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Green Hydrogen and its Potential in Turkey

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ABSTRACT

Green hydrogen is a clean and sustainable energy carrier that plays a critical role in the global energy transition and achieving decarbonization goals. This article addresses multifaceted topics such as the cost analysis of green hydrogen production and its potential in Turkey. Produced through the electrolysis of water using renewable energy sources green hydrogen unlike grey blue and brown hydrogen derived from fossil fuels does not involve carbon emissions. This characteristic makes green hydrogen a crucial tool in combating climate change. Factors affecting the production cost of green hydrogen include electricity costs electrolyzer technology and capacity factor. The decreasing costs of renewable energy and technological advancements are increasing the competitiveness of green hydrogen and supporting its widespread adoption. Turkey with its rich renewable energy potential and strategic location has a significant advantage in green hydrogen production. The National Hydrogen Strategy and private sector investments demonstrate Turkey's determination to progress in this field. Green hydrogen can be applied in various sectors such as energy transportation industry and buildings and can provide numerous benefits such as increasing energy independence economic development and sustainability. In conclusion green hydrogen will play a crucial role in the energy systems of the future and Turkey can achieve significant gains by taking an active role in this transformation.

1. Introductıon

Today, the need for energy is increasing. Due to the decreasing lifespan of fossil fuels and their effects on the environment, the use of renewable energy sources has become widespread. One of these energy sources is hydrogen energy. Hydrogen energy is environmentally friendly and has high energy density. Hydrogen is named according to different production methods. These are gray hydrogen, blue hydrogen and green hydrogen. Gray hydrogen is produced from fossil fuels. Blue hydrogen is produced with carbon capture technologies. Green hydrogen stands out from other hydrogens as a zero-carbon emission and clean energy carrier. Green hydrogen produced using renewable energy sources has the potential to create innovation in our energy system and offers an important opportunity for countries such as Turkey that are dependent on energy imports. Turkey is located in a very suitable geography for green hydrogen production with its solar and wind energy potential. Our country aims to increase both energy security and contribute to environmental sustainability by investing in green hydrogen technologies in line with its energy transformation goals. In this article, the importance of green hydrogen, current policies, projects and future goals in Turkey will be examined in detail.

2. Green Hydrogen

Green hydrogen is the hydrogen that results from the electrolysis of water using renewable energy in the process of which an electric current separates water molecules into hydrogen and oxygen rather than the more traditional methods of producing hydrogen. Unlike conventional techniques for producing hydrogen, the method of green hydrogen production does not entail any release of carbon dioxide to the

air hence no other greenhouse gases. This makes green hydrogen an energy carrier with low carbon content and friendly to the environment[1].

2.1. Advantages of Green Hydrogen

Green hydrogen is in the spotlight as a clean and sustainable fuel, which can have a much more important impact in changing the global energy game. This renewable source of energy holds the potential for driving faster abandonment of fossil fuel reliance and reversing the impacts of global warming. This new green hydrogen does not do anything at all to contribute to global warming due to no greenhouse gas being emitted during production. Current mainstream green hydrogen production, gray hydrogen, comes from natural gas, with a high foul release of carbon dioxides dumped into the air from the process. Blue hydrogen is made in much the same way as gray from natural gas, but carbon capture and storage technology are applied to cut carbon emissions. Despite this improvement, blue hydrogen remains reliant on fossil fuels, and the carbon capture process is costly and energy intensive. Brown hydrogen, specifically, has the undesirable distinction of being the dirtiest fuel, as it carries with it the highest carbon footprint and it's derived from coal – hence, brown, gray, blue hydrogen all contribute to greenhouse gas emissions which drive climate change[2]. The types of hydrogen are compared in Table 1.

Table 1. Comparison of Hydrogen Types

Feature	Green Hydrogen	Gray Hydrogen	Blue Hydrogen	Brown Hydrogen
Carbon Emission	None	High	Low (with CCS)	Very High
Sustainability	High	Low	Medium	Low
Environmental Impact	Minimal	High	Medium	Very High
Energy Source	Renewable Energy	Natural Gas	Natural Gas	Coal
Cost	High	Low	Medium	Low

Generation of green hydrogen entails no emission of greenhouse gases at the production source. This is achieved through electrolysis of water into hydrogen and oxygen using electricity obtained from renewable sources like solar, wind, and hydro. It's made in a very sustainable way without any harmful gases being emitted into the atmosphere in this way. The other importance of green hydrogen is in energy storage. Often, because alternative sources produce energy intermittently, the energy produced may not meet the demanded energy. Hence, green hydrogen is a marvellous solution to accumulate the extra energy and use it when required. Thus, security in the supply of energy could be done while raising the efficiency of alternative sources of energy[3][4].

2.2.Production of Green Hydrogen

The base of green hydrogen production is, in fact, the process of electrolyzing water to separate hydrogen and oxygen from the water using electricity, renewable electricity again achieved using solar, wind, and hydropower. It is therefore renewable electricity that will have carried out the electrolysis as mentioned in Figure 1.

- Renewable energy production: The very first step in this process is energy production through a renewable source, which can be solar panels, winds mills/turbines or power house working on hydro power[5].
- Electrolysis: Electricity is led to a set of electrolyzers, where water molecules are split into hydrogen and oxygen using electrical current[6].
- Hydrogen Collection and Storage: Collected hydrogen gas is stored after separation by different methods.
- Distribution: The stored hydrogen is distributed by pipelines or tankers to the required places.

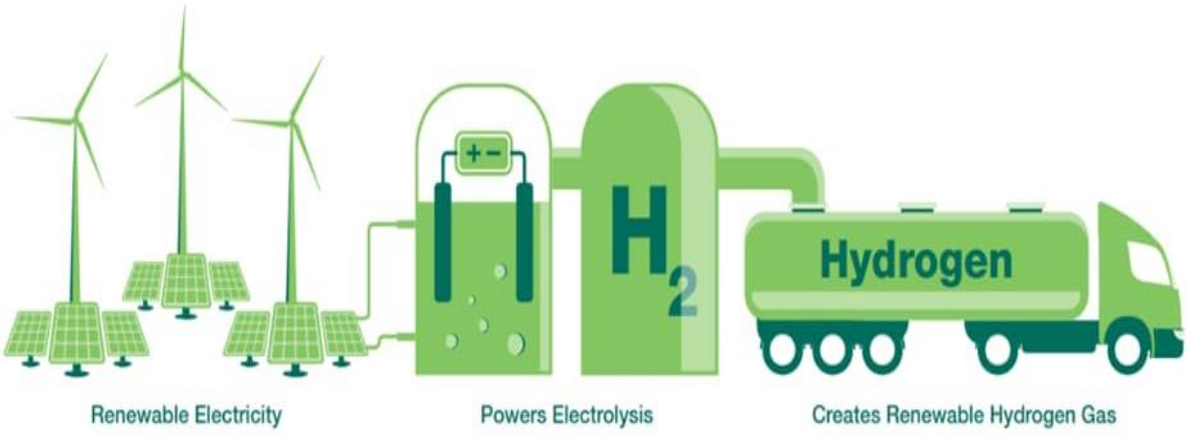

Figure 1. Production of Green Hydrogen

The green hydrogen production cost here comes up impacted by several factors like the cost of electricity, efficiency of the electrolyzer, and also the capacity factor. Renewable sources, particularly those like solar and wind energies, underwent sharp cost declines over the past years and are forecasted for continuation in forthcoming years. Another factor for costs is associated with the technology of the electrolyzer that is used. By using efficient and durable electrolyzers, one can reduce costs. The capacity factor of renewable energy sources decreases the costs of these, while operating maintenance, as well as the costs of storage and distribution all add up to the total costs. This will then optimize all such factors, which will then eventually make green hydrogen become more economically and more commonly used. Such an act would then enhance the competitiveness of green hydrogen and would speed up such a transition into a much more sustainable energy system[7][8].

3. Green Hydrogen in Turkey

It is with this situation that Turkish green hydrogen may become a more substantive matter with the favorable geographical position and the renewable energy potential of the country. Further investments in solar and wind energy will both enhance the prospect of competitiveness through lowering the costs associated with manufacturing green hydrogen and increase Turkey’s capacity to extract hydrogen profitably. In this sense, the strategies and policies of Turkey with regard to the production and utilization of green hydrogen will be vital for energy transition as a country and attaining goals on decarbonization[9][10].

3.1.Green Hydrogen Potential and Benefits in Turkey

Green hydrogen potential in Turkey is quite high, due to several aspects:

- High Renewable Energy Resource Potential: Turkey stands as quite a sunny and windy place on the geographic map. The International Energy Agency (IEA) mentioned that Turkey's technically available solar energy reaches 380 GW. On the other hand, its available wind energy hits 48 GW. Taking advantage of this would lead to the minimization of the costs related to producing green hydrogen and boost its sustainable nature.
- Strategic Geographical Location: Acting as a bridge between Europe and Asia, Turkey holds appreciable merit when it comes to the export of green hydrogen. This country is poised with the potential to meet the growing demand for green hydrogen in Europe. Further, strong trade relations with Middle Eastern and North African countries might help the country export green hydrogen to these places[11].
- Suitable Infrastructure for the Production and Application of Green Hydrogen Technologies: Advanced industrial infrastructure in Turkey offers a ground most suitable for the production and application of green hydrogen technologies. Especially, in the automotive, chemicals, iron

and steel, cement and refinery sectors, etc., there would be big potentials to be the leading sectors not only demanding green hydrogen but also developing and applying green hydrogen technologies[12].

- Green hydrogen is a field where Turkey is drawing attention with increasing investments and political support. It is the national strategy and action plan, the YEKA tenders, R&D incentives, and international collaborations that support the development of the green hydrogen ecosystem.

Figure 2. Places with High Hydrogen Potential in Turkey[11]

Turkey meets a major portion of its energy needs through imported ‘fossil fuels and this poses risks in terms of energy security as well as the current account deficit. The special thing about green hydrogen is that it is produced from renewable resources and therefore, helps a country improve its energy dependency as well as avoid valuable foreign exchange going for energy imports. Furthermore, the application of green hydrogen will contribute significantly to the mitigation of and adaptation to climate change. The road to the Turkish target for 2053 net zero emissions and its nationally determined contribution under the Paris Agreement runs critically through the adoption of green hydrogen.

3.2.Green Hydrogen Developments in Turkey

Green hydrogen is one of the subjects in which Turkey has made huge steps in recent years, establishing ambitious targets in this area. Rounds of developments in the field receive endorsement with public sector policies and incentives, as well as growing private investments.

- National Hydrogen Strategy and Roadmap: This strategy document from Ministry of Energy and Natural Resources will be published in January 2023 and outlines Turkey’s vision and targets for green hydrogen. The strategy intends to achieve an electrolyzer capacity of 2 GW by 2030, 5 GW by 2035, and 70GW by 2053 and intends to make Turkey a key player in the worldwide green hydrogen economy[13].
- Ace for aligning with the Green Deal: The Action Plan is prepared to align with the overall Green Deal framework of the European Union, thereby underpinning the critical operation of

the green hydrogen in meeting the decarbonization targets. The policy sets forth various measures and support systems to promote the production and use of green hydrogen. The YEKA tenders will be commonly perceived to cut the cost of renewable electricity required in green hydrogen production through investment stimulation in solar and wind energy resources. These tenders represent an encouragement to indigenous manufacturing and technology development. Hydrogen Valley is established in Balikesir, and the Hydrogen Valley Project represents an attempt to render Turkey a significant center with respect to green hydrogen production (Figure 3)[14]. As for the project's goals, a minimum of 500 tons of green hydrogen is planned to be produced per year within the ambit thereof, whereas said green hydrogen shall find applications within the industry, transportation as well as energy sectors. Private sector investments and public-private cooperation shall be how this project comes to be executed.

- Pilot Green Hydrogen Production Facilities: To the Bandırma district of Balıkesir in Turkey, a pilot green hydrogen facility will be established by Enerjisa, making them the pioneer in such an endeavor in the country. This marks a crucial step towards testing as well as technology optimization for green hydrogen production. Eti Mine Enterprises; and TC Ministry of Industry and Technology jointly developed a Domestic Production Type Pem Electrolyzer and Enerjisa Üretim aims to place it in Bandırma Energy Base[14].
- Tüpraş: Tüpraş will produce green hydrogen with its refineries it will establish and is targeting the front rank in non-carbon electricity production[15].
- Sectoral Collaborations and Investments: Joint ventures between companies in automotive, chemistry, iron and steel, energy sectors are being contemplated for the purpose of evaluating the potential and investments on green hydrogen. These collaborations are intended to diffuse green hydrogen to other sectors and fast track technological advancements.

Figure 3. Enerjisa Hydrogen Valley[14]

4. Conclusions

The micro-fossil world deposits accumulated over millions of years by the activity of bacteria Laser trimming modifies their structure and nature to liberate small quantities of versatile hydrogen filled with sustainability features. The sustainability of using green hydrogen, which does not emit harmful or

greenhouse gases under the production process, and while being consumed, will be a great leap towards renewable energy and a carbon-free economy. At present, the total production cost of green hydrogen is higher than fossil fuel-based hydrogen. But as renewable electricity costs come down while technology progress and economies of scale in electrolyzers develop further, these tendencies will turn it into a more affordable form of energy in the future. The geographical and industrial properties could combine to make Turkey a big player in green hydrogen. Turkey's plentiful renewable energy sources, strategic location, and well-developed industrial base give the country a potential high standing in the coming green hydrogen scenario. Sectoral policies implemented together with private sector investments and various R&D activities may facilitate the actualization of this possibility. Unlike some other alternatives of renewable energy, green hydrogen may not merely remain confined to specific applications or sectors, but extend to a wide range of applicabilities, such as the transportation system and building complexes wherein they would enable several strategic advantages to be accrued, including enhanced energy independence, the ushering in of new economic prospects, reduction in GHG emissions, and forestalling technological stagnancy; thus, the future must be green. There is indeed a need for nations like Turkey to take on a catalytic role in this energy revolution through the realization of the greening potential of hydrogen. Creating hydrogen R&D investment conditions promoting national technology development encouraging pilot projects in green hydrogen technologies, and all other related investments guarantee the development and broad application of green hydrogen technologies. Effective feeding of this new energy into the system with new "fuel lines" to "tap" it must be developed. International collaboration information sharing, and technology transfer will have to play a crucial role in it. The last one is qualified workforce training and social awareness-raising activities that will give support to society in adopting green hydrogen and development of the sector.

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