

The Transition Toward Clean Energy in Algeria: Between the Requirements of Inclusive Growth and the Challenges of Sustainable Development

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Abstract:

This study aims to explore the role of clean energy in achieving sustainable development and inclusive growth, with a focus on Algeria's experience. The research examines the concepts and dimensions of inclusive growth in energy transitions and analyzes the economic and environmental impacts of clean energy technologiesolar power, wind energy, and green hydrogen. Greenhouse gas emissions in Algeria between 1990 and 2023 were analyzed, alongside the national renewable energy production and ongoing projects, as well as the political and legal frameworks supporting green hydrogen development. International best practices were also reviewed to draw lessons applicable to Algeria.

The findings indicate that clean energy serves as a strategic driver for economic growth, job creation, social equity, and environmental mitigation, making it a key tool for achieving sustainable development both in Algeria and globally.

Keywords: Clean energy; sustainable development; wind energy; solar energy; greenhouse gas emissions;green hydrogen.

JelClassificationCodes: Q1, Q2, Q3.

الملخص:

هدفت هذه الدراسة إلى استكشاف دور الطاقة النظيفة في تحقيق التنمية المستدامة ومسارات النمو الشامل، مع التركيز على تجربة الجزائر في هذا المجال. تناول البحث مفاهيم وأبعاد النمو الشامل في تحولات الطاقة، وأثر تقنيات الطاقة النظيفة الشمسية، طاقة الرياح، والهيدروجين الأخضرعلى الأداء الاقتصادي والبيئي. كما تم تحليل انبعاثات الغازات الدفيئة في الجزائر بين 1990 و2023، واستعراض الإنتاج الوطني للطاقة المتجددة والمشاريع القائمة، بالإضافة إلى دراسة الأطر السياسية والقانونية لتطوير الهيدروجين الأخضر. كما شملت الدراسة مقارنة للتجارب الدولية الناجحة للاستفادة من أفضل الممارسات العالمية.

أظهرت النتائج أن الطاقة النظيفة تمثل رافعة استراتيجية للنمو الاقتصادي، وتساهم في خلق فرص العمل، وتعزيز العدالة الاجتماعية، وتقليل الانبعاثات البيئية، مما يجعلها أداة أساسية لتحقيق التنمية المستدامة في الجزائر والعالم.

كلمات مفتاحية: الطاقة النظيفة، التنمية المستدامة، طاقة الرياح، الطاقة الشمسية، انبعاثات الغازات الدفيئة، الهيدروجين الأخضر.

تصنيفات JEL : Q3, Q2, Q1

1.INTRODUCTION:

The transition toward renewable energy represents a fundamental pillar in global efforts to achieve sustainable development, in line with the United Nations Sustainable Development Goals, particularly Goal 7 related to affordable and clean energy and Goal 13 related to climate action. These efforts come in response to the growing challenges associated with the global climate crisis, as renewable energy sources such as solar power, wind energy, green hydrogen, and geothermal energy provide effective pathways to reduce carbon emissions from energy systems, while achieving economic gains, enhancing energy security, and promoting social justice.

Recent studies indicate a growing scientific interest in the relationship between the deployment of clean energy and sustainable development, with research focusing on technological innovation, implementation strategies, energy storage solutions, and social justice frameworks. The renewable energy sector has witnessed unprecedented growth over the past decade, driven by the significant decline in the costs of photovoltaic solar technologies and wind energy, in addition to strong public policy commitments and increased private sector investment. Moreover, integrating renewable energy into sustainable development policies is not limited to the environmental dimension alone, but extends to promoting economic development, creating job opportunities, and achieving inclusive access to energy, making it one of the core pillars for achieving inclusive growth at both national and international levels.

Research Problem: The world is undergoing a profound transformation in its energy systems as a result of climate change and increasing environmental and economic pressures, which has led to the emergence of clean energy as a strategic option for achieving sustainable development and inclusive growth. In this context, Algeria finds itself facing the necessity of restructuring its energy sector, diversifying its energy sources, reducing greenhouse gas emissions, and enhancing economic and social performance.

Despite the country's vast natural potential for renewable energy, the energy transition in Algeria still faces challenges related to technology, governance, the legal framework, financing, and the weak integration of clean energy into national growth.

Accordingly, the research problem is formulated around the following main question:

To what extent can clean energy contribute to achieving sustainable development and inclusive growth pathways in Algeria, and what are the economic impacts and environmental benefits of these energies, in light of international experiences and the national political and legal frameworks?

Significance of the Study: The importance of this study stems from the multiple economic, environmental, and social dimensions associated with the topic of clean energy and sustainable development, especially in light of the rapid global transitions toward a low-carbon economy. This importance is even greater for Algeria, as a country that has historically depended on the hydrocarbon sector and is now seeking to diversify its economy, enhance its energy security, and fulfill its climate commitments.

The significance of the study can be summarized as follows:

- Highlighting the relationship between clean energy and inclusive growth;

- Emphasizing the economic and technological dimensions of clean energy by examining solar, wind, and green hydrogen technologies and their impacts on countries' economic and environmental performance;
- Analyzing Algeria's reality in the field of energy transition by providing a comprehensive picture of greenhouse gas emissions and their trends, renewable production capacities, and existing clean energy projects;
- Clarifying the position of green hydrogen as a future strategic option for Algeria and examining the political and legal frameworks governing its development.

Objectives of the Study: This study aims to achieve a set of research objectives related to clean energy and sustainable development, namely:

- Analyzing the concepts, dimensions, and strategies of inclusive growth in the context of energy transitions;
- Evaluating the main clean energy technologies (solar energy, wind energy, and hydrogen energy) in terms of innovation, efficiency, and their economic and environmental impacts;
- Studying the evolution of greenhouse gas emissions in Algeria (1990–2023) and analyzing emission intensity and its relationship with population growth and economic activity;
- Analyzing the reality of renewable energy production in Algeria by reviewing solar and wind energy projects and the national programs associated with them;
- Assessing the status of green hydrogen in Algeria in terms of potential, projects, political and legal frameworks, and prospects for its development as a strategic sector in the energy transition.

2. Theoretical Framework:

Clean energy refers to energy sources that produce electricity or heat with minimal harmful emissions to the environment, especially greenhouse gases such as CO₂ and CH₄. These sources include solar energy, wind energy, hydropower, geothermal energy, green hydrogen, and renewable bioenergy. The main objective of clean energy is to provide energy in a sustainable way that reduces environmental impact and enhances energy security.

2.1 Inclusive Growth in Energy Transitions: Concepts, Dimensions, and Strategies

Inclusive growth refers to economic development that provides opportunities for all segments of society and contributes to reducing poverty and addressing inequalities. It represents an important analytical framework for evaluating energy transitions. The relationship between clean energy and inclusive growth is reflected through several key dimensions and strategic mechanisms, including the following: (Mirela & al, 2024)

- **Energy access and poverty reduction:** Decentralized renewable energy systems enable remote and disadvantaged communities to access electricity, which enhances economic and social development and reduces development gaps.
- **Job creation:** The renewable energy sector contributes to job creation along the entire value chain, including manufacturing, installation, operation, and maintenance, thereby supporting local economic development.
- **Community ownership:** Renewable Energy Communities (RECs) can direct economic benefits directly to local populations, which strengthens sustainable development at the local level.

- **Gender and social justice:** Studies show that improved access to energy has a positive impact on women's well-being and social equality, thereby enhancing inclusion.
- **Rural–urban balance:** Clean energy technologies provide integrated pathways for rural electrification and emission reduction in urban areas, supporting balanced and inclusive development at national and regional levels.

These dimensions show that achieving inclusive growth through energy transitions requires the adoption of multi-level policies and strategies, including supporting renewable energy infrastructure, strengthening community participation, and developing sustainable financing mechanisms, in order to ensure the inclusion of all segments of society in the development process.

2.2 Clean Energy Technologies: A Comprehensive Overview of Innovation, Economic and Environmental Performance

A comprehensive assessment was conducted on the most prominent clean energy technologies, focusing on economic, market, and environmental aspects, in addition to tracking the latest innovations and developments during the period 2020–2025. The analysis includes solar energy, wind energy, and hydrogen energy, which represent the fundamental pillars of the global transition toward sustainable, low-emission energy systems. This evaluation also aims to illustrate how each technology can contribute to sustainable development, support climate policies, and enhance inclusive growth opportunities, while considering the economic and technical challenges associated with their large-scale adoption. (Suriya & al, 2025)

2-1 Solar Energy: Solar energy is one of the most prominent and widely adopted clean energy technologies globally, due to its significant cost reductions and high efficiency in converting sunlight into electricity. This technology also contributes to environmental sustainability and the reduction of carbon emissions, making it a pivotal choice in national and international renewable energy plans. Solar energy exemplifies the power of technological innovation and supportive policies in making renewable energy both economically and environmentally sustainable.

- **Technical Profile and Market Status:** Photovoltaic (PV) solar technologies have experienced a dramatic decrease in costs around 90% since 2010 making them economically competitive with fossil fuel-based electricity in most global markets. Utility-scale solar projects achieve levelized costs of energy (LCOE) below 30–40 USD/MWh.

- **Economic Feasibility:** Solar energy has become a central component of national renewable energy plans worldwide, with rapid adoption especially in Asia and Europe, and growing interest in Africa and Latin America. Key market drivers include:
 - Economies of scale in manufacturing, particularly in the dominant Chinese PV supply chain.
 - Technological improvements in cell efficiency and module durability.
 - Innovative financing models, including power purchase agreements and community solar projects.
 - Supportive policy frameworks, including competitive auctions.

- **Environmental Benefits:** Life cycle assessments show that solar energy reduces emissions by 90–95% per kWh compared to fossil fuels, while also improving air quality and providing health benefits for local communities.

Recent Developments (2020–2025):

- Bifacial solar modules to increase energy output.
- Perovskite and tandem solar cells to enhance efficiency.
- Building-integrated photovoltaics (BIPV) for integrating solar energy into buildings.
- Agrivoltaic systems to optimize land use by combining solar power generation with agricultural activities.

2.2.1 Wind Energy: Wind energy is one of the core pillars of clean energy and plays a pivotal role in global decarbonization efforts. This technology is capable of efficiently generating electricity from both onshore and offshore winds, with continuously declining costs, making it a reliable economic and environmental option. Wind energy also supports climate and development goals by reducing carbon emissions and enhancing opportunities for sustainable economic growth.(Muhammad Shafiq & al, 2022)

- **Technical Profile:** Wind energy is a fundamental component of global decarbonization strategies, with mature onshore and offshore wind technologies achieving competitive economic levels. Advances in turbine design have expanded suitable deployment sites and improved capacity factors.

- **Economic Feasibility:** Wind energy has achieved levelized costs of energy (LCOE) comparable to fossil fuels in many markets, with auction results in several countries showing prices below 30 USD/MWh. The market features mature onshore wind technologies and rapid growth in the offshore wind sector.

- **Environmental Benefits:** Wind energy reduces greenhouse gas emissions by 95–98% compared to coal and is highly suitable for decarbonizing utility-scale operations due to high capacity factors (30–50% onshore, 40–60% offshore).

Recent Developments:

- Larger turbines, with offshore turbines now exceeding 15 MW.
- Floating offshore wind for deployment in deep waters.
- Hybrid projects combining wind, solar, and storage.
- Digitalization: improved forecasting and advanced automation.

2.2.2 Green Hydrogen: Green hydrogen has emerged as a growing strategic technology within the clean energy system, particularly for sectors that are difficult to decarbonize, such as heavy industry, long-distance transport, and seasonal energy storage. Hydrogen offers significant potential for achieving a low-emission economy, reflecting the integration of technological innovation and supportive policies to develop sustainable and efficient solutions for future energy.(Victor & al, 2024)

- **Emerging Role:** Hydrogen has become a strategic priority in decarbonization strategies, especially in sectors that are hard to decarbonize, including heavy industry, long-distance transport, and seasonal energy storage.

- **Economic Potential:** The economic feasibility of green hydrogen depends on the cost of renewable electricity and electrolyzer capital. Projections indicate that parity with gray hydrogen could be achievable at suitable locations by 2030. Several countries have launched national hydrogen strategies with substantial public sector investment commitments.

Applications of Clean Energy and Sustainable Development in Algeria

In recent years, Algeria has been striving to strengthen its energy transition by developing various sources of clean energy, aiming to reduce carbon emissions, decrease dependence on fossil fuels, and achieve sustainable development across its economic, environmental, and social dimensions. In this context, the government has taken several practical measures, including monitoring greenhouse gas emission trends, expanding renewable energy production capacities, increasing reliance on solar and wind energy projects, and initiating the development of the green hydrogen sector as a strategic option for the future.(Rajesh K., 2024)

Analyzing these applications provides a deeper understanding of the success of Algeria's energy policies, through evaluating emission trajectories, measuring the expansion of clean energy projects, and studying the accompanying political and legal frameworks. It also allows for assessing the alignment of current efforts with sustainable development goals and their role in supporting inclusive growth and improving quality of life.

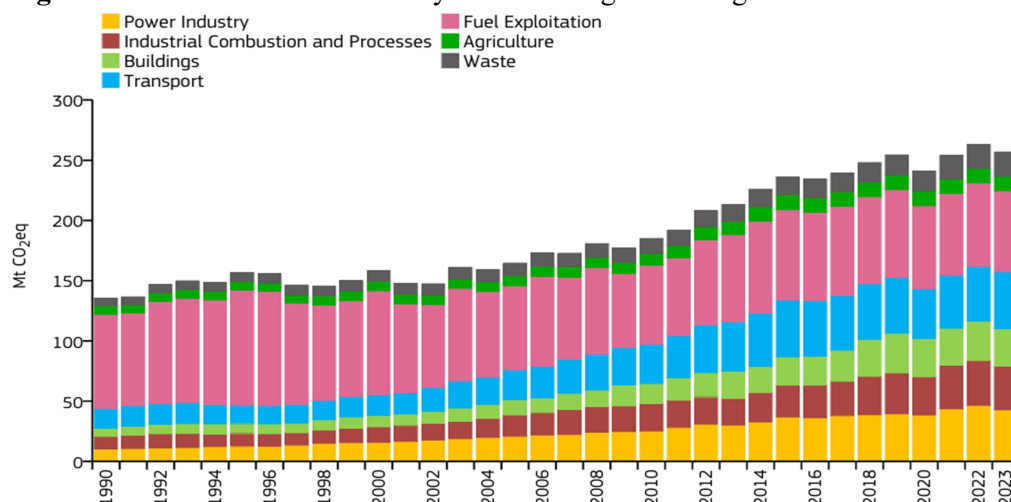
3. Greenhouse Gas Emissions in Algeria

Algeria is one of the largest energy producers in Africa, giving it a significant role in regional and global greenhouse gas (GHG) emission dynamics. This is primarily due to the economy's reliance on hydrocarbons, where the production, processing, and export of oil and natural gas constitute the main sources of these emissions.

Although per capita emissions are relatively high compared to many developing countries, they are closely linked to industrial activities, energy-intensive sectors, and a growing transportation network. From this perspective, the transition to renewable energy and the development of clean energy technologies have become essential tools for reducing emissions while promoting environmental sustainability and inclusive economic growth.

Over the past decade, the Algerian government has adopted national clean energy policies and joined international agreements such as the Paris Agreement, while launching strategies to develop renewable energy, implement solar and wind energy projects, and explore green hydrogen production. Understanding the trends of carbon dioxide, methane, and other greenhouse gas emissions is crucial for evaluating the effectiveness of these policies and guiding the transition toward a low-emission future aligned with the 2025 Sustainable Development Goals.

Fig.1.Greenhouse Gas Emissions by Sector in Algeria during the Period 1992–2023



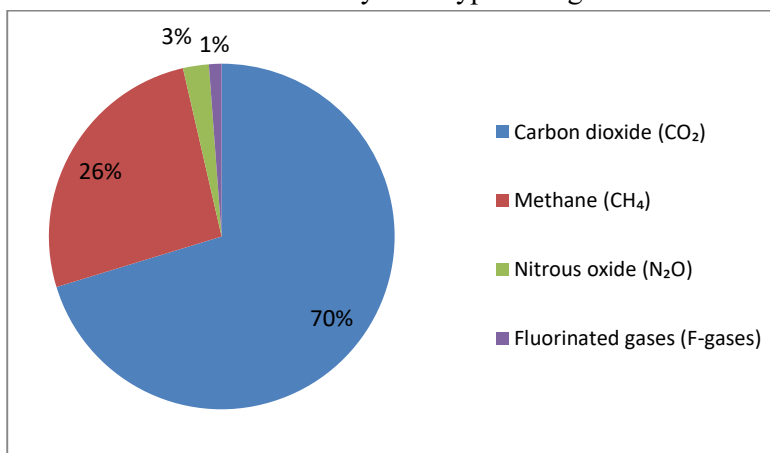
Source:European Commission. (2023). Greenhouse Gas Emissions of all World Countries, p: 56.

This figure illustrates the evolution of greenhouse gas (GHG) emissions in Algeria from 1990 to 2023, broken down by economic sectors. The results indicate a continuous upward trend in emissions, particularly after the early 2000s, with total emissions rising from less than 150 million tons of CO₂ equivalent in 1990 to over 250 million tons of CO₂ equivalent by 2023.

Sectoral analysis shows that fossil fuel exploitation has remained the largest contributor to emissions, reflecting Algeria's reliance on hydrocarbons as an economic driver and primary energy source. Over time, the contributions of the transport, industrial combustion, and industrial processes sectors have increased significantly, especially after 2010, due to the rapid growth in the number of vehicles, industrial expansion, and rising domestic energy demand.

Emissions from the electricity and buildings sectors have also shown notable growth, in line with urbanization and increased electricity consumption. In contrast, emissions from agriculture and waste have remained relatively stable, with a gradual increase observed in recent years, reflecting mounting environmental pressures from population growth and consumption patterns.

Overall, the data indicate a shift in Algeria from a period of relative emission stability during the 1990s to a sharp growth trajectory after 2005, highlighting structural challenges in balancing economic development and environmental sustainability. This underscores the urgent need for diversified energy strategies, technological innovation, and robust environmental policies to reduce future emissions in line with the 2025 Sustainable Development and Clean Energy Goals.

Fig.2.Greenhouse Gas Emissions by Gas Type in Algeria for the Year 2023.

Source:European Commission. (2023). Greenhouse Gas Emissions of all World Countries, p: 56.

Illustrates the composition of greenhouse gas emissions in Algeria for the year 2023 by gas type. The data show that carbon dioxide (CO₂) represents the largest share of emissions, accounting for 70.2% of the total, reflecting the country's heavy reliance on fossil fuel combustion in energy production, industry, and the transport sector.

Methane (CH₄) constitutes 26.1% of emissions and is primarily associated with hydrocarbon exploitation, natural gas systems, and agricultural activities, particularly livestock. Nitrous oxide (N₂O) accounts for 2.4%, mainly arising from agricultural practices and fertilizer use, while fluorinated gases (F-gases) make up only 1.2%, generated by industrial activities and refrigeration systems.

This distribution highlights the dominance of CO₂ as the main driver of Algeria's emissions, while emphasizing the significant role of methane, which, despite its smaller volume, has a higher global warming potential. The composition indicates that focusing on reducing carbon dioxide emissions remains essential, but targeted strategies to curb methane emissions could deliver rapid and tangible climate benefits for Algeria.

Accordingly, by 2025, Algeria aims to expand its capacities in solar, wind, and green hydrogen energy, with these projects serving as key tools to reduce reliance on fossil fuels and substantially lower CO₂ and methane emissions. Large-scale solar projects and wind farms provide clean electricity for industrial and urban sectors, while green hydrogen offers opportunities for energy storage and the decarbonization of heavy industries. This approach reflects the integration of clean energy technologies with emission reduction policies, underscoring the importance of investing in renewable energy infrastructure, improving grid efficiency, and adopting sustainable financing to ensure the achievement of sustainable development and green economy goals in Algeria.

3.1 Trends in Greenhouse Gas Emissions, Emission Intensity, and Population Growth in Algeria (1990–2023)

Table 1 provides data on greenhouse gas emissions in Algeria between 1990 and 2023, including total emissions, per capita emissions, emission intensity, and population figures.

Table 1. Trends in Greenhouse Gas Emissions, Emission Intensity, and Population Growth in Algeria (1990–2023).

Year	GHG emissions Mt CO ₂ eq/yr	GHG emissions per capita t CO ₂ eq/cap/yr	GHG emissions per unit of GDP PPP t CO ₂ eq/kUSD/yr	Population
2023	256.792	5.684	0.367	45.179M
2015	236.184	5.924	0.387	39.87 M
2005	164.488	4.941	0.362	33.288 M
1990	135.530	5.230	0.455	25.912 M

Source: European Commission. (2023). Greenhouse Gas Emissions of all World Countries, p: 56.

The data on greenhouse gas emissions in Algeria from 1990 to 2023 reveal significant trends in total emissions, per capita emissions, emission intensity relative to GDP, and population growth. Over the 33-year period, total greenhouse gas emissions increased markedly from 135.53 million tons of CO₂ equivalent in 1990 to 256.79 million tons in 2023, nearly doubling. This rise is closely associated with the expansion of industrial activity, energy production, and demographic growth.

Population growth has been a key factor, with the population increasing from approximately 25.9 million in 1990 to 45.2 million in 2023. Despite this rise, per capita emissions exhibit a more complex pattern: they were 5.23 tons of CO₂ equivalent per person in 1990, rose slightly to 5.92 tons in 2015, and then declined somewhat to 5.68 tons in 2023. This suggests slight improvements in emission efficiency on a per-person basis or changes in energy usage patterns, despite the increase in total emissions.

Regarding emission intensity relative to economic output, the data show a decrease in greenhouse gas emissions per unit of GDP (measured in tons of CO₂ equivalent per thousand dollars, adjusted for purchasing power parity). In 1990, emission intensity was 0.455 tons per thousand dollars, gradually declining to 0.367 tons per thousand dollars by 2023. This reduction indicates a gradual decoupling between economic growth and emissions, reflecting improvements in energy efficiency and potentially greater adoption of cleaner technologies or energy sources.

3.2 Renewable Energy Production in Algeria

Renewable energy production has become a core component of international efforts to mitigate climate change and transition toward a sustainable energy future. Although it is a fundamental element of sustainable development, the definition of renewable energy varies depending on context and methodology. (Anthony, 2021)

The International Renewable Energy Agency (IRENA) defines renewable energy as “energy derived from natural processes that are replenished at a rate equal to or faster than the rate at which they are consumed.” This definition emphasizes the sustainability aspect of renewable energy by highlighting the renewability of resources such as sunlight, wind, and water.

The European Commission considers renewable energy to include energy generated from biomass and non-fossil renewable sources, including wind, solar, geothermal, and hydro energy. This definition provides a comprehensive overview of the main renewable energy sources recognized in regulatory and policy frameworks.

The World Bank defines renewable energy as “energy generated from naturally replenishing resources that are never depleted.” This concept emphasizes the enduring nature of renewable resources, supporting the idea that they can be used without exhaustion.

Renewable energy provides numerous economic, environmental, and social benefits, including:

- Reducing carbon emissions and air pollution from energy production.
- Enhancing the reliability, security, and resilience of electricity networks.
- Creating jobs through the expansion of renewable energy production and technology manufacturing.
- Lowering energy costs.

Moreover, improving energy efficiency, along with wind and solar energy, is projected to contribute to approximately half of the emissions reductions by 2030 under the Net Zero Emissions (NZE) scenario. These sources are expected to continue reducing emissions beyond 2030. In addition, behavioral changes by citizens and companies could avoid around 1.7 gigatons of CO₂ emissions in 2030, help curb the growth in energy demand, and facilitate the transition to clean energy.

Over the past two decades, Algeria’s renewable energy policy has undergone significant transformations aimed at reducing the country’s reliance on fossil fuels and transitioning toward a more sustainable and diversified energy mix. Currently, Algeria generates a relatively small share of electricity from renewable sources, estimated at approximately 3%, equivalent to 686 MW annually. This includes solar energy (448 MW), hydropower (228 MW), and wind energy (10 MW).

Given the vital role of hydrocarbons in supporting the Algerian economy, the country faces increasing pressure to preserve these resources for export rather than domestic consumption. Analysts warn that if Algeria does not significantly expand its renewable energy capacities by 2035, it may be forced to sacrifice hydrocarbon export revenues to meet the growing domestic electricity demand.

A key milestone in Algeria’s renewable energy journey was the launch of the National Renewable Energy and Energy Efficiency Program in 2011, which set an ambitious target of achieving a total renewable energy capacity of 22 GW by 2030, with a primary focus on solar and wind energy. This program aims to diversify energy sources, enhance energy security, and align with global sustainable development goals. However, progress has been affected by a range of challenges, including implementation difficulties, regulatory obstacles, and financing issues.

The most abundant renewable resources in Algeria are solar, wind, hydropower, and biomass. The desert regions benefit from some of the highest levels of solar radiation globally, with the potential to generate 1,850 to 2,100 kWh per square meter annually, and up to 3,500 sunshine hours per year. Additionally, the 1,300-kilometer Mediterranean coastline experiences wind speeds exceeding 8 meters per second, complemented by winds from the southern Saharan regions.

To accelerate the adoption of renewable energy, Algeria launched a 1,000 MW Solar Energy Project (2023–2027), aiming to install photovoltaic farms in areas with high solar potential. This project is expected to attract both domestic and foreign investments, create employment

opportunities, and increase the share of solar energy in the national grid. However, challenges remain regarding grid integration, financing, and the shortage of skilled labor.

In addition to solar energy, Algeria's Wind Energy Development Plan (2020–2030) targets a capacity of 5 GW by 2030, focusing on high-wind regions such as Adrar, Tindouf, and Ghardaia. Despite the significant potential, the development of large-scale wind farms has been slow, with a limited number of operational projects, such as the Caperten Wind Farm (2014), which faces technical, financial, infrastructural, and regulatory challenges.

By 2035, Algeria aims for renewable sources, particularly solar energy, to contribute 27% of national electricity production. In 2021, the government intensified efforts to strengthen strategic partnerships with countries such as China, Germany, and the United States, focusing on engineering services, storage technologies, solar tracking systems, quality certification, and agricultural applications of solar energy. A tender was also launched in 2021 for a 1 GW solar project, consisting of five power plants ranging from 50 to 300 MW each. Additionally, Sonatrach, the national oil company, is investing in large-scale solar projects to power off-grid oil and gas processing facilities, replacing fossil fuel-based energy.

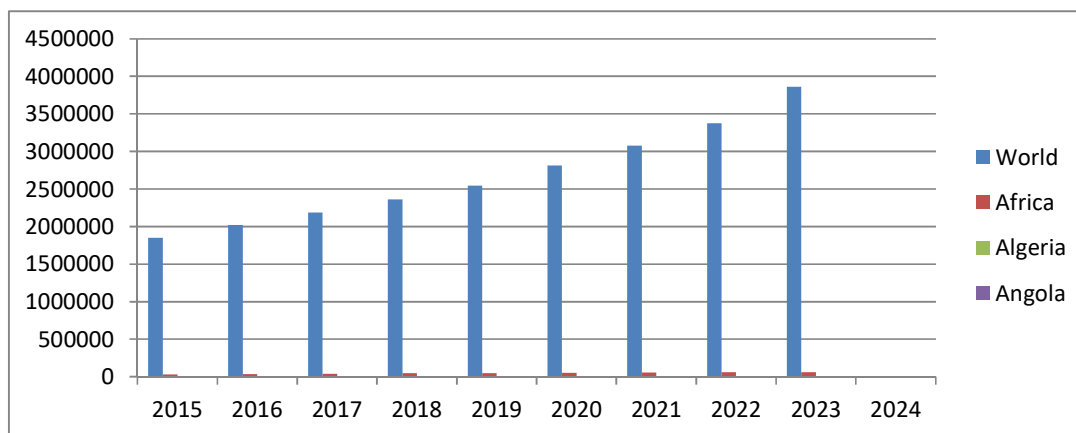
The renewable energy sector in Algeria is dominated by state-owned companies, notably Sonatrach, Sonelgaz (the national electricity utility), and the Algerian Energy Company (AEC), a joint venture between Sonatrach and Sonelgaz. Foreign companies, particularly from the United States, also participate through SHAEMS, the joint Sonatrach-Sonelgaz company serving as an integrated hub for large independent power producer projects. Future tenders are expected to involve these entities primarily. Other active government bodies in renewable energy include the Ministry of Environment and Renewable Energy, the Ministry of Energy and Mines, and the Regulatory Commission for Electricity and Gas.

Long-term power purchase agreements (PPAs), often up to 20 years, are commonly used, with most projects awarded through reverse auctions favoring the lowest bids. Sonatrach typically structures contracts according to a Build-Transfer-Operate model.

International companies from Germany, China, Italy, Egypt, Spain, and the United Kingdom also participate in Algeria's renewable energy market. Some foreign investors have established local manufacturing facilities and enjoy preferential access to tenders. Furthermore, strategic government agreements facilitate the entry of foreign technologies and services, paving the way for broader international participation in Algeria's transition to renewable energy.

Fig.3.Total Installed Renewable Energy Capacity

(MW).



Source: International Renewable Energy Agency. (2025). Statistics Bank. Abu Dhabi.p:54.

The graph of total renewable energy capacity for the period 2015–2024 shows a clear and accelerated global trend, with capacities nearly doubling between 2015 and 2023 and stronger annual increases observed after 2019. This trend reflects significant cost reductions and supportive policies, with no evident slowdown during the pandemic years.

In contrast, the African continent exhibits relatively modest growth from a very low base, highlighting a significant gap compared to the global total. This is due to structural constraints such as limited grid capacities, financing difficulties, and a low project pipeline.

At the country level, some African nations have achieved gradual progress through small-scale hydropower expansions. However, Algeria's growth in renewable energy has remained nearly stagnant during this period, falling short of exploiting its substantial solar and wind potential.

3.2.1 Solar Energy Projects in Algeria: Algeria possesses significant solar potential, with an average annual solar radiation in the desert regions of approximately 2,650 kWh per square meter. Key solar energy projects include: (Greenhouse Gas Emissions of all World Countries)

- **HassiR'mel Hybrid Plant (2011):** Algeria's first hybrid (solar-gas) power plant, featuring a 25 MW solar component.

- **Algerian Photovoltaic Solar Program (2015–2030):** Aims to install 13.6 GW of solar energy by 2030.

- **1,000 MW Solar Energy Project (2023–2027):** Launched in 2023 to develop large-scale photovoltaic farms in multiple regions.

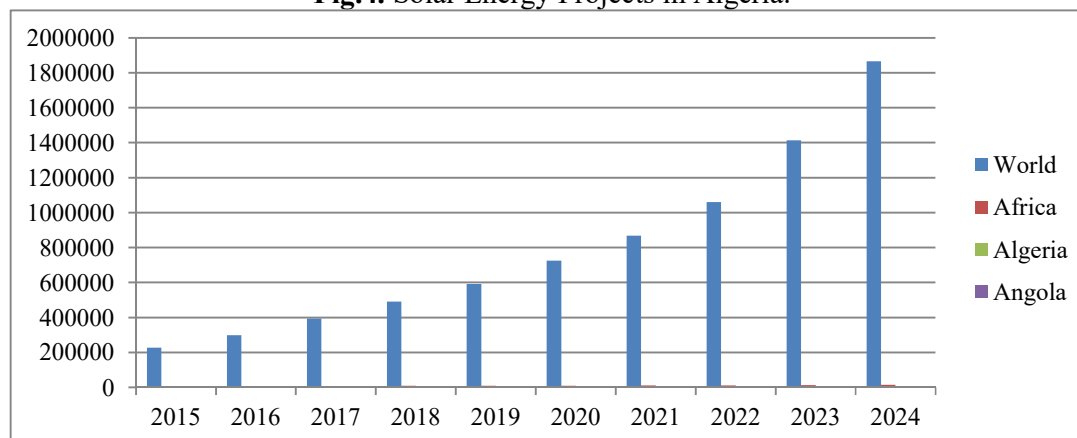
Despite these ambitious targets, solar energy development in Algeria faces several challenges:

- **Slow implementation:** Project delays due to administrative bottlenecks.

- **Investment barriers:** Limited private sector participation due to unclear regulatory frameworks.

- **Grid integration issues:** Weak electricity grid infrastructure, constraining large-scale solar expansion.

Fig.4. Solar Energy Projects in Algeria.



Source: International Renewable Energy Agency. (2025). Statistics Bank. Abu Dhabi. P: 54.

The figure above, illustrating solar energy projects globally between 2015 and 2024, shows rapid growth, with global installed capacity nearly tenfold. This reflects declining technology costs, strengthened policy incentives, and international commitments to decarbonization.

In contrast, Algeria's contribution remains almost negligible on the global scale, despite being among the countries with the highest solar radiation potential in the world. While global actors, particularly in Asia, Europe, and North America, have successfully made solar energy a central pillar of their renewable strategies, Algeria continues to face bureaucratic hurdles, financing constraints, and slow implementation of its national renewable energy programs.

The National Renewable Energy and Energy Efficiency Program, along with the recently launched 2035 Energy Transition Strategy, set ambitious targets, including the installation of up to 15,000 MW of solar energy. However, actual expansion by 2024 has remained very limited.

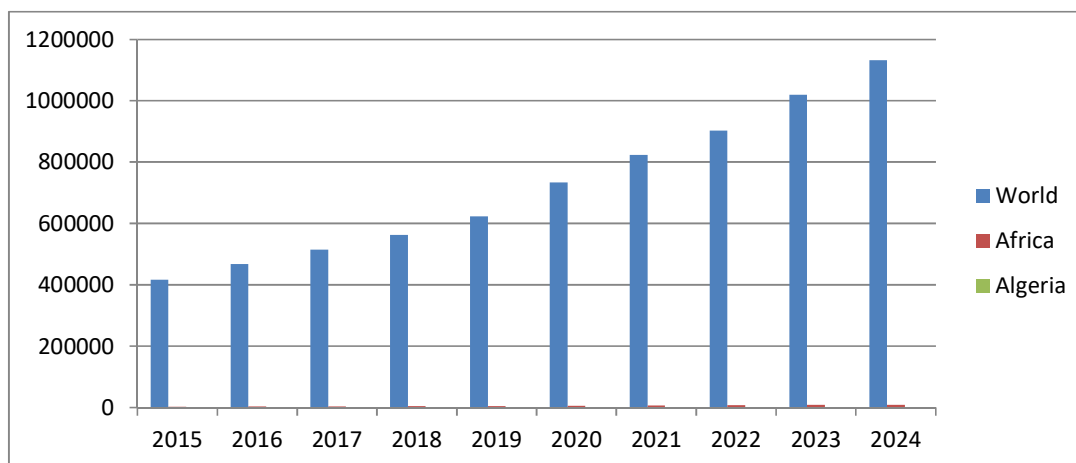
This gap between Algeria's true potential and its actual performance highlights the country's structural challenges in aligning national policies with global renewable energy trends. To bridge this gap, Algeria needs to strengthen institutional coordination, attract private and foreign investments, and accelerate the implementation of large-scale solar tenders. Doing so would enable the country to transform its natural comparative advantage into a driver for sustainable economic growth and energy security.

3.2.2 Wind Energy Projects in Algeria: Algeria's wind energy potential is estimated at approximately 35 GW, particularly in the high plateau and desert regions. Key wind energy projects include:(Younes & al, 2021)

- Caperten Wind Farm (2014): Algeria's first operational wind farm, with a capacity of 10 MW, located in Adrar.
- Wind Energy Development Plan (2020–2030): Targets 5 GW of wind energy capacity by 2030.
- Planned Wind Farms (2025–2030): New projects in Tindouf, Naama, and Béchar aimed at expanding the contribution of wind energy.

Barriers to Wind Energy Expansion:

- **High upfront costs:** Wind farms require substantial initial investments.
- **Technical constraints:** Advanced wind turbine technologies and skilled labor are needed.
- **Policy gaps:** Lack of consistent government incentives to support wind energy development.

Fig.5. Wind Energy Projects in Algeria

Source: International Renewable Energy Agency. (2025). Statistics Bank. Abu Dhabi. P: 54.

3.2.3 Green Hydrogen in Algeria: Algeria possesses enormous potential in clean energy and seeks to leverage these natural resources as part of its energy transition strategy, particularly through the development of green hydrogen production technologies. Algeria is among the sunniest countries globally, benefiting from approximately 3,000 hours of sunlight annually, making it one of the top countries worldwide in terms of solar energy potential. Wind energy potential is estimated at around 35,000 MW, in addition to abundant water resources and a geographic location close to the European market, which enhances opportunities to use renewable energy for green hydrogen production. These conditions provide a strong basis for producing green hydrogen through electrolysis. In 2022, Algeria launched its National Hydrogen Strategy, aiming to develop a green hydrogen-based economy, with plans to produce and export between 30 to 40 TWh by 2040, meeting approximately 10% of the European market's demand. Approximately 300,000 tons of green hydrogen production have been allocated to meet domestic demand, which would allow saving between 16.4 and 38.2 billion cubic meters of natural gas during 2035–2040, equivalent to around 9.1\$ to 21.2\$billion. The cost of producing one kilogram of green hydrogen is currently estimated between \$3 and \$6, with expectations to decrease to 1.2\$–2\$in the future. Algeria's National Hydrogen Strategy is structured around three main phases:

- **Formation Phase (2023–2030):** Implementation of short-term pilot projects with capacities ranging from 2 to 50 MW to test production and utilization technologies.
- **Expansion Phase and Development of National and International Markets (2030–2040).**
- **Global Competition Phase through Manufacturing and Export (2040–2050).**

The strategy relies on integrating renewable energy into hydrogen production, with **solar** energy contributing approximately 70% and wind energy 30% of the electricity required for electrolysis. The Algerian government is investing in research and development to enhance hydrogen technologies and support the necessary infrastructure, with projected investments of

approximately 25–30\$ billion by 2040, and potential annual export revenues reaching up to 10\$billion.

In line with this strategy, Algeria has launched several short-term pilot projects with capacities between 2 and 50 MW to test production and utilization technologies, followed by the expansion and market development phase (2030–2040), and then the global competition phase through manufacturing and export (2040–2050).

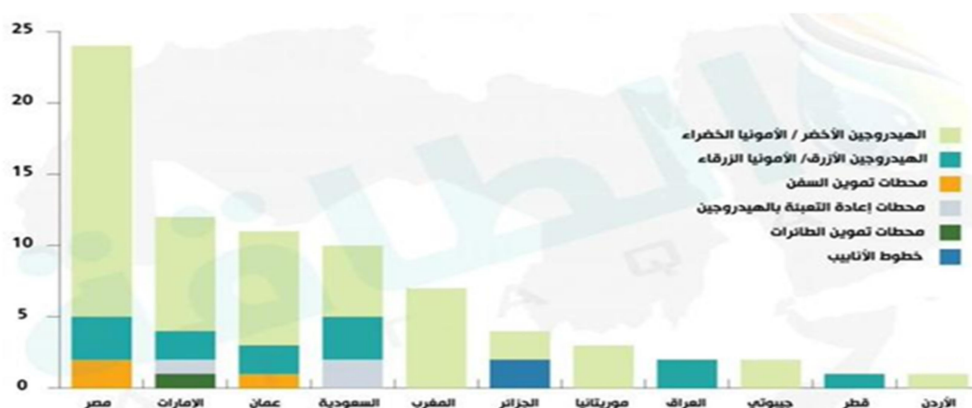
In this context, Algeria has launched several pilot projects in collaboration with European companies aimed at testing production technologies and building a future production base. Among the most notable projects is the HassiR'mel Solar Hydrogen Project, targeting the production of 1.5 million tons of green hydrogen annually by 2030, which is expected to reduce carbon emissions by approximately 10 million tons per year, equivalent to removing around 2.1 million cars from the roads.

Additionally, a 50 MW demonstration project was launched with German participation, valued at 35 €million, as part of technology transfer efforts and national capacity building. Algeria is seeking to establish strategic partnerships with European countries such as Germany and France to develop green hydrogen projects, including cooperation in technology transfer, investment, and infrastructure development.

However, several challenges remain, the most significant being insufficient infrastructure for hydrogen production, storage, and distribution, requiring substantial investment in related facilities. Nevertheless, these initiatives represent a real opportunity to diversify the Algerian economy away from hydrocarbons, through the creation of new jobs, the promotion of technological innovation, and attracting foreign investment, thanks to Algeria's abundant renewable resources and strategic location.

Estimates indicate the potential creation of around 100,000 direct and indirect jobs in the renewable energy and hydrogen sectors.

Fig.6.Green Hydrogen Production Projects in Arab Countries as of March 2025



Source: Yasser Nasser, 2023, OPECReveals Major Arab Hydrogen Projects and the List of Key Players, Energy Research Unit.

4. Political and Legal Frameworks for the Development of Green Hydrogen in Algeria

In recent years, Algeria has adopted a strategic orientation toward the development of green hydrogen, considering it one of the future pillars for diversifying the economy and promoting the energy transition. To support this approach, the state has established political and legal frameworks to regulate hydrogen production activities and define their pathways, through a set of programs, policies, and regulatory decrees.

4.1 Political and Legal Frameworks for Green Hydrogen Development in Algeria

4.1.1 Political Framework:

- **National Renewable Hydrogen Strategy (2023–2040):** The National Hydrogen Strategy was officially announced in 2023, aiming to transform Algeria into a regional and international hub for green hydrogen production and export. The strategy is based on three main pillars:

Industrial Development: Establishing large-scale hydrogen production projects.

Attracting Foreign Investment: Forming partnerships with countries such as Germany, Spain, the Netherlands, and Italy.

Domestic Use: Integrating hydrogen into transport, industry, and clean energy applications.

National Energy Transition Policy (NEP): This policy focuses on reducing dependence on fossil gas and expanding renewable energy capacity to reach 15,000 MW by 2035. Green hydrogen is considered a core pillar for implementing the energy transition.

4.1.2 Legal and Regulatory Framework:

- **Establishment of the National Hydrogen Agency (under development):** The Ministry of Energy announced the creation of a national agency responsible for drafting hydrogen-related legislation, issuing project licenses, and regulating investments and partnerships. This agency represents the most significant legal step, with its executive decree expected to be issued officially.

- **Investment and Renewable Energy Decrees:** Although there is currently no dedicated hydrogen law, the legal framework relies on:

- **Investment Law 22-18 (2022):** Provides tax and customs exemptions for hydrogen projects.

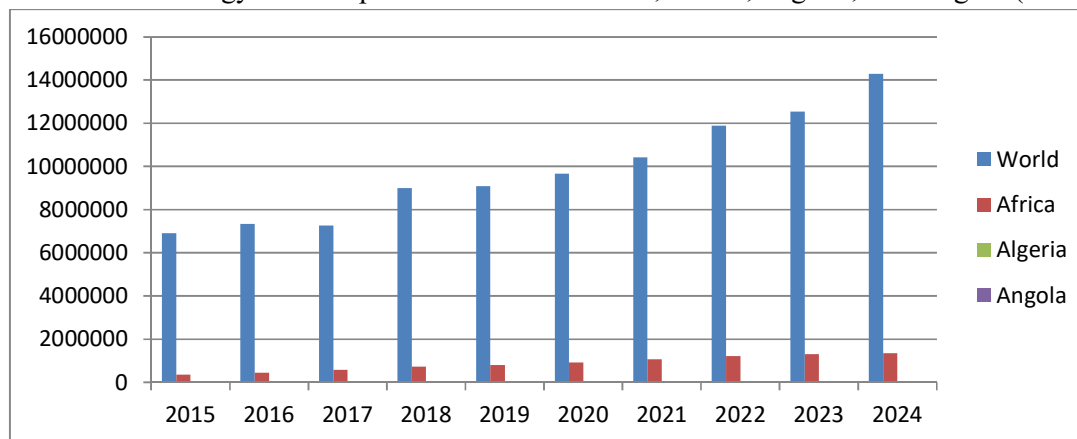
- **Executive decrees for renewable energy:** Regulate energy land allocation, preferential taxation, foreign partnerships, and classify hydrogen projects as nationally prioritized.

- **Regulatory Framework for Transport and Export:** Algeria is developing specific legislation to govern: Hydrogen transport via pipelines, Hydrogen liquefaction and export, Integration into gas networks (initially allowed at 10% according to technical studies). Joint legislation with the European Union is expected to ensure that Algerian hydrogen meets European standards.

4.1.3 Off-Grid Renewable Energy in Algeria: Due to Algeria's vast and diverse geography, providing reliable electricity to remote and rural areas not connected to the main grid remains a major challenge. Off-grid renewable energy solutions, such as photovoltaic (PV) solar systems and small wind turbines, play a vital role in supplying these areas with clean and sustainable energy.

These decentralized systems help improve energy access, support local development, and reduce reliance on fossil fuels. As Algeria continues to expand its renewable energy capacity, off-grid energy projects are becoming increasingly important as a key element for achieving energy equity and promoting sustainable growth across the country.

Fig.7.Evolution of Energy Consumption/Production: World, Africa, Algeria, and Angola (2015–2024)



Source: International Renewable Energy Agency. (2025). Statistics Bank. Abu Dhabi. P: 54.

5. Renewable Energy and Environmental Investment Program in Algeria 2025

Algeria aims to expand its renewable energy capacity in response to national and international sustainable development targets and emissions reduction goals. The national renewable energy program focuses on exploiting solar and wind potential, with the objective of adding 13.5 GW of solar energy by 2030 through independent power producer projects, developing the legal and regulatory infrastructure, and building the capacity of public institutions to manage projects.

Regarding project financing, national and international funds, such as the Sustainable Energy Fund for Africa and MIC TAF, provide technical and financial support, along with legal advisory services to ensure bankable and fundable projects. The program seeks to increase private sector participation, reduce emissions, and create jobs, while emphasizing the integration of solar, wind, and green hydrogen projects into the national grid.

In terms of public environmental spending, Algeria allocated approximately 1.3–1.5% of its general budget to environmental and energy sectors, supporting waste management programs, biodiversity protection, and encouraging the adoption of environmental management systems such as ISO 14001. However, direct funding for renewable energy remains relatively low, accounting for only 0.09% of the national budget in 2023–2024, compared to the planned target of achieving 27% of electricity from renewable sources by 2030.

Consequently, the current situation indicates a need to strengthen investment in renewable energy infrastructure, accelerate the implementation of major projects, and develop regulatory and financing frameworks to ensure that Algeria achieves its clean energy and green economy objectives by 2030 and beyond.

6. Successful International Experiences in Clean Energy

Clean energy has experienced rapid development globally, becoming a key driver of sustainable development and emission reduction. Countries are adopting innovative policies and strategies to stimulate innovation in this sector while balancing economic growth and environmental protection. Studying successful international experiences provides a framework for understanding

best practices and identifying policies that can be adapted to the needs of other countries, including Algeria.

- **Germany:** The German energy transition (Energiewende) offers important lessons, including long-term political commitment, the adoption of feed-in tariffs followed by auction mechanisms, a focus on distributed generation with citizen participation, and the expansion of electricity networks. Achievements include renewable electricity accounting for more than 50% by 2023 and a significant reduction in costs. Challenges include high electricity prices, grid integration issues, and the slow phase-out of coal.

- **Denmark:** Denmark is a leader in wind energy, generating more than 80% of its electricity from renewable sources. Success factors include early political support, cooperative ownership traditions, strategic spatial planning, and leadership in offshore wind energy.

- **Spain:** Spain experienced rapid growth due to feed-in tariffs, followed by a slowdown caused by regressive political changes, and then renewed acceleration through auction mechanisms.

- **China:** China achieved unprecedented expansion, surpassing 1,200 GW of renewable energy capacity by 2023. Enabling factors include state-led industrial policy, dominance in manufacturing, massive grid expansion, and extensive government financing. The country's huge manufacturing capacity contributed to global cost reductions.

- **India:** India aims to reach 500 GW of renewable capacity by 2030 through competitive auctions, solar parks, rooftop solar programs, and green hydrogen initiatives. Achievements include auction prices below \$20/MWh and improved electricity access through decentralized solar solutions.

- **United States:** Renewable transition is driven by a mix of state-level renewable energy standards, federal tax credits, and corporate power purchase agreements, despite inconsistent federal policies.

- **Morocco:** Morocco relies on an ambitious strategy targeting 52% renewable electricity by 2030, implemented through MASEN, large-scale solar projects, and an export-oriented vision. Morocco has already achieved over 40% renewable electricity, making it a regional leader.

- **Kenya:** Kenya has invested in geothermal energy and pioneered pay-as-you-go household solar systems, achieving more than 90% renewable electricity.

- **South Africa:** The REIPPPP program is a successful example of competitive auctions with socio-economic conditions and standardized contracts. The program has procured over 7 GW and attracted significant foreign investment.

- **United Arab Emirates and Saudi Arabia:** Gulf countries rely on large-scale solar projects and hydrogen strategies to diversify their economies. The UAE has achieved record-low auction prices below \$15/MWh. Saudi Arabia, through Vision 2030, aims to generate 50% of electricity from renewable sources and develop a green hydrogen project in NEOM.

It can be observed from these experiences that there are common success factors that enhance the effectiveness and sustainability of the transition to clean energy:

Clear and long-term objectives: These provide a stable strategic vision for investors and governments, facilitating project planning and efficient allocation of resources.

- **Stable political frameworks:** They are essential to ensure the continuity of national programs and to reduce risks associated with sudden changes in policies or legislation, thereby strengthening the confidence of the private sector and foreign investors.
 - **Transparent competitive procurement mechanisms:** These attract investments by providing fair opportunities for both local and international developers, while encouraging cost reduction and improving project implementation efficiency.
 - **Sufficient grid and transmission capacity:** This is necessary to ensure the efficient integration of renewable energy sources into the national grid and to avoid energy losses or instability in electricity supply.
 - **Technical competencies in government institutions, local content policies, and community engagement:** These factors support the development of local skills, enhance economic development, and ensure social acceptance of new technologies.
- Together, these factors constitute a comprehensive framework for the successful implementation of clean energy programs at both national and international levels.

7. Conclusion

This study emphasizes the pivotal role of clean energy in achieving sustainable development and inclusive growth, both globally and within the specific context of Algeria. The analysis shows that the transition to renewable energies such as solar power, wind energy, and green hydrogen not only reduces carbon emissions and protects the environment but also serves as an economic driver by creating job opportunities, enhancing social equity, and contributing to a balanced development between rural and urban areas.

In Algeria, despite challenges related to infrastructure, policies, and legislation, the state has adopted clear programs and strategies for developing clean energy. These include solar and wind energy projects, as well as plans for green hydrogen development within the national political and legal frameworks. Furthermore, studying successful international experiences provides valuable lessons that can be leveraged to accelerate the energy transition and maximize the use of renewable natural resources.

The study concludes that achieving sustainable development goals is directly linked to continuous investment in clean technologies, strengthening legal and policy frameworks, and integrating national efforts with international expertise. From this perspective, clean energy is not only an environmental choice but also a strategic lever for economic and social growth, paving the way for a more sustainable future for Algeria and the world alike.

8. References:

- Anthony, P. (2021). Enabling frameworks for sustainable energy transition. London: Commonwealth Secretariat.
- Greenhouse Gas Emissions of all World Countries. (2023). European Commission.
- Mirela, D., & al, e. (2024). Towards renewable energy transition: Insights from bibliometric analysis on scholar discourse to policy actions. *Energies Journal* , 17 (18).

- Muhammad Shafiq, M., & al, a. (2022). A comprehensive analysis of the power demand supply situation, electricity usage patterns, and the recent development of renewable energy in China. *Sustainability* , 14 (06).
- Rajesh K., A. (2024). *Powering tomorrow: Pioneering trends in sustainable energy innovation*. India: Iterative International Publishers.
- Suriya, P., & al, e. (2025). , “Policy and socio-economic impacts of renewable-integrated smart grids in developing economics,” , vol. 2, no. 4, 2025. *International Journal of Educational Practices and Engineering* , 02 (04).
- Victor, A., & al, a. (2024). The role of renewable energy in achieving sustainable development goals. *International Journal of Engineering Research Updates* , 07 (02).
- Younes, Z., & al, a. (2021). Current status, scenario, and prospective of renewable energy in Algeria: A review. *Energies* , 14 (09).