

**Prospecting the Energy Transition through Green Hydrogen:
A Case Study of Algeria during the Period (2026–2050) Using Python**
استشراف الانتقال الطاقي عبر الهيدروجين الأخضر: دراسة حالة الجزائر خلال الفترة (2026–2050)
باستخدام برنامج **python**

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Abstract:

This study aims to forecast the future of green hydrogen production in Algeria by 2050 through the development of gradual quantitative scenarios based on technical and economic data, particularly those outlined in the National Hydrogen Strategy. Three prospective phases were adopted, covering the period from 2026 to 2050. The study employed mathematical modeling using the Python programming language to calculate the expected hydrogen output based on installed electrical capacity, technological efficiency, and annual operating hours. It also analyzed the gap between targeted and actual production. The results indicate a production capacity that significantly exceeds the declared targets, reflecting Algeria's substantial potential, especially given its abundant solar resources and vast geographic areas. However, the findings also highlight institutional and structural challenges related to financing and governance. The study concludes that a successful transition to a green hydrogen economy requires an integrated approach combining technological advancement, an attractive investment environment, and clear institutional planning. Practical recommendations were proposed to support this promising energy transition pathway.

Keywords: Green hydrogen; renewable energies; foresight; strategy; scenarios.

JEL Classification Codes: Q42 ; Q47

ملخص:

تهدف هذه الدراسة إلى استشراف مستقبل إنتاج الهيدروجين الأخضر في الجزائر بحلول عام 2050، من خلال بناء سيناريوهات كمية تدريجية مستندة إلى المعطيات التقنية والاقتصادية، خصوصاً تلك الواردة في الاستراتيجية الوطنية للهيدروجين. تم اعتماد ثلاث مراحل استشرافية تغطي الفترة من 2026 إلى 2050. اعتمدت الدراسة على النمذجة الرياضية باستخدام لغة *Python* لحساب الإنتاج المتوقع من الهيدروجين بالاعتماد على القدرة الكهربائية المثبتة، الكفاءة، وعدد ساعات التشغيل السنوي، مع تحليل الفجوة بين الأهداف والإنتاج الفعلي. أظهرت النتائج قدرة إنتاجية تفوق بكثير الأهداف المعلنة، ما يعكس إمكانات الجزائر الهامة، خاصة بفضل وفرة الطاقة الشمسية والمساحات الجغرافية. في المقابل، أبرزت النتائج تحديات مؤسسية وهيكلية تتعلق بالتمويل والحكومة. خلصت الدراسة إلى ضرورة اعتماد مقاربة متكاملة تجمع بين التطوير التكنولوجي، بيئة استثمارية ملائمة، وتخطيط مؤسسي واضح، واقترحت توصيات عملية لدعم مسار الانتقال إلى اقتصاد قائم على الهيدروجين الأخضر.

الكلمات المفتاح: هيدروجين أخضر ؛ طاقات متجددة ؛ استشراف ؛ استراتيجية ؛ سيناريوهات.

تصنيفات JEL : Q42 ؛ Q47

INTRODUCTION:

In recent decades, the world has witnessed profound transformations in energy systems, driven by the need to mitigate climate change and reduce dependence on fossil fuels. In this context, green hydrogen has emerged as one of the most promising solutions for achieving a sustainable energy transition, given its clean characteristics and high flexibility in industrial applications, transportation, and energy storage. Considering the abundance of natural resources, particularly solar energy, Algeria stands out as one of the countries with significant potential for developing a green hydrogen economy.

This study comes at a time when Algeria is experiencing growing interest in activating a national hydrogen roadmap, especially in light of its substantial energy potential and its strategic geographical location, which positions it as a gateway for supplying the European market. However, transforming these potentials into an economic and industrial reality requires accurate foresight-based approaches that take into account technical, economic, and institutional dimensions.

Research Problem:

Based on this context, the main research problem revolves around the following question:

To what extent is it possible to build realistic foresight scenarios for green hydrogen production in Algeria by the 2050 horizon, and what are the associated challenges and opportunities?

Sub-research Questions:

- What are the technical and economic parameters that frame the development of the hydrogen sector in Algeria?
- How can the expected hydrogen production be modeled using quantitative scenarios?

Hypotheses:

Main Hypothesis:

Algeria, by relying on its renewable resources and a phased strategic planning approach, can achieve gradual growth in green hydrogen production and become a key player in the regional and international clean energy markets by 2050.

Sub-hypotheses:

- Expanding renewable energy capacity and relying on high-efficiency electrolyzers significantly increases green hydrogen production capacity at a rapid pace.
- Infrastructure and financing constitute decisive factors in determining the success or failure of foresight scenarios.

The importance of this research lies in addressing a vital issue related to the future of energy in Algeria, amid global climate challenges and shifts in the international energy landscape. It is also considered one of the few studies that combine strategic vision with quantitative analysis using modern programming tools to estimate hydrogen production, thereby enhancing its practical value for policymakers and researchers.

Research Objectives:

- To develop quantitative and foresight-based scenarios for the evolution of green hydrogen production in Algeria between 2026 and 2050.
- To estimate expected production using Python-based models and link it to real technical data.
- To analyze the impact of these scenarios on the national economy and energy security.

Prospecting the Energy Transition through Green Hydrogen: A Case Study of Algeria during the Period (2026–2050) Using Python

- To provide strategic recommendations for developing an effective national green hydrogen system.

Previous studies

- The study by Saliha Hawasni, entitled *Modern Trends in Achieving Sustainable Energy Security in Algeria: Green Hydrogen between Future Vision and Practical Challenges*, aimed to explore the extent to which green hydrogen contributes to achieving sustainable energy security. It adopted a descriptive-analytical approach to discuss the relationship between the development of the hydrogen sector and reducing dependence on fossil fuels. The results concluded that developing this sector could serve as a strategic tool within Algeria's energy transition framework.

- The study by Yassine Ben Chenina et al., entitled *Advancing Green Hydrogen Production in Algeria with Opportunities and Challenges for Future Directions*, published in *Nature Scientific Reports*, used technical simulation tools such as HOMER Pro to identify optimal geographical locations for hydrogen production from solar energy. It focused on technical and economic feasibility and recommended integrating seawater electrolysis into Algeria's national strategy.

- The study by Tabti Ihsane and Ben Ahmed Dahou Rachida, entitled *Green Hydrogen Strategy to Enhance the Position of the Environmental Economy*, aimed to analyze the impact of green hydrogen development on strengthening the environmental economy. It relied on the analysis of government documents and the national strategic framework, proposing phased development stages starting with experimentation and ending with industrialization and export. It also provided recommendations related to investment incentives and market structure.

Previous studies on green hydrogen in Algeria share a common objective of analyzing the national potential of this sector and its role in the energy transition, largely relying on secondary data and strategic documents. Their methodologies have varied between descriptive, analytical, and simulation-based approaches using tools such as HOMER. Their findings converge in emphasizing the promising opportunities available to Algeria. This current study distinguishes itself by adopting foresight scenarios extending from 2026 to 2050 and by linking quantitative analysis using Python with strategic analysis, thereby providing greater accuracy and realism.

1- Theoretical Framework and Previous Studies:

1-1 Concept of Hydrogen

Renewable hydrogen can be defined as hydrogen produced from solar energy, tidal energy, wind energy, and hydropower, and supplied through sustainable feedstocks. However, sustainable methods of hydrogen production are costly and require numerous technological advancements to enable large-scale production. (Khazouz & Evangelos, 2020, p. 2)

Hydrogen is considered one of the renewable energy sources and the most abundant element in the universe. The Sun and other stars are composed primarily of hydrogen, and outer space is rich in it in high proportions. However, hydrogen does not exist on Earth as a free element; rather, it is found in small amounts in the air and in large quantities combined with oxygen in the waters of oceans, seas, and rivers. Given its importance, some believe that hydrogen will become the ideal fuel of the future, due to its economic and technical feasibility and its positive

impacts on the environment. (Mohamed, 2013, p. 1099)

Hydrogen is also a source of clean and sustainable energy, as it is extracted from water, which consists of two hydrogen atoms and one oxygen atom. When hydrogen is burned, it combines with oxygen to form water vapor, making it environmentally non-polluting. Experiments have successfully demonstrated the transportation of hydrogen in both gaseous and liquid forms, which facilitates its storage in large tanks for long periods and its use when needed. In addition, a team of American scientists has managed to use liquid hydrogen as fuel for vehicles instead of gasoline. (Ismahan, 2019, p. 107)

1-2 Types of Hydrogen

1-2-1 Grey Hydrogen

Grey hydrogen is produced using natural gas, while black hydrogen relies primarily on coal as a main source. Steam Methane Reforming (SMR) is the most commonly used technology in this context, where high temperatures and steam are applied to extract hydrogen from methane gas (CH_4). However, this process has a significant negative environmental impact, as it generates approximately 9 kilograms of carbon dioxide (CO_2) for every kilogram of hydrogen produced. (Khalifat, 2020, p 6)

1-2-2 Blue Hydrogen:

Blue hydrogen is hydrogen produced from natural gas (similar to grey hydrogen), but with the use of Carbon Capture and Storage (CCS) technologies to reduce greenhouse gas emissions resulting from the production process. (IRENA, 2020, p. 9)

1-2-3 Green Hydrogen

Green hydrogen is a type of hydrogen produced using electricity generated from renewable sources to electrolyze water, without carbon emissions. It is considered a key component in supporting the transition to sustainable energy and transport systems (Arcos & Diogo, 2023, p. 26)

Green hydrogen is produced by exploiting renewable energy sources—such as onshore and offshore wind energy and solar energy—to power electrolyzers that separate hydrogen from water molecules. (Housna et al, 2024, p. 201)

1-2-4 Black Hydrogen

Black or brown hydrogen refers to hydrogen produced through coal gasification. The colors black and brown are often used to indicate the type of coal used: hard coal (black) or lignite (brown). This process produces large amounts of carbon dioxide emissions, estimated at around 19 tons of CO_2 per ton of hydrogen produced (Blasio, 2024, p. 2)

1-2-5 Yellow Hydrogen

Yellow hydrogen can also be produced from water; however, instead of using renewable energy, nuclear energy is used. It is sometimes referred to as “pink ydrogen” . (Zaki, 2023, p 7)

1-2-6 Turquoise Hydrogen

Turquoise hydrogen is produced from natural gas through thermal decomposition without carbon emissions, as the carbon is converted into solid carbon black that can be sold or easily stored. However, this technology is still in the experimental stage and

Prospecting the Energy Transition through Green Hydrogen: A Case Study of Algeria during the Period (2026–2050) Using Python

requires further research before being deployed on a large scale. (IRENA, 2020, p. 9)

1-2-7 Orange Hydrogen

Orange hydrogen is produced from plastic waste, providing a dual solution for clean energy generation and plastic waste management. However, it is still in its early stages, with experiments being conducted on various technologies such as pyrolysis, microwave-assisted catalysis, and photo-reforming. (Blasio, 2024, p. 2)

1-3 Technologies for Harnessing Hydrogen Energy

Hydrogen is produced and its energy utilized through the following methods:

1-3-1 Electrolysis

In light of the continuous decline in renewable electricity costs, water electrolysis has emerged as one of the cleanest and most efficient hydrogen production technologies, as it enables the production of carbon-free hydrogen, unlike conventional fossil fuel-based methods. (Yue et al, 2021, p. 3)

Electrolysis is the process in which an electric current passes through water, breaking chemical bonds and separating hydrogen and oxygen with the help of an electrolyte solution that facilitates bond cleavage. (Touat, 2020, p. 3)

Nuclear energy can also play an important role in green hydrogen production, contributing to the promotion of a sustainable, low-carbon hydrogen economy. Some key points regarding the role of nuclear energy in green hydrogen production include:

Low-carbon electricity generation: Nuclear power plants produce electricity with nearly zero direct greenhouse gas emissions. This low-carbon electricity can be used directly in the electrolysis process to produce green hydrogen, significantly reducing the carbon footprint of hydrogen production. (Mahdy, 2022, p. 4)

1-3-2 Steam Methane Reforming

Steam Methane Reforming (SMR) is the most common and cost-effective method for producing grey hydrogen, accounting for about 80% of global demand. It is based on the reaction of natural gas with steam to produce a mixture of hydrogen and carbon monoxide under high temperatures and pressures. The resulting hydrogen is mainly used in industries such as ammonia, methanol, and liquid fuels. Despite its reliance on fossil fuels for energy supply, recent experiments have explored the use of concentrated solar power; however, the technology still faces operational challenges, such as the need for large land areas and the risk of carbon deposition inside the reactor. (Arcos & Diogo, 2023, p. 32)

1-3-3 Direct Solar-Driven Hydrogen Production

Photosynthesis in plants represents a natural model for converting solar energy into chemical energy, where water is used as a hydrogen source and split into hydrogen and oxygen through the action of chlorophyll and sunlight. Since water does not efficiently absorb solar radiation, photochemical catalysts have been used in artificial systems that mimic this mechanism, such as certain salts capable of transferring electrons and activating water splitting under light exposure. This technology is considered promising for developing sustainable solutions for green hydrogen production through artificial photolysis. (Ramadan and Ali, 1988, p. 137-138)

2- Potential and Challenges of Green Hydrogen in Algeria:

In light of the rapid global transformations toward clean energy and the achievement of carbon neutrality, green hydrogen has become a strategic option for many countries, especially those possessing renewable energy resources and a favorable geographical location. Algeria is among these countries, as it has vast potential to develop a green hydrogen-based economy, thanks to the following factors

2-1 Solar, Wind, and Water Resource Potential

2-1-1 Solar Energy Potential

Algeria enjoys significant solar energy potential due to its geographical location and the high number of sunny days throughout the year (Sara and Tar 47). The annual sunshine duration across the national territory exceeds 2,000 hours and can reach up to 3,900 hours in the High Plateaus and the Sahara. Moreover, the daily available solar energy on a horizontal surface of one square meter reaches about 5 kWh in most regions of the country, ranging annually from 1,200 kWh/m² in the north to 2,263 kWh/m² in the south.

Algeria possesses one of the world's most important solar energy fields, particularly in the Mediterranean basin region, thanks to its strategic geographical position (Mzraq, 2021, p. 158-159). This is illustrated in the following table:

Table (01): Distribution of Solar Energy in Algeria

Regions	Coastal Zone	High Plateaus	Sahara
Area (%)	04	10	86
Average Sunshine Duration (hours/year)	2,650	3000	3500
Average Energy Yield (kWh/m ² /year)	1700	1900	2650

Source: Ministry of Energy and Mines, Renewable Energy Guide, Algeria, 2007, p. 39.

2-1-2 Wind Energy Potential

Although Algeria does not possess sites with very high wind intensity, wind energy appears less attractive for investment compared to solar energy. Algeria ranks relatively low among countries attractive to wind energy investments, especially when compared to countries such as Egypt, Turkey, France, South Africa, and even Portugal. This lag is mainly attributed to the current focus on onshore wind farms, while offshore wind turbine investments remain limited due to high costs and technical complexity. (Mzraq, 2021, p. 162)

Table (02): Renewable Energy Production during 2011–2023

Year	Total Renewables	Hydropower	Wind Energy	Solar Energy
2011	252.6	227.6	0	25
2012	252.6	227.6	0	25
2013	253	228	10	25
2014	266	228	10	28
2015	299	228	10	61
2016	499	228	10	261
2017	592	228	10	354
2018	604	228	10	366
2019	604	228	10	366
2020	585	209	10	366

Prospecting the Energy Transition through Green Hydrogen: A Case Study of Algeria during the Period (2026–2050) Using Python

2021	505	129	10	366
2022	590	129	10	451
2023	590	129	10	451

Source: International Renewable Energy Agency (IRENA).

2-1-3 Water Resources:

Algeria is characterized by diverse water resources, both surface and groundwater, reflecting its geographical and natural diversity. This diversity is mainly due to its vast area and varied topography, which directly affect rainfall patterns—the primary source of water resources in the country. (Aqila, 2009, p. 233)

Annual rainfall is estimated at about 65 billion m³. Despite receiving considerable rainfall, the number of rainy days has been steadily declining, and precipitation is concentrated in limited areas, with significant evaporation losses due to high temperatures.

Geographically, surface water resources decrease toward the south. Algeria has approximately 30 surface watercourses, most of which are located in the Tell region and flow into the Mediterranean Sea. However, these watercourses suffer from irregular flow, with a total capacity of about 12.4 billion m³. (Takwasht, 2012, p. 153)

In 2007, renewable and usable water resources were estimated at around 25 billion m³, two-thirds of which were surface water. The country has 103 completed dams and 50 under construction. (Aqila, 2009, p. 233)

Regarding seawater desalination, Algeria recently inaugurated five desalination plants in Tipaza (Fouka), Boumerdes (Cap Djinet), El Tarf (Keddiet Eddraouch), Béjaïa (Tighremt), and Oran (Ras El Abyad), with a total capacity of approximately 3.7 million cubic meters per day.

2-1-4 Renewable Energy Legislation and Regulations

The legal and regulatory framework in Algeria reflects growing interest in promoting renewable energy and controlling energy consumption, forming an institutional foundation supportive of green hydrogen projects. This orientation began early with Decree No. 85-235 (1985), which established an agency for energy efficiency and conservation, followed by Law No. 99-09 (1999), which laid the foundations for energy management.

Law No. 04-09 (2004) further integrated renewable energy promotion into the sustainable development strategy. These frameworks were strengthened by several executive decrees, notably Decree 04-314 (amended), reorganizing the National Agency for Energy Efficiency, and Decree 15-319, establishing the National Renewable Energy Fund. Decrees 17-98 and 17-204 (2017) represent important regulatory steps defining tendering procedures for renewable energy production and its integration into the national electricity grid, reflecting a gradual shift toward a regulatory environment conducive to developing a hydrogen economy in Algeria.

2-1-5 Availability of Scientific and Technical Workforce

The presence of vocational and technical training programs enables the preparation of a skilled mid-level workforce capable of contributing to installation, maintenance, and

operation phases, enhancing Algeria's ability to localize new technologies and control hydrogen value chains.

Human capital is a key pillar for the success of energy transition projects, particularly in the green hydrogen sector, which requires multidisciplinary skills. Algeria possesses a strong scientific and human resource base, supported by an extensive educational network comprising 117 higher education institutions and 74 public and private institutions, along with a significant number of graduates in science and technology fields. Students in these disciplines account for more than 40% of total university enrollment, providing a pool of talent that can be trained for energy sectors. (Statistics)

The country also hosts specialized research centers and institutes, such as the Renewable Energy Development Center (CDER), and has expertise in key areas such as electrolysis, energy storage, and fuel cells. In addition, vocational training programs contribute to preparing a technical workforce capable of supporting hydrogen project implementation, reinforcing Algeria's ability to localize technology and manage related value chains.

2-1-6 Cost and Geographical Location:

The cost of producing green hydrogen in Algeria is among the lowest globally, with estimates ranging between USD 1.68 and USD 2.70 per kilogram, giving Algeria a competitive advantage over several major industrial countries such as Germany and Australia. (Abboud)

Algeria's strategic geographical location represents one of its most significant competitive advantages in the global energy transition, providing direct proximity to the European market—one of the largest future importers of clean hydrogen. This location enables hydrogen exports through existing gas pipelines such as Medgaz and TransMed after adaptation, or by maritime transport at lower costs than those faced by distant countries in Asia and South America.

Moreover, Algeria's stability and role as a reliable energy supplier strengthen its position amid geopolitical challenges and the European Union's desire to diversify energy sources. If this geographical advantage is leveraged through infrastructure upgrades and suitable technical and financial partnerships, Algeria is well positioned to become a regional hub for exporting green hydrogen and its derivatives by the 2040–2050 horizon.

2-2 Foresight Modeling of Green Hydrogen in Algeria

2-2-1 Study Methodology

The applied study adopts a quantitative foresight approach aimed at assessing the prospects for the development of green hydrogen production and use in Algeria by 2050, through modeling three future scenarios (2026–2030, 2031–2040, 2041–2050). Scenario analysis is employed as an effective tool to understand the impact of technical, economic, and environmental variables on energy policies.

Python programming was used to develop a simplified computational model based on equations for hydrogen production from renewable energy, considering factors such as production efficiency, cost, domestic demand, and export potential. Data were drawn from official sources such as the International Renewable Energy Agency (IRENA) and

Prospecting the Energy Transition through Green Hydrogen: A Case Study of Algeria during the Period (2026–2050) Using Python

the National Hydrogen Strategy, lending strong analytical credibility to the assessment of opportunities and challenges associated with this vital resource.

2-2-2 Scenario Development

Based on official data from Algeria's National Hydrogen Development Strategy, three foresight scenarios extending from 2026 to 2050 were developed, taking into account the evolution of renewable energy sources, technology, domestic and external demand, and Algeria's geostrategic positioning.

2-2-2-1 Scenario One: Gradual Launch Phase (2026–2030)

2-2-2-1-1 Characteristics

- Launch of pilot green hydrogen production units with limited capacity.
- Near-total reliance on photovoltaic solar energy in the initial phase.
- Construction of the first electrolysis plants connected to a clean electricity grid.

2-2-2-1-2 Key Indicators

Table (03): Gradual Launch Scenario for Green Hydrogen Production

Year	Renewable Capacity (GW)	Hydrogen Production (TWh)	PV (%)	Wind (%)
2026	0.2	0.2	1	0
2027	0.2	0.2	1	0
2028	0.3	0.3	1	0
2029	0.4	0.4	1	0
2030	0.5	0.5	1	0

Source: Prepared by the authors based on the National Hydrogen Development Strategy in Algeria, Figure (02), p. 11.

2-2-2-2 Scenario Two: Technical Expansion and Widespread Deployment (2031–2040)

2-2-2-2-1 Characteristics

- Accelerated growth of installed renewable capacity.
- Gradual integration of wind energy starting in 2035.
- Increasing hydrogen production with improved efficiency.

2-2-2-2-2 Key Indicators

Table (04): Expansion and Deployment Scenario

Year	Renewable Capacity (GW)	Hydrogen Production (TWh)	PV (%)	Wind (%)
2031	1	1	100%	0%
2032	2	2	100%	0%
2033	3.5	3	100%	0%
2034	5	5	100%	0%
2035	7	7	~85%	~15%
2036	10	12	70%	30%
2037	13.5	17	70%	30%
2038	16.5	23	70%	30%
2039	19	30	70%	30%
2040	23	40	70%	30%

Source: Prepared by the authors based on the National Hydrogen Development Strategy in Algeria, Figure (02), p. 11.

2-2-2-5 Scenario Three: Industrialization and Intensive Export (2041–2050)

2-2-2-5-1 Characteristics

- Achievement of industrial-scale production capacity.
- Expansion of green hydrogen and derivative exports.
- Operation of high-capacity facilities and integration with European networks.

2-2-2-5-2 Estimated Indicators

Table (05): Industrialization and Export Scenario

Year	Renewable Capacity (GW)	Hydrogen Production (TWh)	PV (%)	Wind (%)
2041	~25.0	50	70%	30%
2042	~27.0	60	70%	30%
2043	~30.0	75	70%	30%
2044	~32.0	90	70%	30%
2045	~35.0	105	70%	30%
2046	~37.0	120	70%	30%
2047	~39.0	135	70%	30%
2048	~41.0	150	70%	30%
2049	~43.0	165	70%	30%
2050	~45.0	180	70%	30%

Source: Prepared by the authors using Python based on the National Hydrogen Development Strategy in Algeria.

3- Results and Discussion

3-1- Results of the Pilot Scenario (2026–2030):

Table (06) presents a comparison between targets and expected green hydrogen production in Algeria across the three scenarios (launch, expansion, export). Expected hydrogen production was calculated using the following equation:

$$\text{Expected Production (TWh)} = \frac{\text{Capacity (MW)} \times \text{Efficiency} \times 8760 \times 33.6}{10^6}$$

Table (06): Estimates for the Gradual Launch Scenario (2026–2030)

Year	Capacity (MW)	Efficiency	Target (TWh)	Expected Production (TWh)	Difference
2026	200	0.75	0.2	0.88	0.68
2027	200	0.75	0.2	0.88	0.68
2028	300	0.75	0.3	1.32	1.02
2029	400	0.75	0.4	1.77	1.37
2030	500	0.75	0.5	2.21	1.71

Source: Prepared by the authors based on Python results.

he results presented in Table (06) indicate that the gradual launch phase of green hydrogen production in Algeria during the period 2026–2030 is characterized by a cautious and well-controlled energy planning approach. Installed capacity starts at 200 MW in 2026 and 2027, then increases progressively to reach 500 MW by 2030, while efficiency remains constant at 75% throughout this phase.

The data reveal that expected production exceeds planned targets in all years, with a surplus ranging from 0.68 TWh at the beginning of the period to 1.71 TWh by 2030. This surplus can be attributed to conservative production targets relative to actual technical potential, reflecting policymakers' intention to minimize risks during the early deployment phase.

Prospecting the Energy Transition through Green Hydrogen: A Case Study of Algeria during the Period (2026–2050) Using Python

Maintaining a constant efficiency level of 75% suggests reliance on mature and proven electrolysis technologies, without assuming major technological improvements during this initial stage. Such an approach aligns with a strategy of gradual learning and experimentation before large-scale expansion and provides a high degree of implementation flexibility to absorb potential regulatory or financial constraints.

The production surplus represents a dual strategic opportunity. On one hand, it can be directed toward emerging domestic demand, particularly in the transport and industrial sectors. On the other hand, it enables early export initiatives, especially to European markets, given Algeria's geographical proximity. Consequently, these results confirm Algeria's readiness to progressively enter international green hydrogen markets before 2030.

3-2- Results of the Second Scenario: Technical Expansion and Widespread Deployment (2031–2040)

Table (07): Estimates for the Expansion Scenario (2031–2040)

Year	Capacity (MW)	Efficiency	Target (TWh)	Expected Production (TWh)	Difference
2031	1,000	0.75	1	4.42	3.42
2032	2,000	0.75	2	8.84	6.84
2033	3,500	0.76	3	15.47	12.47
2034	5,000	0.76	5	22.1	17.1
2035	7,000	0.77	7	30.92	23.92
2036	10,000	0.78	12	45.94	33.94
2037	13,500	0.78	17	62.01	45.01
2038	16,500	0.79	23	76.47	53.47
2039	19,000	0.79	30	88.06	58.06
2040	23,000	0.8	40	108.94	68.94

Source: Prepared by the authors based on Python results.

The second scenario represents a decisive phase in Algeria's green hydrogen development, marked by a significant expansion in both installed capacity and technological efficiency. Installed capacity increases sharply from 1,000 MW in 2031 to 23,000 MW by 2040, alongside a gradual improvement in efficiency from 75% to 80%.

The results show a substantial widening of the positive gap between expected production and planned targets, with the surplus rising from 3.42 TWh in 2031 to approximately 68.94 TWh by 2040. This trend reflects a combination of technological progress, accumulated operational experience, and the continued adoption of relatively conservative production targets.

The growing surplus indicates that Algeria is not only aiming to meet domestic demand but is also building excess capacity oriented toward industrialization and export. Furthermore, the gradual efficiency improvement reflects the integration of more advanced electrolysis technologies and better renewable energy management, contributing to cost reductions and enhanced international competitiveness.

Accordingly, this phase can be considered the strategic foundation for transitioning toward a hydrogen-based economy, as Algeria moves from pilot-scale deployment to regional and international positioning, with strong potential for developing hydrogen-related value chains such as green ammonia and synthetic fuels.

3-3- Results of the Third Scenario: Industrialization and Intensive Export (2041–2050)

Table (08): Estimates for the Industrialization and Export Scenario (2041–2050)

Year	Capacity (MW)	Efficiency	Target (TWh)	Expected Production (TWh)	Difference
2041	25,000	0.8	50	118.42	68.42
2042	27,000	0.8	60	127.89	67.89
2043	30,000	0.8	75	142.1	67.1
2044	32,000	0.8	90	151.57	61.57
2045	35,000	0.8	105	165.78	60.78
2046	37,000	0.8	120	175.25	55.25
2047	39,000	0.8	135	184.71	49.71
2048	41,000	0.8	150	194.18	44.18
2049	43,000	0.8	165	203.65	38.65
2050	45,000	0.8	180	213.12	33.12

Source: Prepared by the authors based on Python results.

The third scenario illustrates Algeria’s transition toward a fully mature green hydrogen economy, with installed capacity increasing from 25,000 MW in 2041 to 45,000 MW by 2050, while efficiency stabilizes at 80%, reflecting a high level of technological maturity and operational stability.

Although the positive gap between expected production and targets persists, it gradually narrows over time, decreasing from 68.42 TWh in 2041 to 33.12 TWh by 2050. This trend indicates improved strategic planning accuracy and a closer alignment between production objectives and actual output, signaling a shift from quantitative expansion toward supply–demand balance optimization.

This scenario represents a phase of intensive focus on industrialization and exports, with the majority of production expected to be directed toward international markets, particularly Europe, alongside the development of hydrogen-based derivatives and downstream industries. Such a trajectory strengthens Algeria’s position as a reliable clean energy supplier and supports economic diversification away from conventional hydrocarbons.

Overall, this scenario embodies Algeria’s long-term vision of leveraging green hydrogen as a cornerstone for building a sustainable, low-carbon economy by mid-century, effectively integrating environmental, economic, and energy security objectives.

4- Conclusion:

Green hydrogen represents a key strategic option for Algeria within its broader vision of energy transition and economic diversification away from conventional hydrocarbons. By adopting a forward-looking approach based on quantitative scenarios spanning the period 2026–2050, this study demonstrates that Algeria possesses significant technical and natural potential to become an active player in the green hydrogen economy at both regional and international levels.

The results of the Python-based modeling indicate that projected green hydrogen production exceeds planned targets across all scenarios, including the gradual launch phase, the technical expansion phase, and the industrialization and intensive export phase. This projected surplus reflects a high degree of production flexibility and provides policymakers with strategic leverage to allocate output either toward meeting domestic demand—particularly in industry and transport—or toward export markets, especially Europe.

Prospecting the Energy Transition through Green Hydrogen: A Case Study of Algeria during the Period (2026–2050) Using Python

Moreover, the study highlights that the gradual improvement in electrolysis efficiency, combined with Algeria's abundant renewable energy resources—most notably solar energy—enhances the economic feasibility of green hydrogen and contributes to lowering production costs over the long term. These findings confirm that green hydrogen can serve as a cornerstone for building a low-carbon national economy, strengthening energy security, and creating new industrial and investment opportunities.

Ultimately, Algeria's ability to fully harness its green hydrogen potential depends on the coherence of public policies, the establishment of an enabling regulatory framework, and the strengthening of human and technical capacities. Such conditions are essential to move from strategic planning to effective implementation and to develop a sustainable national green hydrogen ecosystem.

Recommendations:

- Launch pilot-scale green hydrogen projects to test technical and economic feasibility while building national expertise.
- Establish a clear and stable national strategy and legal framework that encourages investment across the entire hydrogen value chain, from production to storage, transport, and export.
- Strengthen scientific and technical partnerships with leading countries and institutions in green hydrogen technologies to facilitate technology transfer and knowledge sharing.
- Increase investment in scientific research and specialized training

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