

THE PROMISE OF GREEN HYDROGEN



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INTRODUCTION

Hydrogen is poised to play a major role in the global energy transition. In recent years, there has been a growing interest in “green hydrogen” – hydrogen that is produced using renewable energy sources.

The production of green hydrogen – using renewable energy sources to power the electrolysis of water – is one of the key steps in the decarbonization of the economy and the fight against climate change as it can be used in a variety of sectors without emitting greenhouse gases.



“THIS PAPER EXPLORES THE POTENTIAL OF GREEN HYDROGEN AND HOW PUBLIC-PRIVATE PARTNERSHIPS CAN CONTRIBUTE MAKING IT A REALITY. IT ALSO PROVIDES AN OVERVIEW OF GREEN HYDROGEN MARKET SIZE, SECTOR APPLICATIONS, AND PROJECT FINANCING MECHANISMS.

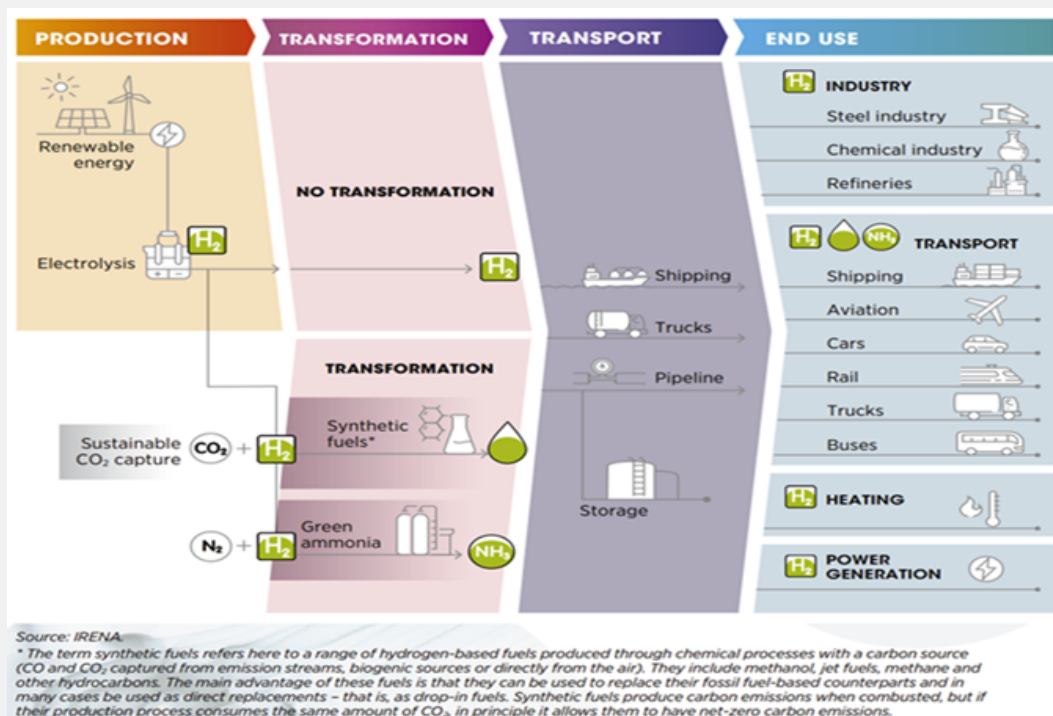
WHAT IS GREEN HYDROGEN?

Green hydrogen is a clean and environmentally friendly fuel produced using renewable energy sources. There are several ways to produce green hydrogen. The most common method is through electrolysis, which involves using electricity to split water molecules into oxygen and hydrogen.

Other methods include using biomass or fermentation. Biomass can be converted into hydrogen through a process known as gasification, while fermentation can be used to produce hydrogen from organic materials such as food waste.

According to the International Renewable Energy Agency (IRENA), the global capacity of green hydrogen production is expected to reach 140 GW by 2030. This would be equivalent to the production of nearly 10 million tons of hydrogen per year.

FIGURE 1: GREEN HYDROGEN VALUE CHAIN



SOURCE: 1 INTERNATIONAL RENEWABLE ENERGY AGENCYIRENA

THE POTENTIAL OF GREEN HYDROGEN

Green hydrogen has a number of potential applications. It can be used as a fuel for transportation, as a way to store energy, or as a source of heat and power.

Green hydrogen can also be used in the petrochemical industry, as a replacement for natural gas in the production of fertilizer and other chemicals. Additionally, green hydrogen can be used to reduce emissions in the steel and aluminum industries, as a way to reduce emissions.

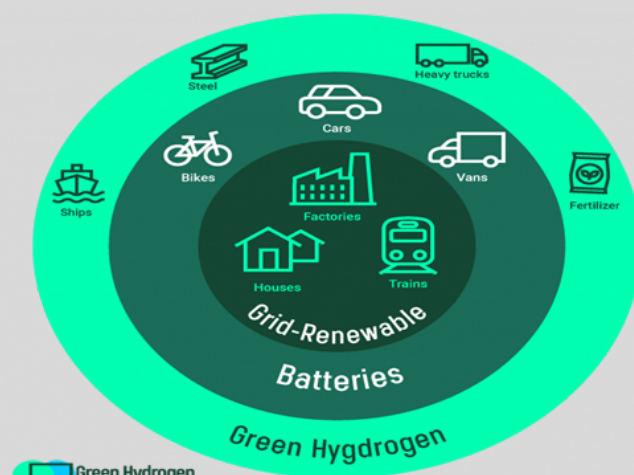
Green hydrogen can be used in a number of different sectors to decarbonize the economy. There are three key sectors where green hydrogen PPPs could have the biggest impact: power, industry and transport.

In the power sector, green hydrogen PPPs could help to decarbonize electricity generation. This would be achieved by using green hydrogen to generate electricity, either through direct combustion or by using it in fuel cells. Fuel cells are a type of battery that converts chemical energy into electrical energy.

In the industry sector, green hydrogen PPPs could help to decarbonize industrial heat. This would be achieved by using green hydrogen to replace natural gas in industrial processes. Green hydrogen can be used in a variety of industrial processes, including steelmaking, glassmaking, and cement production.

In the transport sector, green hydrogen PPPs could help to decarbonize road transport. This would be achieved by using green hydrogen to power vehicles, either through direct combustion or by using it in fuel cells. Fuel cells are a type of battery that converts chemical energy into electrical energy.

FIGURE: KEY ENERGY USES OF GREEN HYDROGEN



SOURCE: GREEN HYDROGEN ORGANIZATION

WHY IS THE GREEN HYDROGEN MARKET GAINING WORLDWIDE TRACTION?

The green hydrogen market is gaining worldwide traction for a few reasons :

First, *the Paris Agreement and the Sustainable Development Goals* have put the fight against climate change and the promotion of sustainable development at the top of the global agenda. This has created a strong market incentive for the development of green hydrogen technologies.

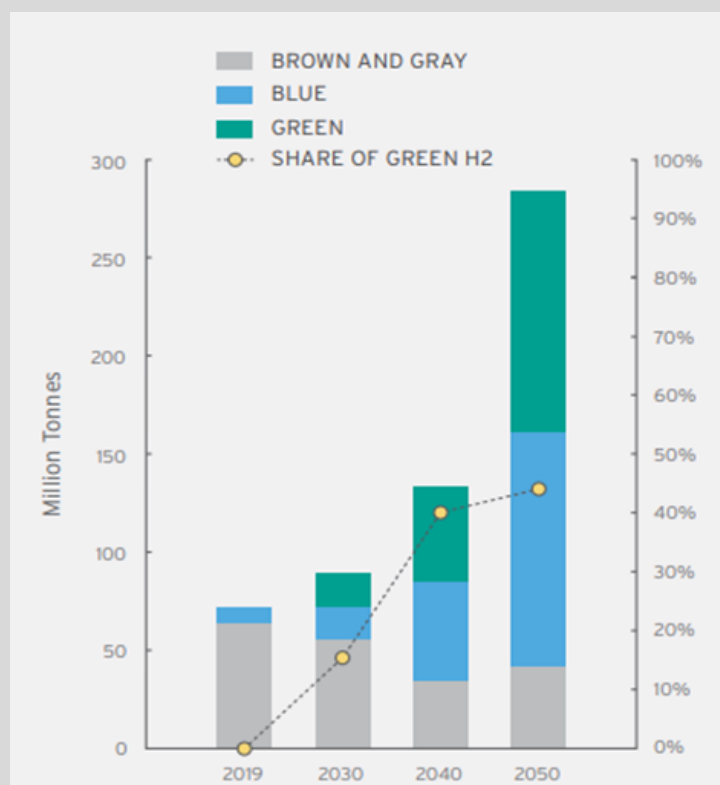
Second, *the declining cost of renewable energy technologies*, such as solar and wind power, has made green hydrogen production increasingly economically viable. In fact, according to a recent report from Bloomberg New Energy Finance, the cost of producing green hydrogen is expected to fall by up to 60% by 2030.

Also, there is a growing recognition of the role that green hydrogen can play in the wider energy system. Green hydrogen can be used to decarbonize a number of sectors, including transportation, industry, and buildings.

It can also be used to store renewable energy when there is surplus production from wind and solar farms. This flexibility makes green hydrogen an important part of the transition to a low-carbon economy.

Third, *several countries have started to develop ambitious plans for the development of green hydrogen*. For example, the European Union has set a target for 12% of its hydrogen to be produced from renewable sources by 2030, while Japan has announced a plan to build 20GW of green hydrogen production capacity by 2050

FIGURE: GREEN HYDROGEN PRODUCTION OUTLOOK



SOURCE: IRENA, BNEF, IEA



THE CHALLENGES OF GREEN HYDROGEN

Despite its many potential applications, there are also some challenges associated with green hydrogen.

One of the biggest challenges is scalability – that is, the ability to produce green hydrogen on a large enough scale to meet global demand; Currently, most green hydrogen is produced on a small scale using electrolyzers that have a relatively low capacity (usually less than 1MW). To meet the demand for green hydrogen, there will need to be a significant increase in production capacity.

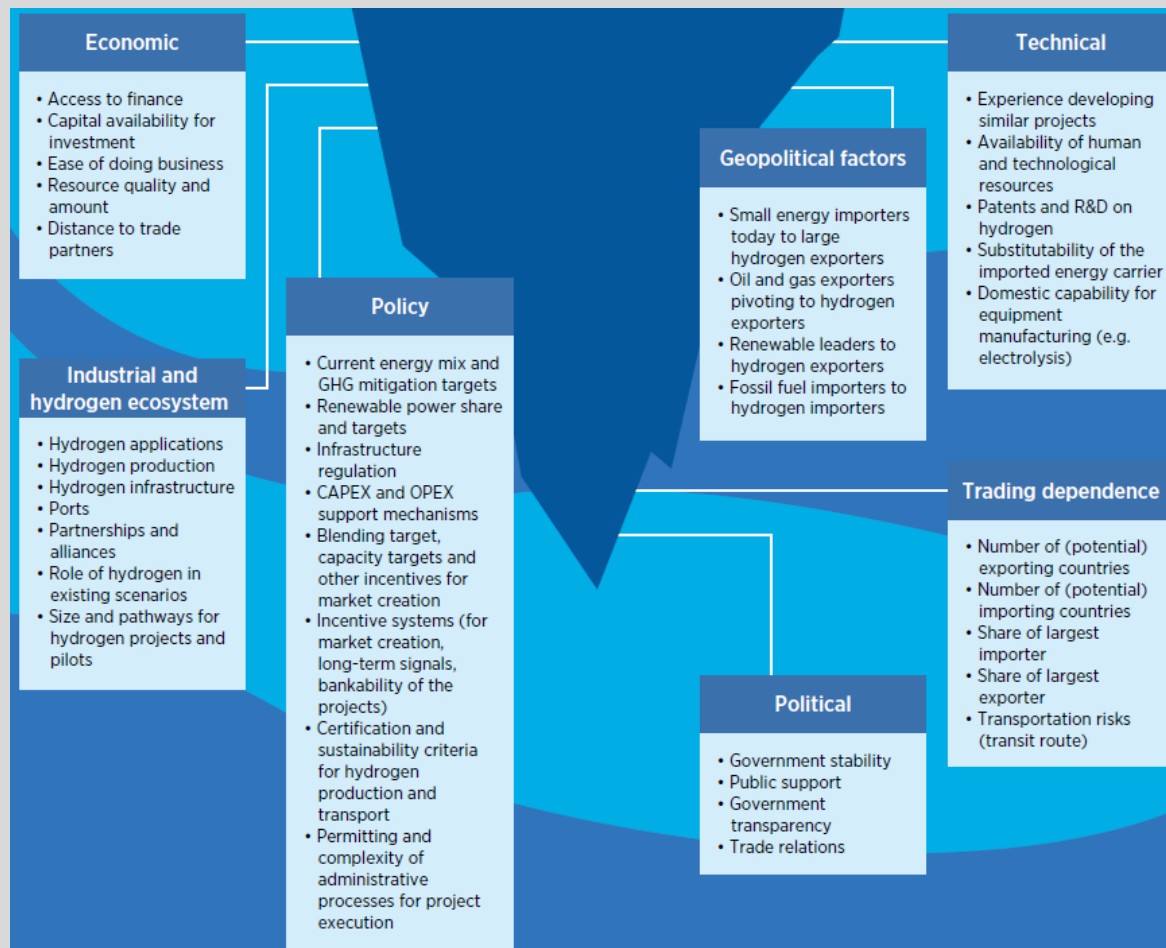
Another obstacle to market development is the lack of financing options.

Green hydrogen projects are often complex and require significant upfront investment. This can make it difficult to secure the financing needed to get projects off the ground.

Despite the growing interest in green hydrogen, there are still a number of obstacles to its wider adoption.

One of the biggest challenges is the lack of large-scale production facilities.

FIGURE: MAJOR CHALLENGES FACING GREEN HYDROGEN PRODUCTION



SOURCE: IRENA, BNEF, IEA

PUBLIC-PRIVATE PARTNERSHIPS FOR GREEN HYDROGEN

BENEFITS OF PPPS

One way to overcome some of the challenges facing the green hydrogen market is through Public Private partnerships Partnerships (PPPs). PPPs can provide significant financing and support for early-stage projects that may otherwise struggle to get off the ground. In addition, PPPs can help to de-risk projects and attract private sector investment. There are already a number of a few examples of successful PPPs in the green hydrogen arena space.

In Europe, the Hydrogen Council is an initiative that brings together companies and organizations from across the hydrogen value chain.

In the United States, the Department of Energy has launched the Fuel Cell Technologies Office, which is supporting research and development into fuel cells and electrolyzers – devices that are essential for producing green hydrogen

Hydrogen Mobility Europe (H2ME)

A joint initiative between eight European countries that is working to develop a large-scale market for fuel cell electric vehicles (FCEVs). Under the H2ME initiative, around 1,000 FCEVs will be deployed in eight European countries by 2020. Another example is HyFIVE, a five-year project that is working to deploy 500 fuel cell cars

➤ **Accelerating investment in green hydrogen technologies:** Green hydrogen PPPs can help to accelerating investment in green hydrogen technologies by providing a mechanism framework for the public and private sectors to cooperate on projects. This can help to reduce the risks associated with investing in modern technologies and can also lead to economies of scale.

➤ **Stimulating economic growth:** Green hydrogen PPPs can help to stimulating economic growth by creating new jobs and industries associated with the production and use of green hydrogen.

➤ **Improving energy security:** Green hydrogen PPPs can help to improving energy security by reducing dependence on imported fossil fuels.

➤ **Reducing greenhouse gas emissions:** Green hydrogen PPPs can help contribute to reducing greenhouse gas emissions by promoting the use of renewable energy sources for hydrogen production.

➤ **Creating social and environmental benefits:** Green hydrogen PPPs can create social and environmental benefits by promoting the use of cleaner and more sustainable energy sources.

CHALLENGES

- **High investment costs:** One of the main challenges associated with green hydrogen PPPs is the high investment cost associated with setting up projects. This is due to the fact that green hydrogen technologies are still relatively new and require significant research and development investment before they can be deployed at scale

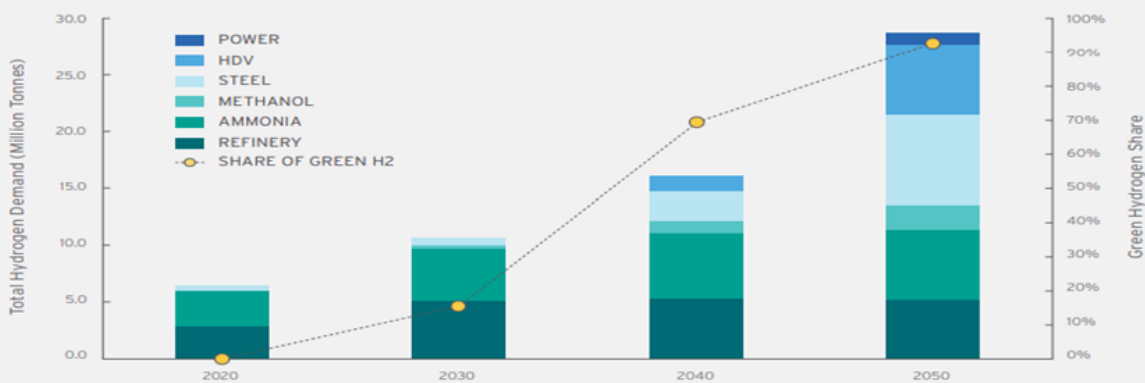
● *Technological challenges: Another challenge associated with green hydrogen PPPs is the technological challenges associated with producing and using green hydrogen. These challenges need to be overcome before green hydrogen can be used on a large scale*

THE ROLE OF INNOVATIVE FINANCING

Innovative financing mechanisms will also play an important role in supporting the development of the green hydrogen market. One example of an innovative financing mechanism is crowdfunding. Crowdfunding platforms like Kickstarter and Indiegogo have been used successfully to finance a wide range of projects, including many in the clean energy space. Crowdfunding can provide critical early-stage funding for green hydrogen projects and help to build public support for these technologies.

Another example of innovative financing is government procurement programs. These programs can help to stimulate demand for new technologies and drive down costs through economies of scale. Several governments, including those in Japan and South Korea, have already launched procurement programs for fuel cell vehicles. These programs are expected to play a key role in supporting the growth of the green hydrogen market in these countries.

FIGURE: HYDROGEN DEMAND OUTLOOK AND POTENTIAL GREEN HYDROGEN SHARE AT COST PARITY



SOURCE: MOS, MOC&F, MOPNG, IEA, TERI, BCG, WORLD BANK, RMI ANALYSIS

GREEN HYDROGEN INITIATIVES IN AFRICA AND THE MIDDLE EAST

MOROCCO

VISION

Morocco has exceptional potential in renewable energy sources, which combined with its expertise will provide momentum to the green hydrogen development. Establishing a national industry based on green hydrogen is also aimed at replacing ammonia imports with local production. The demand potential in large economies and markets like Europe represents an opportunity to export green energy.

NATIONAL STRATEGY

Morocco's Ministry of Energy, Mines and Environment set out a roadmap on green hydrogen in 2021 under the National Hydrogen Commission (created in 2019). The country is expecting a demand up to 30 TWh for hydrogen by 2030 and 307 TWh by 2050, that would require 2GW in renewable energy sources

PROJECT SPOTLIGHT

GREENH2A

"Green Hydrogen & Applications Park" is a research platform that aims to be a national, regional, and continental reference in terms of R&D and Innovation. This platform will deal with subjects relating to the "Power-To-X" sector, in particular hydrogen, ammonia, green methanol, and the various synthetic fuels, as well as themes related to desalination and water treatment.

MOROCCO HYDROGEN CLUSTER

The ambition of the cluster is the organization of the green hydrogen sector and derivatives at the national level, by interacting with regional actors and by connecting all of its parties' stakeholders. The clustering of the different actors will be both physical and virtual and will make it possible to implement its three different dimensions: economic, relational, and territorial.

TOTAL ENERGIES PROJECT

Total Energies is targeting to set up a plant with a green hydrogen production capacity of 10 GW of clean electricity in the Guelmim-Oued Noun of Morocco starting 2027. This implementation is expected to term Morocco as one of the most advanced African countries after Namibia in the development and production of green hydrogen

GREEN HYDROGEN LEADS

- The Moroccan Ministry of Energy, Mines and Environment
- The Research Institute for Solar and New Energies (IRESEN)

FINANCING

In the green hydrogen roadmap, it is estimated that the development of the green hydrogen industry in Morocco would require an investment of 140 billion dirhams (€13 billion) up to 1,000 billion dirhams (€95 billion) between 2020 and 2050 to meet the potential demand by 2050.

Total Energies is investing €9.4 billion in a green hydrogen and green ammonia project to set up facilities in the Guelmim-Oued Noun of Morocco.

GERMAN MOROCCAN ENERGY PARTNERSHIP (PAREMA)

The Moroccan Government within the German Moroccan Energy Partnership (PARMA) signed an active partnership to advance green hydrogen, and is developing a roadmap to 2050 to develop the green industry in Morocco.

In June 2020, the Germany-Morocco Hydrogen Agreement was signed in Berlin for the joint development of the production of green hydrogen for its use in Morocco and Germany.

An investment of €300 million has already been pledged, allowing Germany to source green hydrogen from Morocco in the future

THE RENEWABLE ENERGY POLICY - HERE PHOTOVOLTAIC IN OUARZAZATE - MAKES MOROCCO ONE OF THE BEST EQUIPPED COUNTRIES TO DEVELOP THE PRODUCTION OF GREEN HYDROGEN FOR ITS DOMESTIC MARKET AND EXPORT



SOURCE: IRENA

EGYPT

VISION

Egypt aims to be one of the largest exporters of clean hydrogen in the region, this has become a major goal considering global changes related to the energy sector, as well as global economic and environmental changes in relation to climate change and the green economy.

Egypt's world-class solar and wind resources give it a long-term competitive advantage in producing green hydrogen and green ammonia.

NATIONAL STRATEGY

The national strategy for green hydrogen is currently being prepared in cooperation with the European Bank for Reconstruction and Development (EBRD), and it will be finalized and announced during the COP 27 conference.

A standard memorandum of understanding has been prepared for green hydrogen production and trading projects, and an independent electricity transmission grid is being studied to transfer renewable energy for use in green hydrogen production. The goal is to ensure that the energy sources are clean and green.

PROJECT SPOTLIGHT

THE BORG EL ARAB PROJECT

The project is a joint venture between the Egyptian navy and a number of private companies. The project involves the construction of a hydrogen production plant at the Borg El Arab naval base. The plant will use renewable energy to produce hydrogen. The hydrogen will then be used to power a few naval vessels. The project is still in the early stages of development. However, it is expected to cost US\$1 billion and to be completed by 2023.

THE EGYPTIAN - BELGIAN HYDROGEN PROJECTS

El-Sisi unveiled a new Egyptian-Belgian green hydrogen initiative which he co-sponsored with Belgian Prime Minister Alexander De Croo. The initiative will establish a permanent platform for dialogue between hydrogen-producing and hydrogen-consuming countries as well as the private sector, organizations and financial institutions operating in this field.

THE 4TH GENERATION NUCLEAR POWER PLANT

The plants will use nuclear energy to produce hydrogen. The plants are being developed by a consortium of companies, including the French company Areva and the Egyptian company Elsewedy Electric. The plants are expected to be completed by 2027. The consortium has signed a US\$2.2 billion contract with the Egyptian government to develop the plants. The plants are expected to have a capacity of 1,200 MW each.

GREEN HYDROGEN LEADS

-  The Cabinet
-  Ministry of Electricity and Renewable Energy

FINANCING

It is expected that investments in the field of green hydrogen production in Egypt will reach large numbers, and it is expected that Egypt will contribute a small share in these investments while providing all kinds of governmental and logistical support and setting investment incentives in this field.

CAPACITY AND PRICE

The capacity and prices of hydrogen will be clarified after finishing the National Strategy of Green Hydrogen.

IMPACT TARGETS

- ✓ Consolidating Egypt's position as a regional and global energy center, especially in the production and circulation of green hydrogen.
- ✓ Increasing the rates of renewable energy production for Egypt.
- ✓ Maximizing the utilization of the site of the Suez Canal and the surrounding seaports.
- ✓ Attracting large direct investments in this field.
- ✓ Providing many direct and indirect job opportunities in the various operational sectors to produce hydrogen and its derivatives.
- ✓ Contribute as a source of clean energy to accelerating efforts to protect climate and reduce carbon emissions.

FIGURE: EGYPT'S FIRST GREEN HYDROGEN PLANT



SOURCE: BUSINESSGREEN.COM



The New Suez Canal Project

The New Suez Canal Project is one of the latest hydrogen projects in Egypt. The project involves the construction of a parallel canal to the existing Suez Canal. The new canal will be used to transport hydrogen. The project is being overseen by the New Suez Canal Authority.

The European Bank for Reconstruction and Development (EBRD) is supporting the decarbonisation and Paris alignment of Egypt's economy with a US\$ 80 million loan to Egypt Green to develop the country's first green hydrogen facility.

Egypt Green is owned, built and operated by Fertiglobe, one of the largest seaborne exporters of combined urea and ammonia, Scatec ASA, a Norway-based integrated independent power producer, Orascom Construction, one of the largest engineering and construction groups in the Middle East and North Africa, and the Sovereign Fund of Egypt, a state-owned, privately managed investment fund positioning itself as the partner of choice in Egypt.

The EBRD's financing will be used to acquire and construct a 100 MW electrolyser facility to be powered by renewable energy. When fully developed, the facility will deliver up to 15,000 tonnes of green hydrogen annually. This, in turn, will be used as an input for the production of green ammonia to be sold on the Egyptian and international markets.

This landmark project is a first step towards the decarbonisation of the ammonia sector in Egypt. It will serve as a benchmark for future green hydrogen projects and showcase that hydrogen and ammonia production can be decarbonised in Africa's largest ammonia-producing country, where current production is natural gas based, generating significant carbon emissions.

At full capacity, the facility's green hydrogen production will save more than 130,000 tonnes of CO2 emissions per year

KENYA

VISION

Kenya produces more than 90% of its electricity from hydropower, geothermal, solar, wind, and biomass energy. Given its abundance of elements required to develop green hydrogen, Kenya is well placed to acquire green hydrogen as an alternative energy source. This could enable Kenya to replace fossil fuels completely, generating domestic jobs and economic growth.

NATIONAL STRATEGY

Kenya's hydrogen development program is ongoing. The Ministry of Energy is planning to produce green hydrogen using extra capacity in its grids, especially at night during low electricity demand. Kenya is presently identifying industrial pathways to further pursue green hydrogen use. The Hydrogen Development program, soon to be launched, will have insights on how to use hydrogen, methanol or ammonia to convey energy off-grid, produce green steel;

PROJECT SPOTLIGHT

KEPSA PROJECT

The Kenya Private Sector Alliance (KEPSA) has signed a Memorandum of Understanding (MoU) with green energy company Fortescue Future Industries (FFI) to help facilitate its members participation in large new scale green energy projects in Kenya. Through KEPSA, FFI will engage with private sector players in seeking and taking advantage of supply chain and downstream green industrialization opportunities through green industry advocacy and collaboration with public sector stakeholders to support rapid project mobilization. The Borg El Arab Project

A BASELINE POWER-X-STUDY

A baseline Power-X study indicates by the Ministry of Energy of Kenya in partnership with the German Development Cooperation on the potential for green hydrogen in Kenya highlights that Kenya has potential to produce fertilizers and derivatives in the short to medium terms with pilot projects starting 2025. The Coast region, Rift Valley and wider Nairobi provide suitable location for successful green hydrogen production and markets.

GREEN HYDROGEN LEADS

- Ministry of Energy of the Republic of Kenya
- Cabinet Secretary: Ambassador (Dr.) Monica

IMPACT TARGETS

- ✓ 100% use of clean energy by 2030.
- ✓ 100% access to clean cooking by 2028.
- ✓ Nationally determined contribution of reducing GHG emissions by 32% by 2030.
- ✓ According to the 10-point Corporate Commitment charter to climate change and sustainability in Kenya by representatives from the private sector in Kenya, there is a commitment to reduce greenhouse gas emissions by at least 5% per annum with a base of 2020.



MAURITANIA

VISION

Mauritania has excellent renewable energy prospects making it a potential leading green hydrogen producer in Africa. Significant green hydrogen project developments and Mauritania's proximity to the European market has the potential to increase export benefits, in addition to providing power to the national grid and various industrial activities, such as green steel production.

NATIONAL STRATEGY

The national road map for Mauritania is under preparation by the government.

In May 2022, the Ministry of Petroleum, Energy, and Mines, signed three key projects contributing to Mauritania's leadership in the green hydrogen scene, two for green hydrogen and one focused on green steel, with plans to increase green hydrogen and ammonia production from 2030 onwards.

GREEN HYDROGEN LEADS

 Minister of Petroleum, Energy, and Mines

PROJECT SPOTLIGHT

PROJECT AMAN

The Government of Mauritania and renewable energy developer CWP have signed an MoU for the development of a US\$40 billion project on the construction of the green hydrogen production facility.

The project is situated in an 8,500km² site in the country's northern desert and coastal regions of Dakhlet Nouadhibou and Inchiri. The hybrid generators are made with wind and solar power with a capacity of 30 GW (18 GW wind and 12 GW solar), which will generate 110 TWh of electricity per annum and is expected to produce 1.7 million tons of green hydrogen and 10 million tons of green ammonia.

This output is vast compared to the neighboring country Morocco, almost three times higher than Morocco's annual energy consumption. This project is expected to increase Mauritania's GDP by 50-60% by 2035.

PROJECT NOUR

El-Sisi unveiled a new Egyptian-Belgian green hydrogen initiative which he co-sponsored with Belgian Prime Minister Alexander De Croo. The initiative will establish a permanent platform for dialogue between hydrogen-producing and hydrogen-consuming countries as well as the private sector, organizations and financial institutions operating in this field.

FINANCING

In June 2022, Mauritanian President El Ghazouani signed a declaration with Werner Hoyer, President of the European Investment Bank (EIB), to discuss cooperation with the world's largest international public bank and agreed to strengthen collaboration to scale up wind, solar and green hydrogen investment. Going forward, EIB will support Mauritania's green hydrogen investment plans.

Project Aman with CWP is worth US\$40 billion.

GREEN STEEL WITH ARCELORMITTAL

In May 2022, Mauritania's state backed SNIM (Société Nationale Industrielle et Minière de Mauritanie) signed an MoU with ArcelorMittal establishing a steel unit. The project will involve the production of 2.5 million tons of green steel per year. ArcelorMittal will carry out a pre-feasibility study over the next four to six months.

TUNISIA

VISION

FIGURE: GIZ'S WORKSHOP IN 2022



SOURCE: THEMAGHREBTIMES.COM

Tunisia is one of several countries around the world that has embarked on a green hydrogen strategy in recent years. Green hydrogen, sometimes referred to as "the energy of the future," has the potential to play a major role in the global energy sector. While Tunisia's green hydrogen strategy is mainly focused on exports to Europe, there is a growing movement within the country calling for a "just transition" to green energy that prioritizes the needs of the Tunisian people.

The Tunisian Government has just announced its plans to develop a green hydrogen production facility as part of its goal to achieve carbon neutrality by 2030. The project will be in the southern city of Tozeur and will be the first of its kind in Africa. The facility will use renewable energy sources to produce green hydrogen, which is a clean and environmentally friendly fuel that can be used in a variety of ways, including power generation, transportation, and industry.

Tunisia's green hydrogen project is a significant step forward in the country's transition to a clean energy future. It is also a sign of the growing global interest in green hydrogen as a key part of the world's response to climate change.

PROJECT SPOTLIGHT

THE H2VERT PROJECT

The "Green hydrogen for sustainable growth and a low-carbon economy in Tunisia" (H2Vert.TUN) project was launched on Tuesday with a workshop in Tunis by GIZ. This is the first specific commitment of Tunisia to produce green hydrogen.

The purpose of the project is to improve the regulatory framework for developing a value chain based on renewable energy for green hydrogen and its related products in Tunisia.

The project is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by GIZ in collaboration with the Tunisian Ministry of Industry, Mines and Energy.

Tunisia's main assets for green hydrogen are its zero emissions, clean energy, which is an asset for the decarbonization of industry in Tunisia, and its flexibility, as it can be stored and distributed on demand, which is an asset for the export market.

The most likely medium-term opportunities for Tunisia are in the fertilizer industry as imported ammonia could now be replaced by green ammonia produced locally from renewable electricity.

The project is built on four strategic components, namely to develop the national strategy for green hydrogen, support the creation of a green hydrogen economy, boost research, training and innovation and set up a Tunisian-Bavarian technology hub for green hydrogen.

CONCLUSION



Green hydrogen has immense potential as a clean and environmentally friendly fuel source. While there are challenges associated with its development, these can be overcome with continued research, innovation, and investment. Public-private partnerships will be essential for making green hydrogen a reality.

Despite the challenges, there is reason to be optimistic about the future of green hydrogen. As costs come down and technology improves, it will become increasingly competitive with other forms of energy.

And as awareness grows about the role that green hydrogen can play in combating climate change, there is likely to be continued political support for its development.

About us

Jade Advisory is a consulting firm that focuses on PPP and infrastructure projects with an international scope. The company was founded in 2019 in Tunis and added an office in London in 2020.

It has a strong team of PPP experts, transport economists and infrastructure planning specialists.

Jade has developed a particular expertise in strategy, consulting and PPP services.

The knowledge and quality services we offer contribute to building confidence in capital markets and in the economies of emerging countries.

Jade Advisory provides technical advice for the development of cost-effective, sustainable and innovative solutions, expertly guiding its clients in understanding all the technical constraints of projects throughout their life cycles.

Our references cover a variety of sectors and countries in Africa and the Middle East. Our specialization in PPP allows us to focus on providing high quality reports and advice to the private sector and government agencies.

We stand out with a senior trilingual team in English, French and Arabic.

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