

Green Hydrogen as a low carbon growth potential

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1 Abstract

Hydrogen is the most abundant element in the universe and yet, on Earth, it is rarely found in a free state. It is necessary an energy source to break down water molecules and separate H₂ from oxygen.

The great attraction of hydrogen is that it offers, in the long term, the possibility of establishing an intrinsically clean closed energy cycle scenario.

Hydrogen is an energy carrier (an energy vector), and this is one of the main aspects to take into account to achieve the benefits that the hydrogen economy promises. The increasing ambition of climate targets creates a major role for hydrogen especially in achieving carbon-neutrality in sectors presently difficult to decarbonise.

Green hydrogen has the versatility to play a significant role in non carbonizing various sectors and achieving a sustainable energy future. This natural gas has a wide range of potential uses across various sectors. Green hydrogen can be used as a fuel for various modes of transportation, including cars, buses, trucks, trains, ships, and even airplanes.

Several countries have the potential for green hydrogen production due to their abundant renewable energy resources and favorable conditions for electrolysis. This article shows some countries that could have significant green hydrogen potential and its economic benefits.

2 Resumen

El hidrógeno es el elemento más abundante en el universo y, sin embargo, en la Tierra rara vez se encuentra en estado libre. Es necesaria una fuente de energía para descomponer las moléculas de agua y separar el H₂ del oxígeno.

El gran atractivo del hidrógeno es que ofrece, a largo plazo, la posibilidad de establecer un escenario de ciclo energético cerrado intrínsecamente limpio.

El hidrógeno es un vector energético (un vector energético), y este es uno de los principales aspectos a tener en cuenta para conseguir los beneficios que promete la economía del hidrógeno. La creciente ambición de los objetivos climáticos crea un papel importante para el hidrógeno, especialmente para lograr la neutralidad de carbono en sectores que actualmente son difíciles de descarbonizar.

El hidrógeno verde tiene la versatilidad de desempeñar un papel importante para no carbonizar varios sectores y lograr un futuro energético sostenible. Este gas natural tiene una amplia gama de usos potenciales en varios sectores. El hidrógeno verde se puede utilizar como combustible para diversos modos de transporte, incluidos automóviles, autobuses, camiones, trenes, barcos e incluso aviones.

Varios países tienen potencial para la producción de hidrógeno verde debido a sus abundantes recursos de energía renovable y condiciones favorables para la electrólisis. Este artículo muestra algunos países que podrían tener un importante potencial de hidrógeno verde y sus beneficios económicos.

3 Introduction

Green hydrogen refers to hydrogen gas that is produced using renewable energy sources, such as solar or wind power, through a process called electrolysis. Electrolysis involves splitting water molecules (H_2O) into hydrogen (H_2) and oxygen (O_2) using an electric current. The term "green" in green hydrogen signifies the environmentally friendly aspect of its production. Unlike traditional methods of hydrogen production, such as steam methane reforming, which relies on fossil fuels and emits greenhouse gases, green hydrogen is produced without generating carbon dioxide (CO_2) or other harmful pollutants. This makes it a clean and sustainable energy carrier with various potential applications.

Green hydrogen has a wide range of potential uses across various sectors. Green hydrogen can be used as a fuel for various modes of transportation, including cars, buses, trucks, trains, ships, and even airplanes. Hydrogen fuel cell vehicles produce zero emissions, with the only byproduct being water vapor, making hydrogen a clean alternative to fossil fuels in the transportation sector. Also, green hydrogen can be used as a feed stock or fuel in industrial processes, such as ammonia production, steel manufacturing, and petrochemical refining. Hydrogen is a versatile chemical that can help non carbonize these industries by replacing fossil fuels or reducing carbon-intensive processes.

Power Generation is other area where hydrogen can be used as a fuel in gas turbines or hydrogen fuel cells to generate electricity. This can provide a reliable and dispatch able source of power, particularly when integrated with renewable energy sources. Hydrogen power plants can serve as backup or peaking power facilities to support the grid during periods of high demand or intermittency.[kumar2022overview]

Green hydrogen can be used as a means of energy storage, helping to balance the intermittent nature of renewable energy sources like solar and wind. Excess electricity generated during times of low demand can be used to produce hydrogen through electrolysis, which can then be stored and converted back into electricity when needed.

In the cases of heating and Residential, green hydrogen can be used for heating buildings and homes, either through direct combustion or by converting it into synthetic natural gas. This can help non carbonize the heating sector,

which is traditionally reliant on fossil fuels like natural gas or heating oil.

Related to transportation green hydrogen can be injected into existing natural gas pipelines and utilized for grid balancing and ancillary services. It can serve to store excess renewable energy and release it when demand is high, helping to stabilize the grid and support grid flexibility.

4 Green hydrogen provides a way to reduce greenhouse gas emissions

As the technology and infrastructure for hydrogen production and continue to develop, new applications and possibilities are emerging. Green hydrogen has the versatility to play a significant role in non carbonizing various sectors and achieving a sustainable energy future.

Green hydrogen has gained significant attention as a promising solution for non carbonizing sectors that are difficult to electrify directly, such as heavy industry, long-haul transportation, and energy storage. Some key benefits of green hydrogen include:

4.1 Non carbonization

Green hydrogen provides a way to reduce greenhouse gas emissions by replacing fossil fuels in various industries. When used as a fuel or energy carrier, it only emits water vapor when consumed.

Hydrogen can be stored and used as a means of energy storage. It can help balance intermittent renewable energy sources by storing excess electricity during periods of low demand and supplying it when demand is high. Green hydrogen can be used in various sectors and applications. It can be used as a fuel for transportation, feed stock in industrial processes, or as a heat source for buildings. It also has the potential for power generation through hydrogen fuel cells.[kazi2021green]

4.2 Resource Availability

Hydrogen is the most abundant element in the universe, but it is primarily found in compound form. Green hydrogen production allows us to tap into water, which is widely available, making it a potentially sustainable and abundant energy resource. The growing interest in green hydrogen has spurred advancements in electrolyze technology and renewable energy systems. These developments have the potential to reduce the cost of production and make green hydrogen more economically viable. [ball2009future]

However, it's important to note that the widespread adoption of green hydrogen faces challenges. These include the high cost of production compared to fossil fuel-based hydrogen, the need for significant renewable energy capacity to scale up production, and the development of infrastructure for hydrogen storage and distribution.[mazloomi2012hydrogen]

Overall, green hydrogen holds promise as a clean and versatile energy carrier, with the potential to contribute to a more sustainable and low-carbon future. Ongoing research, development, and investment are critical for its further deployment and integration into various sectors of the economy. Gas pipelines for natural gas are sometimes used to transport hydrogen, but it is not without challenges. Many pipelines would need to be upgraded for hydrogen transport. The natural gas industry and its infrastructure could pose a barrier to the adoption of green hydrogen for countries aiming to achieve carbon neutrality. A pilot program in Cappelle-la-Grande, France, has already mixed hydrogen into the gas grid serving 100 homes. Natural gas power plants can also be converted to burn hydrogen and serve as backup power during periods of high demand. Options include an emissions trading system (ETS) or comprehensive tax reform that places a price on carbon emissions (with revenues possibly recycled through reductions in other taxes). Verified and high-quality forest offsets could bring sustainable land use into a broader carbon pricing architecture.

4.3 Which countries have the potential to produce green hydrogen?

Several countries have the potential for green hydrogen production due to their abundant renewable energy resources and favorable conditions for electrolysis. Here are some countries that could have significant green hydrogen potential:

Australia has vast renewable energy resources, including solar and wind power. The country is already exploring green hydrogen production and has plans to become a major exporter of hydrogen to Asia. Germany has been actively promoting green hydrogen as part of its energy transition efforts. The country has a strong renewable energy sector and aims to become a global leader in hydrogen technologies.

Netherlands also has set ambitious targets for hydrogen production and aims to develop a green hydrogen economy. The country has a well-developed gas infrastructure that can potentially be repurposed for hydrogen transport. Norway is already a major producer of natural gas and is looking to utilize its infrastructure and expertise to develop green hydrogen production.

Saudi Arabia vast solar resources and is exploring green hydrogen to diversify its economy away from fossil fuels. The country has plans to develop large-scale green hydrogen projects for both domestic use and export.[[hassan2023energy](#)]

Chile has excellent conditions for solar and wind energy production. The country is aiming to become a leading exporter of green hydrogen, leveraging its renewable energy potential.[[acosta2022chile](#)]

Canada has significant renewable energy resources, including hydropower and vast open spaces for wind and solar farms. The country is actively investing in green hydrogen projects.

Japan has limited domestic energy resources and is heavily reliant on energy imports. As part of its non carbonization efforts, Japan is focusing on hydrogen as an energy carrier and has plans to import large quantities of green hydrogen. These are just a few examples, and other countries with substantial renewable

energy resources are also exploring green hydrogen production. The potential for green hydrogen production depends on a combination of renewable energy availability, supportive policies, infrastructure development, and investment in research and development.

Brazil also has significant potential for green hydrogen production. The country is blessed with abundant renewable energy resources, including vast areas of solar radiation and ample wind resources, which are key factors for producing green hydrogen through electrolysis. Brazil has been actively exploring and investing in the development of green hydrogen projects. The country has a strong commitment to renewable energy and has set targets for increasing the share of renewables in its energy mix. The Brazilian government has recognized the potential of green hydrogen and has initiated several initiatives and partnerships to promote its production and use. One advantage Brazil has is its existing infrastructure for natural gas production and distribution. This infrastructure can potentially be repurposed for transporting and distributing hydrogen. [kelman2020can]; [chantre2022hydrogen]

Additionally, Brazil has a large agricultural sector, which presents opportunities for utilizing biomass as a feedstock for hydrogen production through processes like biomass gasification. Moreover, Brazil has a thriving bio fuel industry, particularly in ethanol production from sugarcane. The knowledge and infrastructure from the bio fuel sector can be leveraged to produce green hydrogen through the reforming of bio ethanol.

Furthermore, Brazil has been actively involved in international collaborations and partnerships to advance green hydrogen. For example, Brazil is a member of the Hydrogen Council, a global initiative aimed at promoting the role of hydrogen in the energy transition. Given its favorable renewable energy resources, existing infrastructure, and commitment to clean energy, Brazil has the potential to become a significant player in green hydrogen production and contribute to a sustainable and low-carbon future.

In the case of Ecuador, also possesses potential for green hydrogen production, although it may face certain challenges and considerations. While Ecuador may not have as much international visibility in the context of green hydrogen as some other countries, it does have factors that could contribute to its green hydrogen potential. Even though, Ecuador has significant renewable energy resources, including solar, wind, and hydroelectric power. These resources can serve as the basis for producing green hydrogen through electrolysis, with numerous rivers and water sources that can be harnessed for generating renewable energy.

4.4 Viability

A set of economy-wide interventions is needed to provide the right incentives to households and the private sector, and to enable them to act on climate-related opportunities.

Now days, 770 millions worldwide lack access to electricity. 40 percent of global CO₂ emissions come from buildings; 73 percent of global emissions come

from energy consumption; 60 percent of world energy supply must be powered by clean energy to achieve net-zero emissions.[**wri2009investing**]

The transportation sector is one of the largest contributors to global energy consumption and greenhouse gas emissions. In 2020, the sector accounted for approximately 24 percent of global energy-related CO₂ emissions. The majority of transportation energy demand is still met by petroleum products, such as gasoline and diesel fuel. [**li2022impact**]

Electric vehicles (EVs) are gaining momentum, with global sales reaching around 3.2 million units in 2020, representing a 43 percent increase compared to the previous year. In Industrial Processes case, including manufacturing, cement production, and chemical manufacturing, account for a significant portion of global energy consumption and emissions. In 2020, the industrial sector accounted for about 37 percent of global energy-related CO₂ emissions.[**kumar2023electric**]

Iron and steel production, cement manufacturing, and chemicals are among the most energy-intensive industrial sectors.

Since supply point of view, in 2020, the world's total installed electricity generation capacity was around 7,863 gigawatts (GW). Renewable energy accounted for approximately 28 percent of global electricity generation in 2020, with hydro power, wind, and solar being the primary sources. Coal remained the largest source of electricity generation, accounting for around 36 percent of the global total in 2020. Nuclear power contributed about 10 percent of global electricity generation.

The global renewable energy capacity reached approximately 2,799 GW in 2020, representing an increase of 10Solar photovoltaic (PV) and wind power accounted for the majority of new renewable energy capacity additions in recent years.

The cost of electricity (LCOE) for solar and wind power has significantly declined, making them increasingly competitive with fossil fuel-based generation. The renewable energy sector employed over 11 million people globally in 2019, with the majority of jobs located in China, the United States, and the European Union.

The energy landscape is continually evolving as the world seeks to transition to cleaner and more sustainable energy systems. Building a competitive hydrogen economy requires the concurrent development of hydrogen supply, transportation infrastructure, and demand in a way that ensures low/net-zero life cycle GHG emissions and minimizes material (mineral, water), land, environmental, and social impacts. Many countris could use green hydrogen to decarbonize industry (petroleum refining, petrochemicals, chemicals, steel, etc.) and transport (especially long-haul freight and heavy-duty mining trucks), and to contribute to the flexibility of the power system.

4.5 Conclusions

The hydrogen economy is emerging as a thriving sector that promises to be an alternative to fossil energy and therefore reduce CO₂ emissions into the

atmosphere. Being a viable energy source, it is expected to become an impetus for economic growth for countries that promote it.

The hydrogen economy is consolidated and will become relevant when the technological development necessary to convert it into marketable energy is achieved. It can constitute a significant percentage of the source of energy and services of any country. This vision becomes a reality if hydrogen can be produced internally (as domestic energy) and commercialized in a sustainable way.

Green hydrogen is emerging as an alternative energy source to fossil energy, which will allow countries to reduce dependence on oil, achieve energy independence and contribute to reduce GHG emissions.