydrogen, the most important of which are developing laws and regulations, providing means of transportation and storage, importing new technologies, and finally, the relatively high production costs compared to traditional energy sources.

6 Recommendations

This study recommended starting the production of green hydrogen in Libya due to the availability of the necessary raw materials for its production. In order to achieve this, it is necessary to harness all the necessary elements, such as enacting the necessary laws and regulations and introducing technologies and facilities for the production and storage of green hydrogen.

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