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Localization of hydrogen production and transport technology in Algeria investment opportunities and challenges

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Abstract---This research study examines the significance of localizing hydrogen production and transportation technologies in Algeria to achieve carbon neutrality and global climate objectives, particularly in light of Algeria's substantial solar and wind energy resources for electricity generation and clean hydrogen production. Algeria has a strategic position connecting Africa and Europe, complemented by a network of gas pipelines crossing state boundaries, which are essential for hydrogen supply and international trade. However, challenges remain in localization owing to the absence of a clear vision for a developed market for hydrogen and its compounds. Despite this, Algeria has established a national policy for hydrogen development. The study concluded that it is imperative to improve long-term foreign investment strategies, seek new alliances and partnerships to increase market liquidity and enable the transfer of technological knowledge and expertise, integrate hydrogen into investment projects in all sectors, and preparing society for the transition to clean energy.

Keywords---localization of hydrogen production technology, carbon neutrality, hydrogen market, international trade in hydrogen, foreign investment in hydrogen in Algeria.

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Introduction

Currently, global perspectives are evolving to attain climate objectives through effective clean energy solutions, targeting carbon neutrality by 2050. Algeria is rapidly progressing with essential strategies for sustainable energy development, emphasizing the localization of hydrogen generation from renewable electricity sources, bolstered by its extensive solar, wind, and hydropower resources. Hydrogen represents a promising investment and international commerce opportunity, as it underpins numerous businesses and can be commodified for export. Algeria has enhanced international collaboration and formalized significant agreements for foreign direct investment projects aimed at exporting hydrogen to Germany and Europe, leveraging its strategic geographical position in North Africa along the Mediterranean coast, in proximity to Europe, and its robust infrastructure of dependable cross-border gas pipeline networks for hydrogen transportation.

The Russian-Ukrainian war has influenced European ties, compelling Europe to pursue alternatives to Russian gas and transition to other energy sources. Nonetheless, obstacles persist in realizing the goals of the national hydrogen plan, associated with the advancement of the hydrogen market and its derivatives, as well as the potential for substantial investment costs in new projects necessitating costly technologies such as electrolysis facilities, solar and wind energy, and knowledge transfer. The government should enhance development investments in further pilot projects while overseeing the hydrogen market's evolution and formulating strategies and rules to manage risks and decrease prices.

The government must prioritize the development of carbon-neutral energy systems to meet national demand. This can be achieved by coordinating supply and demand, enhancing public awareness of the energy transition's significance, cultivating a skilled workforce in hydrogen production and supply chain management, and fostering both public and private initiatives to establish local hydrogen industries and facilitating the adoption of hydrogen in both remote and urban populations by developing heating and cooling systems, as well as utilizing hydrogen fuel in multimodal transportation and rail sectors. Considering these dynamics, a comprehensive transition to zero-emission energy should be approached progressively over a long period. It is necessary to meticulously observe energy advancements within a stable regulatory policy framework, analyze the market, issue licenses, and foster an atmosphere favorable to the successful execution of projects in Algeria. Continue to seek new economic partnerships and enhance regional collaboration to augment market liquidity, particularly given that its infrastructure serves as a valuable asset for the energy system and possesses the capability to produce hydrogen.

Hydrogen is an essential energy resource that mitigates carbon emissions, making it a focal point of global interest and a pivotal element for energy security and a sustainable economy. Algeria can enhance economic collaboration in this sector, as it possesses the potential to emerge as a prominent producer and supplier of hydrogen, particularly given its competitive pricing relative to other nations and its status as a politically stable territory.

Consequently, we may articulate the principal research question as follows:
What is the efficacy of foreign direct investment in the localization of hydrogen production and transportation technology and in mitigating associated challenges?
Sub-question: Can hydrogen fulfill climatic objectives and enhance industrial and economic development?
Does hydrogen manufacturing facilitate international trade?
Does Algeria have incentives to increase its foreign investment in the hydrogen sector and facilitate localization?

Research hypotheses:

This issue statement generates multiple hypotheses, including: - Hydrogen may serve as a vital resource in essential industrial and refining processes, as well as a clean, carbon-neutral fuel that aligns with global climate objectives.

- Hydrogen resources influence global commerce, as production expenses in certain areas are lower than in others, thereby fostering the growth of the hydrogen market and establishing supply and demand dynamics. Algeria possesses significant renewable energy potential, facilitating local investment and private sector engagement, alongside foreign investment, due to its strategic proximity to Europe, extensive transcontinental gas pipeline infrastructure, and competitive cost advantages relative to other nations. These elements will position Algeria as a significant and influential player in Africa and globally.

Research objectives:

The aspects of hydrogen and its significance in attaining sustainable economic development and carbon neutrality.

The importance of hydrogen in global trade and global supply chains is significant.

Algeria can attract foreign investment and develop domestic hydrogen production technologies.

The significance of this study lies in its emphasis on hydrogen's role in attaining global climate objectives, particularly in light of prevailing environmental concerns. Hydrogen is considered an efficient means of mitigating carbon emissions. The localization of hydrogen production and transport technology will foster local investments, attract foreign investments, promote clean industries across various sectors, diversify the economy, enhance international trade, and strengthen supply chains. Consequently, it is imperative to facilitate and utilize all opportunities for the localization of hydrogen production and transportation technology in Algeria, implementing it in industrial and transportation sectors, while enhancing and broadening partnerships and trade for exportation, thereby fulfilling economic objectives.

Study approach:

This study employs a descriptive and analytical methodology, concentrating on the theoretical dimension in the initial axis and the analytical approach thereafter.

The second and third axes are addressed through the collection and analysis of statistics.

Primary axis: Categories and applications of hydrogen

Initially: Conceptual Overview of Hydrogen

The generation of carbon-free hydrogen depends on renewable energy sources such as solar and wind, enhancing energy security, promoting sustainability, and mitigating climate change. In this framework, we must examine the notion of renewable energy and associated notions.

Definition of renewable energy:

It pertains to natural resources, encompassing solar energy, wind turbines, biomass, geothermal heat, and the molecular interactions of water that generate hydrogen and oxygen, subsequently yielding energy. These substantial energies can be harnessed and transformed to provide clean electricity and carbon-neutral fuel, thereby safeguarding environmental health.

Definition of alternative energy:

Alternative energy encompasses renewable energy and nuclear energy utilized to generate alternative fuels from non-fossil sources. Kiwan, 2013

Definition of hydrogen: Hydrogen exists in various forms throughout the universe. It exists in stars as a fuel that supplies energy via fusion. Hydrogen exists in space and on Earth's surface within water, as each water molecule has two hydrogen atoms and one oxygen atom. In metals and rocks, it is present at a concentration of approximately 1,500 parts per million. Hydrogen is the most prevalent element in the universe and ranks as the tenth most abundant element in the Earth's crust. (Hydrogen, 2019)

Hydrogen is recognized as an energy carrier, and, devoid of carbon dioxide, it serves as a clean and sustainable energy source. It is versatile in application and may be stored and transported over extensive distances and in substantial volumes using compression or liquefaction. It generates clean fuel and adheres to safety criteria equivalent to those for natural gas and oil.

Second: Hydrogen production methodologies

Hydrogen is derived from natural sources such as water, solar energy, and natural gas. Green hydrogen is generated through the electrolysis of water in an electrolytic cell, utilizing power obtained from renewable sources like solar or wind energy. Furthermore, water desalinated using solar and wind energy is utilized at a rate of 100%. This technique generates no carbon emissions.

- ✓ Gray hydrogen is produced from natural gas by reforming methane with steam.
- ✓ Blue hydrogen is produced through the same steam reforming procedures as gray hydrogen; however, carbon emissions are caught and sequestered to mitigate atmospheric pollution.
- ✓ Yellow hydrogen: Generated by nuclear energy derived from nuclear fission to decompose water, which includes hydrogen, and does not release any pollutants.
- ✓ Turquoise hydrogen: Generated from biomass or coal via thermal decomposition by heating natural gas, resulting in hydrogen gas and a solid byproduct that does not release air pollutants.
- ✓ Hydrogen fuel cells are electrochemical systems that transform chemical energy into electrical energy, akin to batteries and engines. In contrast, they do not necessitate recharging and do not release carbon; instead, they generate energy and pure water via the reaction of oxygen with hydrogen to make electricity. They are ecologically sustainable and can be utilized in the future to create clean energy and attain sustainability. (Mustafa & Al-Husseini Al-Taher, 2020)

Applications of hydrogen fuel cells

Hydrogen fuel cells have applications in various domains, including: (Matoog, 2023):

- ➢ **First: Transportation is a primary impetus**

for the advancement of hydrogen fuel cells. In automobiles, hydrogen fuel cells are utilized as proton exchange membrane fuel cells, which lack moving parts and therefore do not cause noise or harmful carbon emissions, thus protecting the environment.

Hydrogen fuel cells can be utilized for heating and cooling in industrial facilities, permanent installations, and modest residences.

Portable electronic gadgets, such as phones and laptops, have become essential to our daily lives and professional activities, necessitating energy for continued functionality. Fuel cells can recharge lithium batteries in seconds rather than minutes and provide an extended duration of use.

- ➢ **Second: Hydrogen storage methodologies**

Following the production of hydrogen, various technologies exist for its storage, the most notable of which are those mentioned by S. Davis (2009).

Gaseous storage: Hydrogen is kept in high-pressure tanks at pressures ranging from 5.34 to 69 atmospheres, which is the most effective approach.

Hydrogen is held in substantial volumes after being cooled to form a chilled liquid.

Absorption: This process involves solid or liquid objects assimilating hydrogen.

- ➢ **Third: Hydrogen transport methodologies**

Transporting hydrogen necessitates a sophisticated infrastructure to guarantee safety and efficient delivery. Various modes of transportation exist:

Hydrogen is conveyed by specialized pipelines analogous to gas transportation methods.

It is made of either plastic or metal. This necessitates substantial development expenses; however, a more economical approach utilizes the existing gas infrastructure for transportation. Affordable Hydrogen Transportation, 2025

Conveyancers: Hydrogen may be conveyed in cryogenic containers across extensive distances.

Hydrogen can be conveyed via maritime and rail transit in secured tanks.
In fuel cells, power is produced directly from hydrogen without requiring transportation.

The secondary axis: International hydrogen commerce and the factors driving its change in Algeria

- **Initially, the significance of hydrogen in enhancing international trade and attracting foreign direct investment**

The production, storage, and transportation of hydrogen will be pivotal in enhancing international trade and attracting foreign direct investment, as it will facilitate chances for global cooperation in advancing the energy system and fostering economic growth. Throughout the phases of hydrogen production, storage, and transportation, these processes will serve various purposes to achieve the goals of international trade, foreign direct investment, and economic growth.

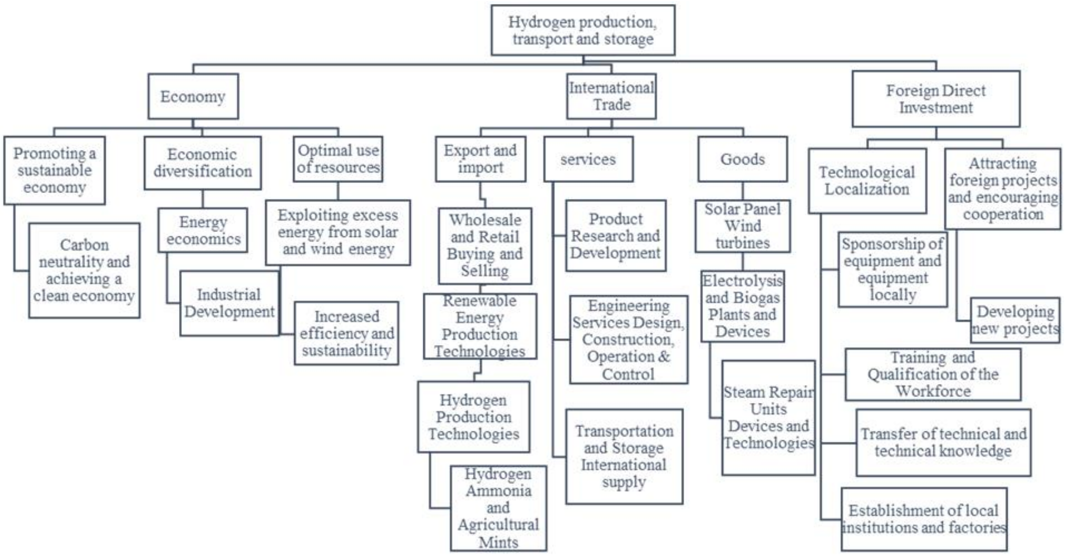

Figure 01: The significance of hydrogen in fulfilling the objectives of international trade, foreign direct investment, and economic development
Prepared by researchers

The image above depicts the transition of hydrogen from fossil fuel markets to zero-carbon markets, facilitating worldwide trade segmented by locations with abundant renewable energy resources for more efficient and cost-effective hydrogen production. The geographic locations and infrastructure will influence variations in hydrogen costs, considering the distance between exporting and importing regions, the hydrogen supply infrastructure connecting them, and the corridors that facilitate additional trade in each region traversed by hydrogen pipelines.

The production of hydrogen, particularly in developing nations that generate it at competitive prices, facilitates the establishment of significant energy-intensive businesses and enhances commodity flows via technological transfer collaborations, thus augmenting local manufacturing capabilities. In 2021, the United Nations Industrial Development Organization (UNIDO) initiated a global campaign for hydrogen in industry, promoting its adoption (IRENA, 2023). The Aid for Trade initiative enhances market access facilitation.

Hydrogen will facilitate the attraction of foreign direct investment and the manufacturing of industrial products, thereby enhancing exports.

Opportunities will emerge in engineering, building, operation, and ancillary services associated with marketing, transportation, distribution, and international supply logistics along hydrogen production lines.

- **Second: Justifications for transitioning to hydrogen energy in Algeria**

-Ecological considerations: Fossil fuels induce ecological imbalance, adversely impacting the Earth, natural ecosystems, and human populations. This disruption deteriorates climate conditions and agricultural output, resulting in diminished crop quality, malnutrition, and health issues for individuals, which subsequently decreases productivity and contributes to deforestation, desertification, and drought. (Fawaz, M. & Suleiman, 2019)

Climate disturbances resulting from elevated temperatures and recurrent, intense heat waves jeopardize essential infrastructure, as high temperatures diminish the efficiency of gas-fired power plants and electrical grids due to increased electricity demand from cooling systems. Elevated temperatures have resulted in an average of 3,000 forest fires a year from 2010 to 2019, devastating agricultural land and woodlands. In southern Algeria, floods are anticipated in the Sahara, impacting infrastructure and refinery operations. Algeria designates 70% of its budget to address catastrophic calamities, averaging 255 US$ annually. These significant losses need a shift to clean energy and the advocacy of hydrogen as a substitute for fossil fuels, which effectively supports carbon neutrality initiatives and climate change mitigation efforts. National Climate Resilience Assessment for Algeria, 2025

-**Financial factors:** This encompasses taxes and expenditures aimed at mitigating the consequences of environmental degradation, including diminished production and water and air pollution, alongside the financial implications of employing costly technologies for remediation, which impose fiscal burdens on companies through taxation when they surpass allowable gas emission thresholds. (Fawaz, M. & Soliman, 2019)

- Diversification of the economy towards the energy sector and enhancement of exports.
- Attracting international investment and enhancing methods for the advancement of hydrogen energy technologies.
- Enhancing remote and rural regions and alleviating their isolation through the utilization of clean fuels, advancement of the transportation sector, and operation of additional sectors.

There is a worldwide economic shift towards carbon neutrality.

Blue hydrogen synthesis uses carbon sequestration to reduce greenhouse gas emissions and conserve energy.

Hydrogen is seen as a clean energy source that addresses the present and future requirements of humanity while safeguarding the environment, mitigating climate change and alterations to life on Earth, and ensuring energy security.

The shift from fossil fuels to hydrogen energy decreases operational expenses, especially those associated with adhering to environmental laws and regulations that levy penalties for carbon emissions.

Accessible renewable energy sources, such as solar and wind power, have the potential to generate hydrogen.

- **Third: Expenses associated with hydrogen production and transportation**

Various factors, including production, transportation, storage, and distribution, influence the price of hydrogen in global commerce.

Costs associated with hydrogen production: Exploratory study on the possibility of Power-to-X (green hydrogen) in Algeria, 2021

A 100 MW power plant necessitates between 1,800 and 20,000 Nm^3/h of hydrogen, requiring an area of 5,000 square meters, and additional power plants are essential.

To transport and distribute hydrogen, it is compressed with techniques and equipment that cost approximately 4,000 US$ per kilogram of hydrogen, which is comparatively affordable relative to other expenses.

Hydrogen storage relies on pressure during its conversion to gas and necessitates many pipes. The expense is contingent upon the hydrogen pressure capacity. A standard truck with a capacity of 30 bars is priced at US$1,800 per kilogram of hydrogen. Increased vehicle length and storage capacity correlate with elevated expenses.

Upon conversion to liquid form, hydrogen's volume diminishes by around 800-fold, necessitating a liquefaction procedure for storage.

Hydrogen can be conveyed through gas pipelines with little alteration, including the elimination of residual nitrogen, closure of fissures, and adjustment of valves. Occasionally, stations necessitate more comprehensive alterations.

Third Axis: Investment Prospects in Hydrogen in Algeria

Algeria is a pivotal nation in North Africa, adjacent to the Mediterranean Sea and linked to Europe. It possesses an expansive and profound desert, abundant in remarkable natural resources and strategically advantageous geographical positioning. The region encompasses a vast expanse in North Africa, characterized by extensive sunlight exposure totaling 3,400 hours annually, with each square meter receiving 1,860 kilowatt-hours in the north and 2,410 kilowatt-hours in the south. Algeria possesses a comprehensive gas and electricity infrastructure, together with substantial expertise in petrochemicals and gray hydrogen generation, positioning it to emerge as a leading producer and exporter of hydrogen, as well as a frontrunner in energy transition and carbon neutrality. Algeria is formulating initiatives for hydrogen investment using renewable energy sources.

Table 01: Renewable energy in Algeria between 2014 and 2023

Years	Hydroelectric energy	Wind energy	Solar	Solar photovoltaic energy	Concentrated solar power
2014	228	10	2	3	25
2015	228	10	61	36	25
2016	228	10	261	236	25
2017	228	10	354	329	25
2018	228	10	366	341	25
2019	228	10	366	341	25
2020	209	10	366	341	25
2021	129	10	366	341	25
2022	129	10	451	426	25
2023	129	10	451	426	25

Prepared by researchers based on the source (RENEWABLE CAPACITY STATISTICS 2024, 2024)

The table above shows the development of total renewable energy in Algeria from 2014 to 2023. It highlights Algeria's enormous potential in hydropower, wind power, solar photovoltaic power, and solar thermal power, all of which are important sources for hydrogen production, particularly solar photovoltaic power, which has seen rapid growth from 3 megawatts in 2014 to 426 megawatts in 2023, while concentrated solar power remained at 25 megawatts and wind power remained at 10 megawatts. The development of this energy has been delayed, while all these figures point to solar photovoltaic energy as the most important element in the energy transition in recent years, as it can be relied upon for electricity generation and hydrogen production.

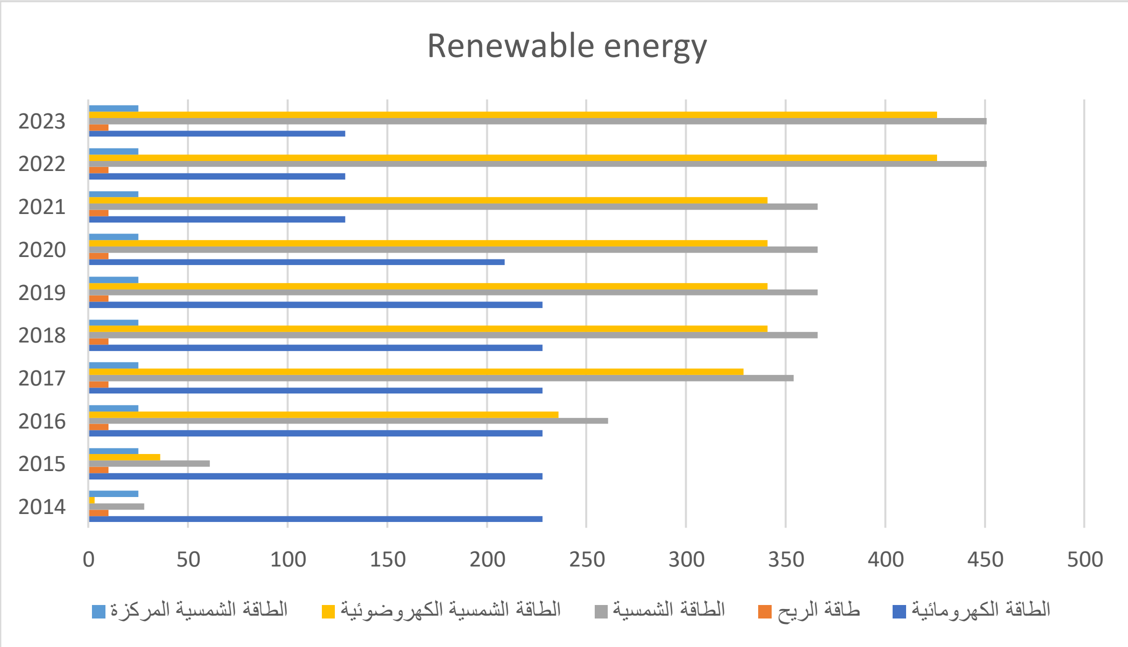

Figure 02: Renewable energies in Algeria in the period (2014-2023)
Prepared by researchers based on the table above

(H2H2 energy.gov.dz, 2023) Algeria has strong and expanding electricity networks, including:

- ✓ The isolated networks in the Great South (RIGS);
- ✓ Adrar-Ain Salah-Timimoun Pole Network (PIAT);
- ✓ The northern interconnected network (RIN);
- ✓ The northern interconnected network encompasses the majority of the nation and extends into adjacent nations. The length is 33,533 km, with 387 transmission stations with a conversion capacity of 367,576 km;
- ✓ Transnational gas pipelines extending to Europe;
- ✓ The hydrocarbon transmission network encompasses 22 STC pipeline lines, which span a distance of over 22,705 kilometers;
- ✓ The national market has a gas transmission network that spans 23,193 kilometers.

Hydrogen generation by steam methane reforming, utilizing solar thermal energy and natural gas, approximates 1.6 million tons annually. Establishing this technology in the southern region of the country is a promising alternative due to the accessibility of natural gas and solar thermal energy. Reformed methane derived from natural gas constitutes 48% of hydrogen synthesis from diverse sources. (Mohamed, Said, and Ahmed Chikouche, 2011)

There are significant groundwater reserves next to the depth of the reservoirs.

- ✓ -Near northern Algeria, there are over 40 hot springs with temperatures surpassing 41°C, some reaching 63°C, while the Hammam Maschoutine spring near Guelma exceeds 96°C, and in the southeast region of Biskra, temps exceed 118°C. (Al-Aziz, 2018-2019).
- ✓ In the desert, there are profound subterranean regions stretching to Tunisia and Libya, specifically:
- ✓ The Albienne continental aquifer is a groundwater layer situated at a depth of 1,000 meters, exhibiting a flow rate of 250 liters per second, with water temperatures surpassing 60°C and salinity levels ranging from 6 to 7 g/L. It encircles the Great Eastern Fault and constitutes the

largest freshwater reserve globally, spanning Algeria, Tunisia, and Libya, with 70% of its volume located in southeastern Algeria.

- ❖ **The Continental Complexe Terminal aquifer:**

It encompasses the lowest desert depressions and is nourished by desert plains originating from the mountain rocks.

Seawater desalination initiatives: 2.1 million cubic meters per day.

Water treatment facilities, sanitation plants, and a national park Over 200 treatment facilities process over 480 million cubic meters of raw water annually.

Algeria possesses extensive expertise and proficiency in the natural gas sector, including liquefaction, transportation, and gray hydrogen production.

- ❖ **Algeria's policy for hydrogen development:**

Algeria has formulated a strategy plan for hydrogen development, transitioning from gray hydrogen to blue hydrogen and subsequently to green hydrogen, structured into three phases: Algerian National Hydrogen Development Strategy, 2023

- ✓ **Phase I**, **Horizon 2030:** Implementation of pilot projects ranging from 2 to 10 megawatts in collaboration with the private sector to mitigate risks and oversee hydrogen production technology and infrastructure advancement.

Proposed initiatives: Pilot natural gas/hydrogen pipeline loop project, separation unit, and salt cavern storage in Hassi Rmel.

Solar energy storage initiative for remote locations for Sonatrach

Production of green ammonia or methanol (Arzew, Annaba, Souk Ahras)

- ✓ **Phase II**, **2030-2040:** Execution of projects on an industrial scale, encompassing the complete green hydrogen value chain and generating demand.
- ✓ **Phase III**: **2040-2050:** Augmenting the hydrogen production infrastructure while prioritizing exports and enhancing competitiveness.

The national plan delineates a definitive roadmap for attaining the specified objectives, as seen in the subsequent figure:

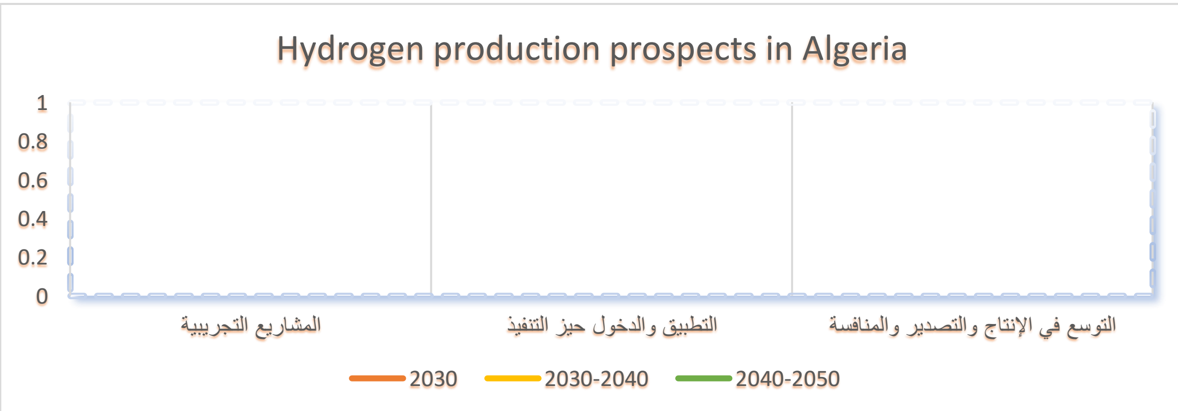

Figure 3: National Strategy for Hydrogen Development in Algeria

Prepared by researchers

- Supplying hydrogen from Algeria to Europe:

As part of Europe's plan to supply hydrogen by 2030, it has been decided to build five large pipelines to provide hydrogen, as follows:

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Table 02: Hydrogen transport corridors for Europe

Corridor "A" The region includes North Africa and southern Europe.	Corridor "B" Southwestern Europe and North Africa.	Corridor "C" and Corridor "D" The Northern areas encompass the Baltic region and the North Sea.	Corridor "H" The region encompasses Eastern and Southeastern Europe.
It will transport large quantities of green hydrogen energy at competitive prices from Algeria and Tunisia via Italy to central Europe, relying on gas infrastructure. The corridor will contribute to decarbonization along the route in Italy, Central Europe, and Germany.	The corridor will transport hydrogen supplies from the Iberian Peninsula and North Africa. France provides access to underground storage sites. The corridor will decarbonize industrial clusters in Portugal, Spain, France, and Germany.	The corridor is designated for supplies of offshore wind energy, blue hydrogen, integrated hydrogen projects in the North Sea, and green hydrogen sourced from both onshore and offshore wind energy in countries surrounding the Baltic Sea.	This corridor connects regions with high supplies from Ukraine, Romania, and Greece. Vast areas of solar and wind energy are being exploited. We are delivering hydrogen to Central Europe and Germany.

Source: (Five hydrogen supply corridors for Europe in 2030 Executive Summary, 2022)

South H2 Corridor: The Southern Hydrogen Corridor project

The Southern Hydrogen Corridor project is a dedicated hydrogen pipeline corridor stretching 3,300 km to 4,000 km from North Africa, specifically Algeria and Tunisia, to Italy, Austria, and Germany. Hydrogen will be produced in Algeria and exported to the European market, as Algeria has the necessary infrastructure, namely gas pipelines that transport hydrogen. New pipelines will be added, covering approximately 30 to 40 percent of the long distances in Europe, (Five countries put hydrogen corridor "SoutH2" on track, 2025) which will allow for an annual energy flow of 163 terawatt hours.

The transition from fossil fuels to renewable energy has led to a shift in power relations and differentiation in geo-economic competition. This has led to the emergence of new strategic technologies and techniques, such as clean hydrogen, and has strengthened value chains, prompting countries to review their traditional energy diplomacy and establish new partnerships based on technological cooperation. The focus is primarily on technological collaboration.

The Hydrogen Atlas (H2Atlas) for the German Federal Ministry of Education and Research and African partners examines the political, economic, and social criteria represented by a favorable business environment, the global governance index, and current energy policies to discuss potential hydrogen partners. In its assessment, countries such as Norway, Algeria, and the United Kingdom are considered suitable trading partners for Europe because they possess these criteria. (Dejonghe, 2023)

Table 03: Comparison of hydrogen production costs in Germany, Algeria, and other countries for 2050

Country	Cost in dollars per kg	Energy in terawatts per hour	Transport	Differences
Imported from Algeria	1.4	Thousands	Pipes	High power and low cost
Imported from Spain	1.31	Thousands	Pipes	Low cost

Country	Cost in dollars per kg	Energy in terawatts per hour	Transport	Differences
Imported from Russia	1	Thousands	Pipes	High cost
Import from Saudi Arabia	2,31 and more	Thousands	Ships	High cost
Produced locally, offshore wind	0.99	Hundreds	Local	Very low cost and limited capacity
Offshore wind production in Germany	1.7	Hundreds	Local	High cost and limited energy
Production Local Solar photovoltaic Germany	1	Tens	Local	Very low energy capacity and high cost
Domestic production with gas and coal with carbon content	1.31-3.25	Hundreds	Local or imported	High cost

This report was prepared by researchers based on the source: (Global Gas Report 2020, 2020)

The table above illustrates the competitive disparity between imports from Algeria, Spain, and Saudi Arabia and domestic manufacturing in Germany. The price of hydrogen in Algeria is highly competitive, ranging from 1.30 $ to 1.50$ per kilogram. The cost of power produced by solar energy in Algeria is low, and the expense of transferring it to Germany through pipelines is likewise negligible, particularly in comparison to the transportation costs from nearby Spain. Simultaneously, China's manufacturing capacity reaches thousands of terawatts, whilst Germany's ranges from tens to hundreds, accompanied by elevated expenses. Consequently, the importation of hydrogen from Algeria is minimal, as the substantial volumes above 1,000 terawatt-hours are transported through pipelines, in contrast to terrestrial and maritime wind sources, which do not approach hundreds. The elevated costs in Saudi Arabia are mainly attributable to its geographical position along maritime routes and the employment of gas and coal-producing methods. The political environment in Russia is unstable, accompanied by regional conflicts. Algeria is regarded as a formidable competitor due to its low costs, proximity to Europe, and vast resources, as well as its established integrated supply chains and networks.

Algeria is endeavoring to develop a pilot plant for an electric analyzer with a capacity of 50 to 100 megawatts to evaluate the feasibility of this technology and its economic viability. Many Algerian organizations and research support this, including one that suggests a way to grow the green hydrogen industry by using technical and financial models to improve future cost predictions with the electrochemical system. This will aid in diminishing the expenses associated with the alkaline water electrolysis network.
Worldwide demand for hydrogen across many industries.

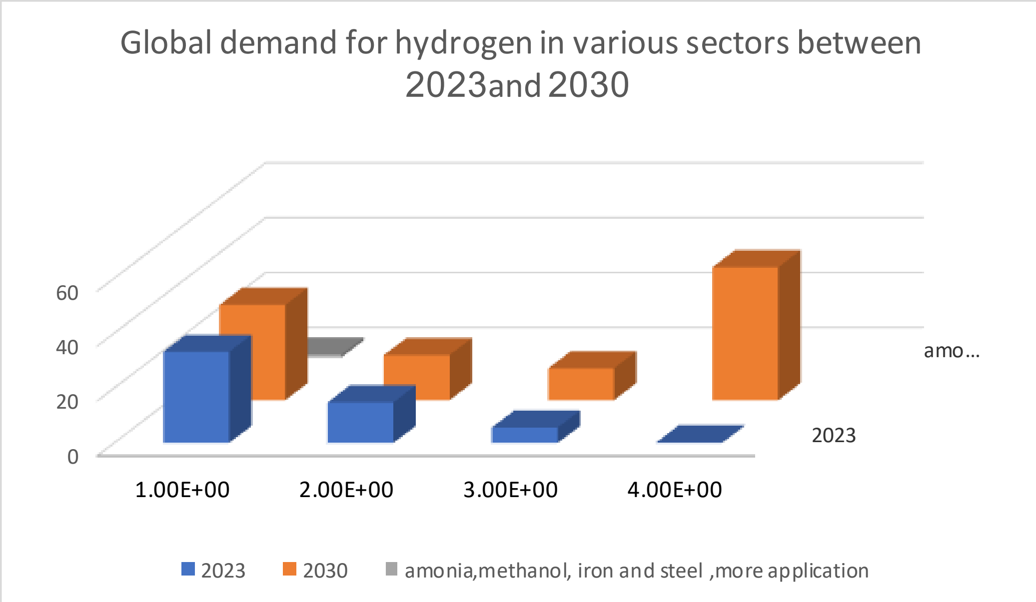

Figure 04: Worldwide hydrogen demand from 2023 to 2030
This document was prepared by researchers using the specified source.
(Global hydrogen demand by sector in the Net Zero Scenario, 2020-2030, 2025)

The illustration above depicts the aggregate global demand for hydrogen across multiple industries, including refining, ammonia production, methanol synthesis, iron and steel manufacturing, and more applications. In 2023, the refining industry is projected to represent the most significant proportion at approximately 43.6 million tons, followed by ammonia at 33.2 million tons, methanol at 14.8 million tons, iron and steel at 5.6 million tons, and other applications at 0.2 million tons. Global demand is projected to rise in 2030, primarily for iron and steel, reaching 11.6 million tons, and methanol, 16.4 million tons. Refining will diminish to 37.5, ammonia will escalate to 34.7, and other applications will surge to 48.4. The data demonstrate a rise in hydrogen consumption and its varied applications, which will transform the economy and promote sustainability.

Risks of hydrogen financing: Hydrogen projects require plans and strategies to address hazards and challenges related to the market, prices, demand, and other challenges outlined in the following table.

Table 4: Hydrogen risk analysis

Risk name	Risk number	Risk percentage	Impact of risk
Limited infrastructure	1	10%	0,1
Political risk	2	10%	0,1
Absence of the hydrogen market	3	11%	0.11
Uncertainty about the hydrogen price	4	19%	0,19
Uncertainty about the number of buyers	5	23%	0,23
Uncertain market demand	6	27%	0,27

Prepared by researchers according to the source: (African Green, 2025)

The table illustrates the risks associated with investing in hydrogen projects, with uncertain market demand being the predominant share at 72%. Market issues are widely recognized as initial barriers to project initiation, necessitating prior analysis. A 23% lack of buyer trust and a 19% risk of price volatility compound this problem. This is influenced by subsequent market developments, with the risk decreasing to approximately 11% due to the absence of a hydrogen market, which presents both a challenge and an opportunity for market initiators. The risk thereafter decreases to 10% owing to constrained infrastructure and political uncertainties, including conflicts, currency exchange challenges, and vague legislation, which are the least impactful and subject to modification.

Table 05 : Hydrogen risk analysis matrix

Impact / Risk	0.1	0.1	0.11	0.19	0.23	0.27
1	0.1	0.1	0.11	0.19	0.23	0.27
2	0.2	0.2	0.22	0.38	0.46	0.54
3	0.3	0.3	0.33	0.57	0.69	0.81
4	0.4	0.4	0.44	0.76	0.92	1.08
5	0.5	0.5	0.55	0.95	1.15	1.35
6	0.6	0.6	0.66	1.14	1.38	1.62

Prepared by researchers according to the table above

Less than 0.50: Low
From 0.50 to 1.00: Average
Above 1.00 High
Risk level = Risk × Impact of risk

The table above illustrates a hydrogen risk analysis matrix, wherein each risk is evaluated by multiplying the probability value (from 1 to 6) by the effect score (from 0.1 to 0.27) to ascertain the risk level. Values below 0.50 indicate minimal danger and are displayed in green. These pertain to inadequate infrastructure, political hazards, the absence of a hydrogen trading market, and volatility in hydrogen pricing. These risks can be mitigated by establishing methods for their management through comprehensive project planning and prioritization, alongside enhancing partnerships and alliances to fund projects and infrastructure. Contract management is enhanced by multi-guarantee agencies that protect investments throughout political turmoil. Furthermore, specific exemptions are provided to enable the conversion of currency shares and their incorporation. To address the lack of a hydrogen market, risks can be alleviated by initiating focused carbon reduction initiatives with a long-term perspective of 20 to 30 years, implementing regulations and standards to curtail emissions, and formulating policies to transition the economic framework towards sustainability.

The hazards linked to unpredictability in hydrogen prices are significantly influenced by market dynamics, which modify prices according to prevailing trends and timing. The current trend towards decarbonization represents a significant advancement towards the future. Values between 0.50 and 1.00 indicate medium risk, denoted in orange, while values beyond 1.00, shown in red, signify severe risk due to a restricted number of buyers and unpredictable demand. Cost reduction, continuity, risk sharing with the purchaser, and extensive credit guarantees are necessary. Demand fluctuates over time during the product life cycle. To mitigate the adverse effects of climate change, marketing initiatives are crucial for educating populations about the risks associated with fossil fuels and the need to transition to renewable and sustainable energy sources.

Conclusion:

Algeria has significant potential to attract hydrogen initiatives aligned with global climate objectives, promoting sustainability and positioning itself as a leading supplier of hydrogen in Africa. This enhances its prospects in international trade, leveraging its ample resources and competitive pricing. An evaluation of national strategic plans indicates that Algeria is endeavoring to harmonize political and regulatory frameworks to enhance regional collaboration. Nonetheless, the institutional and technological infrastructure necessary for the deployment and expansion of hydrogen is a barrier that must be addressed to facilitate localized hydrogen production and transportation.

Hydrogen generation is essential in key industries like ammonia synthesis and refining, mitigates carbon emissions, and serves as a carbon-neutral biofuel in the transportation sector, contributing to climate protection. Variations in hydrogen prices facilitate international trade and foster a developed hydrogen market, contributing to the equilibrium of supply and demand.

Algeria possesses substantial renewable energy resources that enhance domestic investment and attract foreign capital, facilitated by its gas transport infrastructure, crucial for hydrogen delivery to Europe. Moreover, hydrogen is less expensive in Algeria than in other regions, despite the availability of resources there, as such resources are costlier to utilize than importing from Algeria and are significantly limited compared to the production capacity of Algeria.

Algeria possesses the capacity to generate substantial quantities. This is influencing the future of clean energy commerce and is expected to position Algeria as a significant hydrogen exporter, progressively transitioning towards sustainable economic development.

Recommendations:

In light of the findings of this study and the results achieved, the following recommendations are put forward:

- Expedite the technological localization of hydrogen through enhanced investment initiatives and the dissemination of information and expertise, while Algeria remains deficient in hydrogen project implementation.
- Establish hydrogen supply chains and augment supplies to enhance competitiveness and pursue new partnerships for Algeria.
- Encourage local investments in hydrogen and engage the business sector.
- Employ hydrogen locally in initiatives to revitalize and advance both the industrial and transportation sectors, enabling a gradual shift to carbon-free energy sources.
- Establish criteria for the selection of suitable technologies for hydrogen production.
- Promoting research and development in hydrogen storage and distribution technologies.
- Promote international collaboration to advance the hydrogen economy and foster community understanding of the need to transition to sustainable energy sources and move away from fossil fuels.

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