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Policy paper entitled:

Egypt's Exploitation of its Components in Renewable Energy Sources in the National Green Hydrogen Strategy

opportunities and challenges

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Introduction

As all countries are rushing and governments planning to find more effective alternatives to reduce dependence on fossil fuels and reduce global warming, there has been a call to exploit hydrogen in an optimal way so that the production of energy from green hydrogen is free of pollutants and reduces the severity of climate change.

This is because hydrogen is already exploited but not best exploited to be environmentally friendly; energy is produced from hydrogen but not green hydrogen, but blue hydrogen by reshaping methane gas derived from natural gas by steam (steam repair), while **gray hydrogen** is evaporated fossil fuels which ultimately lead to carbon formation.

It is worth mentioning that, hydrogen is present in everything around us and can be exploited in various ways and introduced into all industries for power generation, but depends on the presence of several factors to analyze it in an environmentally friendly way instead of the less environmentally friendly blue and gray hydrogen.

Based on this challenge and the desire of countries to meet their climate obligations in order to preserve the environment, countries and companies have started research and development projects in order to produce green hydrogen and find solutions to overcome obstacles to its production to be more traded in all energy and industry sectors.

In this paper, we will review what green hydrogen is, the factors and methods of its production, explain the most important features resulting from green hydrogen and the generality of its use, and address the most prominent challenges that may hinder its extraction and circulation in all sectors and the possibilities of overcoming these challenges, and finally review the efforts of the Egyptian state and the most prominent international experiences in this area.

What is green hydrogen

The term "green hydrogen" may be unfamiliar to those who hear this term, and simply (green hydrogen) is a type of carbon-free fuel produced using renewable energy such as solar, wind and water. green hydrogen is characterized by its ability to provide clean energy in the industry, transport, transportation and other sectors. It depends in its production on water, as it depends on the separation of water. Through electrolysis, the water separates into hydrogen – oxygen and then hydrogen is

extracted and oxygen volatilizes in space. In this way, the green hydrogen production process is more environmentally friendly and lower in terms of combustion rates, because the two isotopes of green hydrogen depend on fossil fuels, resulting in higher combustion rates.

Hydrogen is the most frequent around us in everything and is versatile; it can be used in the form of gas or liquid, it can be converted into electricity or fuel; in addition to the existence of many ways to produce it. Proof of this is the production of about 70 million tons of hydrogen annually globally and is included in (oil refining - iron and steel industry - fertilizer production - ammonia production - food processing).

What's more, hydrogen is the most available element of any other, with 90% of atom components estimated to be hydrogen. But the dilemma is that hydrogen does not exist individually and separately from the rest of the elements; rather, it must be produced and separated from these elements by fossil fuels, water or plants, and the way it is separated - as we mentioned earlier -

It is who determines its type if it is (green, blue, gray...) Its degree of sustainability is thus determined; green hydrogen is the most

sustainable. [1] Electricity generated by renewable energy such as the sun and wind is the most sustainable and the resulting hydrogen is polluted.

In light of the commitments of countries, especially industrialized countries, to reduce carbon emissions, countries have become increasingly interested in producing green hydrogen.

The importance of green hydrogen

The problem is that emissions from transportation, conventional electricity generation and various manufacturing processes are at the top of the main greenhouse triggers. On the other hand, industrialized countries are struggling to find a single solution to reduce carbon emissions such as the United States of America and the European Union, although the majority of countries can raise energy efficiency by relying on renewable energy sources; but they may fail to supply The heavy industry, aviation sector and others are renewable energy but remain dependent on fossil fuels, and the solution lies in hydrogen; therefore, the term "**hydrogen economy"** has emerged and its aim is to rely on hydrogen as fuel.[2]

As mentioned earlier, hydrogen is abundant around us and can be produced in a number of ways that classify between environmentally sustainable hydrogen

[1]" **Why We Need Green Hydrogen**", Columbia Climate School, Jan 2021, available at: https://bit.ly/3AmLDy2

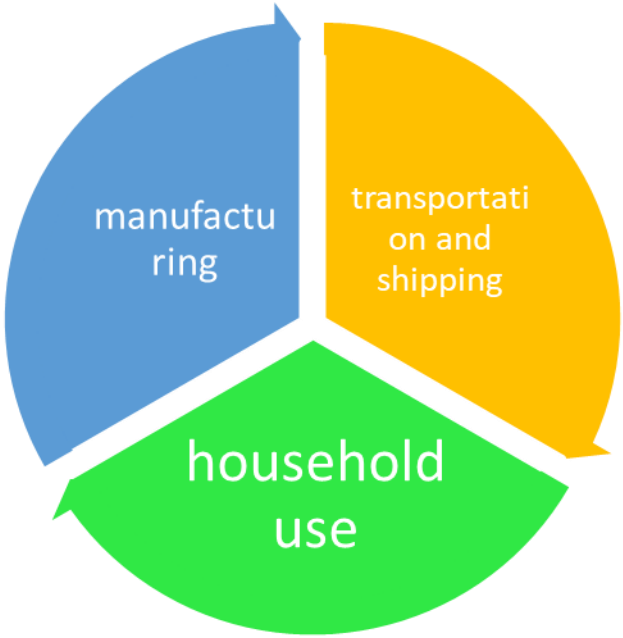
[2] "**economy Hydrogen.. Necessary actions to enhance its role in decarbonization"، The Energy Research Unit, February 2022, is available at: https://bit.ly/3JWOiBL**

and less sustainable and unsustainable hydrogen, because the hydrogen produced by Fossil fuels are unsustainable, blue hydrogen is less

sustainable and green hydrogen is ranked as the most sustainable because its production is through renewable energy sources, and governments

are obliged to shift to a "**hydrogen economy"** system to be the long-term scenario and to reduce carbon emissions as much as possible; however, this involves several challenges.

Advantages of switching to green hydrogen



Green hydrogen is an emissionless energy carrier because it is produced from renewable and clean sources, in addition to the possibility of converting it into electricity or synthetic gas to be used in several uses

such as: industrial sectors and engine operation, and its use in domestic and commercial purposes and the transport sector "ships - public transport and cars".

The distinctive feature of green hydrogen is that it is a power generator with a capacity of 3 times the energy provided by fossil fuels; a little of it may be sufficient and serve the purpose unlike conventional fuels, which are consumed faster and may not perform the desired purpose, green hydrogen is more economical in the **transport sector:** it can be used in the manufacture of fuel cells; to be used for several purposes such as charging electric cars, according to a study I released Columbia Climate School, reported that the hydrogen fuel used to charge electric vehicles a lot more efficient about (2:3) times than the engines of gas-powered cars, and it is also saving in the charging time where the average duration of charging is estimated at about 4 minutes and therefore if green hydrogen is provided and exploited as **fuel in electric cars** and the implementation of this project gradually; it will be an incentive for users as it is more efficient, economical and comfortable, and it is also It has major economic and development returns on countries.[3]

[3] **" Why Green Hydrogen",** Egypt Oil& Gas, available at: https://bit.ly/3QO0gA4

Hydrogen can be used in **maritime transport** such as ships as it is used in the manufacture of liquid ammonia, which container ships use as fuel for them during shipping operations.

In the **industrial sector**: Hydrogen N can be used in steel mills, where it can be used as a source of heat when burned and coal is dispensed with so that factories are operating according to environmental standards. It can reduce the increased burden on electricity by using hydrogen to generate electricity from electric turbines, especially in times of pressure and emergency, to contribute to reducing pressure from the power grid and to ensure its stability.[4]

In **homes**: hydrogen can be used in cooking instead of natural gas, and for heating purposes; it can also be stored in gas pipes to operate household appliances as it can be mixed with gas

Natural ratios of up to 20% using the same gas pipelines and infrastructure, which rationalizes energy consumption.

What increases the enthusiasm of large companies and executives for power generation projects using green hydrogen is that it can be extracted as long as water and electricity are present to generate heat

[4] [4]" **Why We Need Green Hydrogen**", Columbia Climate School, Op.cit

and electricity, and it can also absorb more electrical capacities than conventional batteries, which cannot store large amounts of electricity for long periods of time.

From the foregoing, we find that green hydrogen is the most abundant, versatile, energy-saving, environmentally friendly and sustainable energy carrier, which moved the determination of governments, organizations and research centers to generate green hydrogen from renewable energy sources and introduce its use in different sectors; until they faced several challenges in order to achieve their ideas and plans.

Challenges of Green Hydrogen Generation[5]

In the midst of the quest to localize hydrogenLA in various sectors, several challenges have emerged that have served as an obstacle to progress and achievement in this area, due to several reasons that can be summarized:

First: The flammability of hydrogen like other fuels such as gasoline, propane and natural gas, but on the contrary may outweigh the likelihood of ignition ofother fuels, as hydrogen

[5] **"Hydrogen energy systems: A critical review of technologies, applications, trends and challenges"**, Renewable and Sustainable Energy Reviews, vol 146, Aug.2021, available at: https://doi.org/10.1016/j.rser.2021.111180

It is characterized by being very light, about **57** times lighter than gasoline, which contributes to the navel of its deployment in space, so

the production and use of hydrogen requires very careful and careful care during handling.

Second: The difficulty of transporting and storing hydrogen because it is lighter than gasoline, because it needs a certain degree of cooling in order to liquefy it up to **-253** degrees or is compressed **700** times to complete the process of transporting it as a compressed gas.

Currently, hydrogen is transported via dedicated low-temperature pipelines with liquid trucks.

Third: As we mentioned earlier, hydrogen can be transported and mixed with natural gas, but the fact that it is transported in a limited amount in natural gas pipes; because of the ability of hydrogen to make steel pipes fragile, which causes cracks that may lead to the leakage of hydrogen and hinder its transport between countries, and to compensate for this must modify the infrastructure of natural gas transmission pipes or establish special pipes to transport standards that suit the standards of its transportation safely and without damage completely separate from natural gas pipelines.

Fourth: The high cost of hydrogen fuel cells; because the "platinum" material used in hydrogen division catalysts is expensive to produce profusely, so it is released but restricted, and this appeared a challenge because these cells are scheduled to be used in the operation of electronic devices, electric vehicles, the industrial sector and others, which was a barrier to progress in the localization of green hydrogen in all.

Industries, which have spurred countries to look for solutions and alternatives to manufacture hydrogen fuel cells in less expensive ways and more efficient materials.

Fifth: The scarcity of hydrogen supply stations for electric cars, while mentioning the advantages and pros of green hydrogen, the subject differed on the ground during the application; the United States has built about 46 hydrogen gas stations to charge electric cars, most of them in California, which helped discourage users from using hydrogen-fueled cars.

If they want to charge the car, they have to go thousands of kilometers in order to charge it, in addition to its high cost compared to conventional fuels; a pound of hydrogen is estimated at about $ 8 compared to $ 3 for 3 liters of natural gas.

Sixth: The high cost of producing green hydrogen from renewable energy sources compared to the production of hydrogen from fossil fuels, so the economic competition for it will be minimal compared to hydrogen generated from traditional biosources.

Based on what has already been mentioned, we conclude that green hydrogen, despite its countless benefits and localization in all sectors, will be a radical solution to reduce carbon emissions and global warming, but it faces many challenges that may hinder attempts to localize it, especially in developing countries that may not bear the burden of cost or possess the necessary technologies to produce it, and on the other hand, this does not prevent the production of green hydrogen or exclude it from the strategies of countries for green transformation, but rather It requires more effort and intensified attempts to find solutions to these challenges.

The Future of Green Hydrogen

Despite the high cost of producing hydrogen from renewable energy sources, and the lack of infrastructure necessary for its transport and localization in various sectors, which has provoked a split among energy experts, where a category has emerged that denies the completion of green hydrogen projects, its popularization as a fuel and its introduction

in all industries due to the aforementioned challenges, but other studies have emerged from energy experts that conclude that the future is for hydrogen.

McKinsey conducted a study, the results of which came that the hydrogen economy in the United States will have the lion's share as it will be worth $ 140 billion by 2030, and will boost economic competition, in addition to creating many jobs about 700,000 jobs and raise energy efficiency.[6]

In Europe and Japan, Friedman, the deputy assistant secretary for energy affairs, believes that the demand for green hydrogen will increase over the next ten years, as these countries begin to prepare for the necessary infrastructure such as pipelines and transmission lines dedicated to hydrogen due to its special condition, as the manufacture of hydrogen requires 300% electricity. Friedman reported in his study that sooner or later dependence on green hydrogen will increase. But this may require an abundance of time to equip its infrastructure, transport and manufacturing ports and scientific research that solves

[6] "**Road map to US Hydrogen economy**" , available at: https://bit.ly/3PvGhoP

gaps in application, and we will wait for the training of the human factor in hydrogen techniques and how to extract and localize it in all fields, and change market policies, but Friedman stressed that the future is for the hydrogen economy.

Egyptian State Opportunities in Localizing Green Hydrogen

With its resources, Egypt is a promising country in the production of green hydrogen and dependence on the hydrogen economy in the future, as it has the capabilities and resources to do so. Egypt enjoys **an abundance of renewable energy sources** such as (solar and wind); in addition to Egypt's initiation of projects to generate energy from solar and wind energy translated in Banan Project and Creams Project. Therefore, Egypt has increased opportunities to produce and localize green hydrogen in all fields as long as the main sources of its production are available.

Moreover, Egypt has the **human and mental competence** of promising researchers and competent executives to produce green hydrogen and use it as a fuel source to promote the transition to green vehicles; the main dilemmas and challenges facing the localization of green hydrogen may be facilitated by the support of researchers and owners of pioneering energy project ideas.

Regarding the technical techniques needed to produce green hydrogen, Egypt needs **to use the expertise of some of the leading companies in the field of energy** to avoid opportunities for error and to evaluate the infrastructure to be long-term.

The Egyptian agricultural sector may be one of the greenest when it comes to the use of fertilizers resulting from hydrogen production, which contributes to the development of the **agricultural sector** and the solution of fertilizer and agricultural crop problems.

In **terms of economic returns**, it is expected that the economic return will increase due to the production of green hydrogen and its supply to other countries, which enhances the economic return and increases the sources of national income, and moves Egypt to a greater rank than a regional energy center and even makes it a major and basic source of energy for all countries of the world, as Egypt has all the elements required for this such as **(its privileged geographical location) which overlooks the Red Sea and the Mediterranean – it has the shipping lanes of the Suez Canal – it has large shares of natural gas and so on**). It will also contribute to preserving the Egyptian economy, mitigating the effects of rising oil prices globally, and protecting natural gas from depletion.

Enhancing Egypt's political and strategic position, it is worth mentioning Egypt's accession to the Eastern Mediterranean Gas Forum, which includes the main natural gas centers; this is because Egypt has an abundance of natural gas, and Egypt's being a key component of the Mediterranean Gas Forum makes it an influential international actor in policies between countries, and therefore if Egypt develops the production of green hydrogen in light of the trend of all countries of the world to green energy and desire To reduce thermal emission rates, it will elevate it to a higher position as a major hub and producer of energy from renewable sources. It may be a leader in the region in leading a renewable energy forum, especially in light of the lack of the necessary ingredients for diversification of energy sources by many countries.

In parallel with the above, the localization of the hydrogen economy in Egypt will contribute to the creation of green jobs, eliminating the problem of unemployment and **increasing wage rates**, which raises the standard of living, will contribute to **enhancing awareness** of the dangers of global warming and establishing a new culture that respects the environment and makes citizens and institutions more keen to protect the environment and rely on green energy sources.

The localization of the green economy will make Egypt a place to **attract foreign investment**, as Egypt is close to markets such as the European Union and the Middle East**,** which increases national income rates.

Therefore, progress must be made in forging partnerships to establish green hydrogen infrastructure and to leverage research and scientific contributions in this field to achieve leadership in renewable energy

Egyptian Efforts to Localize Green Hydrogen

In light of Egypt's genuine interest inreducing thermal emission rates in compliance with the Paris Climate Agreement, the Egyptian government is making strenuous efforts to diversify energy sources and increase dependence on renewable energy sources such as solar, wind, hydroelectric and green hydrogen, and we specifically review the efforts of the Egyptian state in the green hydrogen sector.

- **The French state-owned utilities company EDF** and **ZERO WASTE** announced the signing of a memorandum of understanding with

  the Suez Canal Economic Zone, to produce 350,000 tons of green ammonia and green hydrogen annually in the Ain Sokhna region, and is scheduled to start operation in the first quarter of 2026.
- **Maersk, Suez Canal General Authority and the Egyptian Electricity Transmission Company: The three parties signed in the** presence

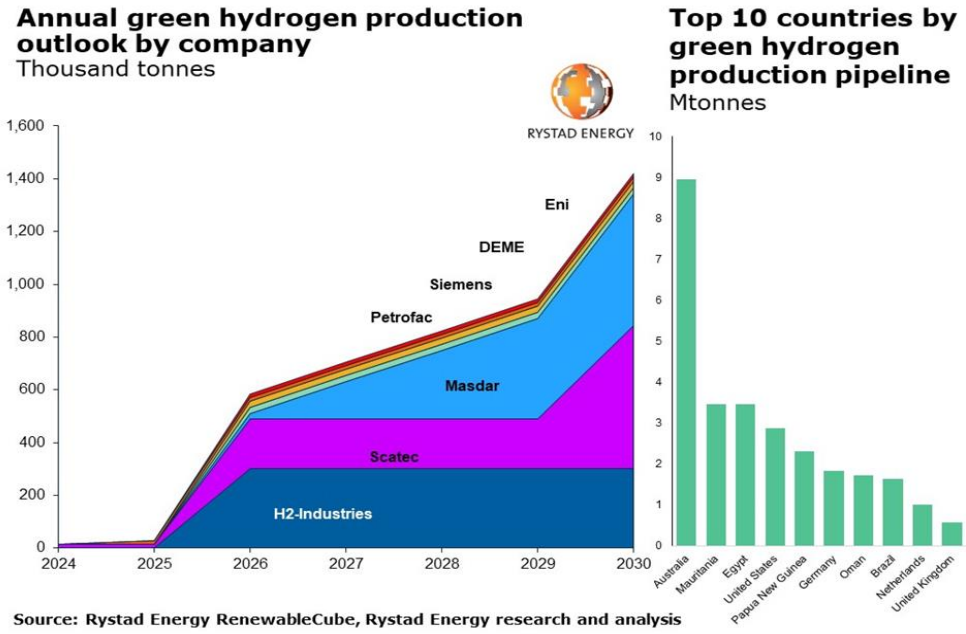
of Prime Minister (Mostafa Madbouly) a memorandum of understanding for the production of green hydrogen for bunkering ships, and the agreement was signed on Hassan Allam Utilities and Masdar to

implement the project in several stages to be completed in 2030, and it is expected that the electrical analyzers necessary to produce hydrogen with a capacity of 4 gigawatts will be installed,and this project will bring 480 thousand tons of green hydrogen. The first phase of the project is also set to lead to the production of 10,000 tons of green methanol per year by 2026, to meet the needs of cargo ships in the Suez Canal and Egyptian seaports on the Mediterranean.

- **UAE: In** April 2022, Emea Power signed a Memorandum of Understanding (MoU) to establish a hydrogen and green ammonia manufacturing facility with a production capacity of 235,000 tons of ammonia per year, in the Suez Canal Economic Zone, expandable up to 390

A thousand tons per year, and the facility is fed with green hydrogen produced from desalinated seawater and renewable energy generated on sites, so that the transmission is carried out

on the national electricity grid until commercial operation begins by the end of 2025.[7]



- **Egypt ranks among the three largest green hydrogen pipelines** with Australia and Mauritania; where Egypt's pipeline for green hydrogen projects is about 11.62gigawatts (about 1.57 million tons), and Egypt **has set an estimated budget for green hydrogen projects without infrastructure and their cost is $ 20 billion**, and following the projects announced by the state in this regard, investors rushed to finance these projects due to Egypt's qualified components. To establish projects in the green hydrogen sector.[8]

[7] **Emia UAE's Power Produces Green Ammonia in Suez Canal،** Al Ain News, April 21, 2022, available on https://bit.ly/3A4GCJm:

[8]**COP27 Host Egypt Commits $40bn to Green Hydrogen Economy to Attract Foreign Investment",** Hydrogen central, May2022, available at: https://bit.ly/3ArsGKB

- The Egyptian government plans to launch and implement the 80% green hydrogen projects in partnership with **SCZONE**, a global logistics

  hub that aims to connect Europe, Africa and Asia via the Arabian Gulf, and to eliminate 20% of international container trade and 10% of seaborne trade. . The Centre's Sokhna Aviation area is close to a seawater desalination plant (150,000 m3/day), a wastewater treatment plant (35,000 m3/day), and bunkering facilities such as ammonia (80,000 tons), making it very suitable for the trade of hydrogen and its derivatives. The production capacity of these projects is about one and a half million tons.[9]

- President Sisi's directives to prepare an integrated national strategy for the production of green hydrogen
- Forming a ministerial committee to look for various possible alternatives to the generation of green hydrogen and the use of international experiences.[10]
- Egypt has begun to strengthen cooperation with international financial institutions and partners; there is cooperation with the

[9] **COP27 Host Egypt Commits $40bn to Green Hydrogen Economy to Attract Foreign Investment, ibid**
[10] **Sisi directs the preparation of an integrated national strategy for hydrogen production، Russia Today, available at: https://bit.ly/3A28jm6**

European Commission to update the Egyptian sustainable energy strategy to include hydrogen in order to support economic development.

Through the Egyptian efforts exerted in the green hydrogen sector, we conclude the Egyptian leadership's urgent desire to achieve leadership in the field of renewable energy, especially Relying on green hydrogen, this is evidence of Egypt's sense of responsibility to diversify energy sources and green transition to mitigate climate variability and reduce carbon emissions in compliance with the Paris Climate Agreement and on the verge of Egypt hosting the COP27 climate summit in Sharm el-Sheikh.

The most prominent international experiences in green hydrogen localization projects

United States[11]

Washington began to develop a plan for the transition to green hydrogen in 2002 but soon discovered the high cost of switching to hydrogen as it requires huge investments in the field of storage and transportation, but

[11] **"Green Economy: Promising Investment Opportunities", Egyptian Center For Thought and Strategic Studies**

Washington believed that the environmental, security and economic benefits and returns of green hydrogen outweigh its challenges, so it decided to agree on a strategy for the transformation of the United

States to the hydrogen economy by 2030, and Washington has engaged experts and academia to draw up this strategy. It wanted to reshape the system and proposed alternatives to processing, storing and energy-converting hydrogen.

Washington has paid close attention to amending some legislative policies to make the strategy realistic and under implementation, as well as to education and awareness of the green economy, specifically green hydrogen and its areas of use and application.

Washington has also committed to providing support for research activities to explore different ways to use hydrogen-derived energy.

In the second phase of the strategy, "integration" was approved, where the parts of the system integrate with each other to work together in parallel and not contradict each other's efforts so as to facilitate technical obstacles in order to coordinate between producers and consumers.

The third phase of this strategy states the importance of building a national vision for the use and production of green hydrogen between individuals and society through a clear long-term plan.

Europe[12]

Europe has designed a plan to rely on green hydrogen and fuel cells, and the plan is based on two main elements: the production and distribution of hydrogen and the development of fuel cells, and according to the time frame drawn by the plan that by 2050 direct production will begin; to produce hydrogen from renewable energy sources.

The plan provided incentives for the private sector to finance research and development programmes to expand hydrogen production and transport. The plan also mentioned the expected benefits to the private sector following reliance on green hydrogen from the production and distribution of commercial hydrogen and transport and storage operations.

Mauritania[13]

In September 2021, the Mauritanian Ministry of Petroleum, Mines and Energy signed a memorandum of understanding with the British company Chariot, which specializes in transitional energy, in order to implement one of the most important hydrogen projects in Africa.

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[12] **Previous Reference**

[13] **Mauritania signs agreement to implement Africa's largest green hydrogen production project-Power, available at: https://bit.ly/3Arfdm3**

The production capacity of the new project "Noor" green hydrogen is about 10 GCUT of clean energy sources, with investments of about 3.5 billion US dollars.

The area allocated to **the Noor project** extends over a land and marine area of about 8600 square kilometers, where pre-feasibility studies will be conducted with the aim of determining the option of generating electricity from solar and wind energy sources for use in electrolysis to divide water boldness and produce hydrogen, oxygen and potable water.

The Noor project is the second green hydrogen production project in Mauritania after the joint venture with **CWB Global**, on which a memorandum of understanding was signed at the end of May 2021.

Mauritania's possession of vast renewable energy resources helps it play a prominent role in the production and development of clean energy and green hydrogen, as in 2020 it launched an ambitious national vision for the transformation of the energy sector based on the optimal utilization of the country's enormous potential of gas and renewable energies in the medium and long term.

Recommendations

In order to move towards the work of the Egyptian government an integrated strategy forgreen hydrogene and after presenting the most prominent international experiences, we recommend the following:

- In drawing up the green hydrogen strategy, it is necessary to take into account the involvement and stimulation of the private sector in the policies of transformation to green hydrogen in order to invest in it in the field of factory operation.
- The Egyptian government should build and provide several charging stations for green hydrogen only and distribute them in different areas, to encourage green vehicles and encourage consumers to turn to green hydrogen fuel.
- The Egyptian government should review and benefit from prominent international experiences to avoid losing sight of any element that might hinder thestrategy.
- A huge budget should be allocated for the development of scientific research and national research centers to encourage researchers to find alternative policies and solutions to all the challenges of green hydrogen.
- It is essential to strengthen international partnerships and take advantage of Egypt's attractive renewable energy assets to ensure access to financing andto ensure the utilization of foreign expertise.

- The government should plan to form an economic forum on renewable energy, including green hydrogen, to strengthen Egypt's economic, geostrategic and security position.
- Civil society institutions should be involved in the role of raising awareness about what green hydrogen is and how tomeet its production and benefits so that it is not frowned upon by citizens, and they are mobilized in relation to the strategy and not against it.
- The Egyptian strategy on green hydrogen should be promoted in an orderly manner to attract all possible investments to finance green hydrogen projects, and to crystallize Egypt's leading role in the commitment to reduce global warming rates and achieve sustainable development.

Conclusion

The expectedconsequences in the event of neglect of the environmental process and disregard for it are serious for individuals, institutions and countries without distinction, so it is the responsibility of each country to search for innovative solutions and ideas commensurate with its available capabilities and resources for green transformation in all sectors.

Despite the ambitious strategies of countries in the field of green hydrogen, many of them do not have the ingredients to produce it unlike Egypt, which has a surplus of renewable energy sources to produce green hydrogen; so it is necessary to exploit this and excel in achieving achievements in this sector; where according to the acceleration of countries globally to own green hydrogen technologies, it is expected that the value of these products will reachabout $ 600 million by 2050 to be used in various sectors such as (energy, transport, industry, and household items and construction work).