ENERGY SECURITY IN ALGERIA: BETWEEN DEPENDENCE ON HYDROCARBONS AND ENERGY TRANSITION
LA SÉCURITÉ ÉNERGÉTIQUE EN ALGÉRIE : ENTRE DÉPENDANCE AUX HYDROCARBURES ET TRANSITION ÉNERGÉTIQUE

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Abstract

This article analyzes energy security in Algeria, which faces dependence on hydrocarbons and the challenges of the energy transition. Using an analytical approach combining a literature review and statistical data, it examines trends in energy consumption and production, the role of natural gas, and the prospects for renewable energy. The findings indicate that rising domestic demand and stagnant exports weaken energy security. The study highlights the need for infrastructure investments and an integrated energy policy to ensure a controlled transition.

***Keywords**: Energy security, Energy transition, Hydrocarbons, Natural gas.*
***JEL Codes :** Q41, Q43, Q48.*

Résumé

Cet article analyse la sécurité énergétique de l'Algérie, qui fait face à la dépendance aux hydrocarbures et aux défis de la transition énergétique. En utilisant une approche analytique combinant une revue de la littérature et des données statistiques, il examine les tendances de la consommation et de la production d'énergie, le rôle du gaz naturel et les perspectives des énergies renouvelables. Les résultats indiquent que la demande intérieure croissante et des exportations stagnantes fragilisent la sécurité énergétique. L'étude souligne la nécessité d'investissements dans les infrastructures et d'une politique énergétique intégrée pour assurer une transition maîtrisée.
***Mots-clés :** Sécurité énergétique, Transition énergétique, Hydrocarbures, Gaz naturel.*
***Codes JEL :** Q41, Q43, Q48.*

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Introduction

Energy security is at the heart of global economic, geopolitical, and environmental challenges. For resource-producing countries, it represents a strategic challenge, heightened by disruptions such as the Russo-Ukrainian conflict, the acceleration of global energy transitions, and increasing pressures related to environmental commitments. Algeria, a major player in the global energy market, faces a dual challenge: ensuring its energy security while initiating a transition toward a more sustainable energy model.

Since the 1970s, the Algerian economy has relied primarily on its fossil resources, particularly natural gas, which accounts for nearly 60% of its primary energy production. While this dependency is strategic, it also comes with significant challenges: rapidly growing domestic consumption, declining net exports, aging infrastructure, and increasing pressure to reduce greenhouse gas emissions. These issues have taken on critical environmental and social dimensions, especially in the context of Algeria's international commitments. As a signatory to the Paris Agreement in 2016, Algeria is striving to diversify its energy sources and strengthen its sustainability policies.

As the world progressively shifts toward renewable energy to meet international climate requirements, Algeria must adapt its economic and energy model. However, this transition is complex and must balance several imperatives, including reducing carbon emissions, meeting the growing energy needs of an expanding population, and maintaining social stability. Furthermore, energy transition requires collective mobilization, where non-state actors—such as businesses, civil society, and research institutions play a crucial role as catalysts for innovation and awareness.

In this context, a key question arises: how can Algeria ensure sustainable energy security while reducing its dependence on hydrocarbons and integrating more renewable energy sources? We hypothesize that, although the energy transition is hindered by institutional and economic challenges, natural gas remains a strategic lever that can reconcile energy security with the gradual diversification of the energy mix.

On the methodological level, this article combines qualitative and quantitative approaches. It relies on official statistics from the Ministry of Energy and Mines, the Bank of Algeria, Sonatrach, and international organizations such as the IEA, OPEC, and the World Bank, covering the period 2000–2023. The analysis mobilizes time series on production, consumption, exports, and external revenues, complemented by international comparisons (e.g., with Norway, Qatar, and other hydrocarbon-dependent countries). It also draws on academic literature on energy security, hydrocarbon dependence, and energy transition, allowing empirical findings to be discussed in light of theoretical contributions.

Building on this methodological framework, the article is structured into five sections. The first section provides an overview of energy security and current dynamics. The second section analyzes Algeria's dependence on hydrocarbons and the resulting economic vulnerabilities. The third section explores the opportunities and challenges of the energy transition, while the fourth highlights the role of natural gas in this process. Finally, the fifth section proposes strategies and perspectives to ensure sustainable energy security for Algeria.

1. Energy security in Algeria: Current status and dynamics

Algeria is undergoing profound energy transformations, driven by rising consumption, evolving production, and challenges related to exports. In a context marked by dependence on hydrocarbons and an emerging energy transition, it is essential to analyze the dynamics shaping the country's energy security.

1.1. Domestic energy consumption

Domestic energy consumption in Algeria has experienced a significant increase over the past two decades. As shown in Figure 1 below, national energy consumption rose from 30.12 million tons of oil equivalent (MTOE) in 2000 to 72.2 MTOE in 2023, representing an increase of more than 140%.

Several factors explain this rapid growth. Demographic expansion is one of the main drivers, with Algeria's population increasing from 40.8 million in 2016 to 46.6 million in 2023 (World Bank, 2025). This growth has led to a rising demand for energy, particularly in the residential sector for electricity, heating, and air conditioning.

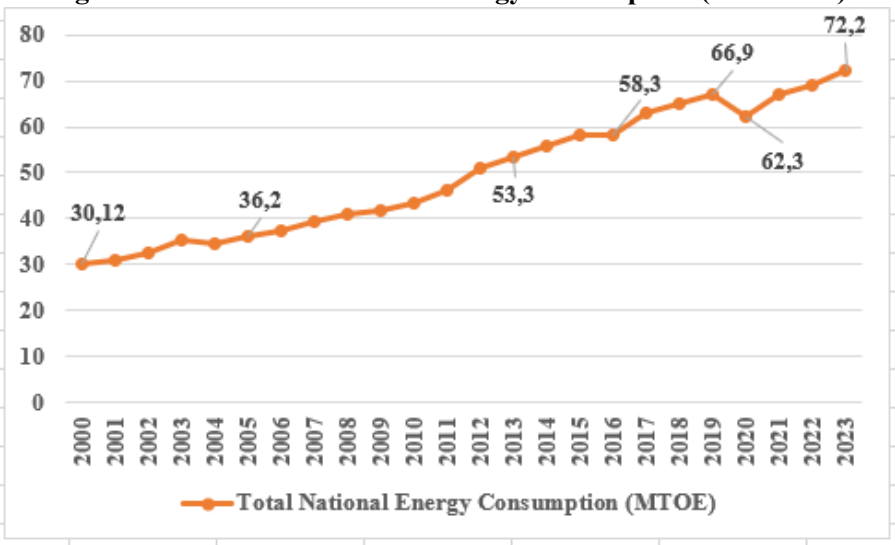
At the same time, economic development and gradual industrialization, combined with increasing motorization, have amplified energy needs in the industrial and transport sectors. However, despite efforts to diversify the energy mix, Algeria remains highly dependent on hydrocarbons to meet its domestic energy needs.

This consumption model, characterized by high energy intensity, limits the system's long-term sustainability. While widespread energy subsidies have ensured energy accessibility for the population, they have also encouraged excessive consumption and hindered the adoption of more energy-efficient practices or the integration of renewable energy sources (Mousli, 2019).

Compared to other energy-producing countries such as Iran or Saudi Arabia, Algeria faces greater structural vulnerability. For instance, in 2023, Iran (90 million inhabitants) consumed 270 MTOE, while Saudi Arabia (35 million inhabitants) consumed 320 MTOE. However, these countries have implemented pricing reforms and invested in diversified infrastructure, contrasting with Algeria's model, which still struggles with low energy efficiency and significant pressure on natural resources (Institut Sapiens, 2024).

This trend suggests that Algeria's current trajectory is unsustainable in the medium term: the combination of rapid demographic growth, subsidies that discourage efficiency, and the absence of large-scale renewable integration creates a systemic vulnerability. Unless corrective measures are taken, the country risks facing energy shortages, fiscal strain due to growing subsidies, and rising social tensions linked to energy access.

Figure 1. Evolution of national energy consumption (2000-2023)



Source: Prepared by the authors based on MEM reports.

1.2. Commercial Production of Primary Energy

The evolution of commercial production of primary energy shows a fluctuating trajectory between 2000 and 2023. After reaching a historical peak of 179.7 MTOE in 2005, production gradually declined, stabilizing around 165 MTOE between 2016 and 2023, before experiencing a slight rebound to 170.3 MTOE in 2023.

The structural challenges of Algeria's energy sector are numerous. The maturity of oil and gas fields, which have been exploited for several decades, limits production capacities without the use of advanced recovery technologies. Furthermore, the lack of foreign investment and technological modernization hampers the exploration of new fields and the development of additional capacities.

Global economic crises, such as the one in 2009, as well as disruptions caused by the COVID-19 pandemic in 2020, have also impacted production volumes.

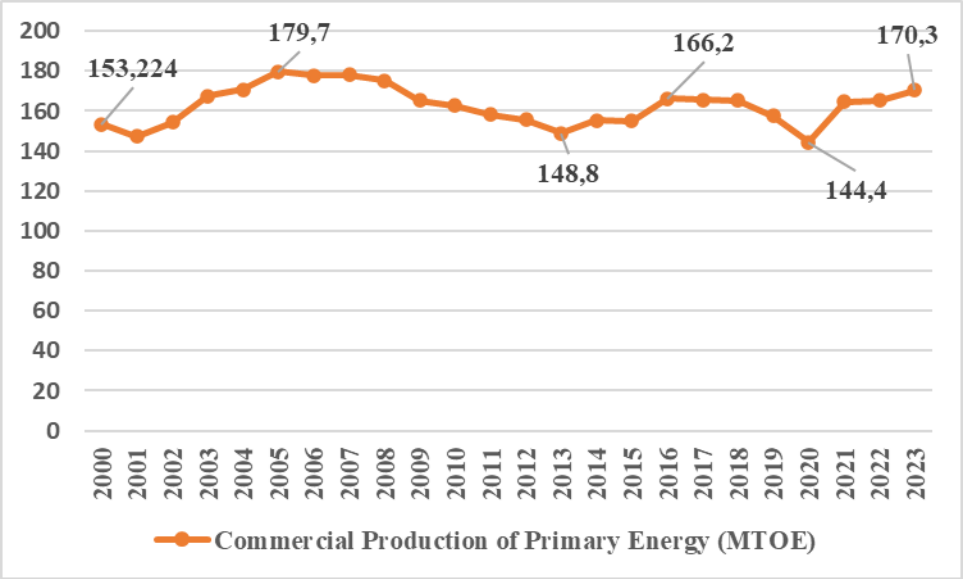
International comparisons highlight the importance of proactive resource management. Qatar, for example, has implemented a strategy of massive investments and strategic partnerships, increasing its liquefied natural gas production to nearly 300 MTOE in 2023 (Agence France-Presse, 2023). Similarly, Norway has maintained a stable production of around 220 MTOE through efficient management and a successful diversification of its energy mix.

For Algeria, it is imperative to undertake structural reforms, modernize its energy infrastructure, and invest in innovative technologies. Diversifying the energy mix by integrating more renewable energy sources is crucial to strengthening energy security and ensuring the sustainable management of resources.

This stagnation in production illustrates a critical paradox: while domestic consumption is rapidly rising, output has plateaued, thereby reducing export capacity and threatening fiscal stability. Unlike Qatar or Norway, Algeria's limited technological modernization and restrictive investment framework have prevented it from converting its resource wealth into

long-term productive capacity. This mismatch between rising demand and constrained supply constitutes one of the central risks to Algeria's energy security.

Figure 2. Evolution of commercial production of primary energy (2000-2023).



Source: Prepared by the authors based on MEM reports.

1.3. Energy exports

According to Figure 3, Algeria's primary energy exports have followed a downward trend between 2000 and 2023, decreasing from 124.2 MTOE in 2000 to 96.9 MTOE in 2023.

This decline can be attributed to several factors, notably a growing domestic consumption driven by demographic growth and the energy-intensive nature of the residential and industrial sectors.

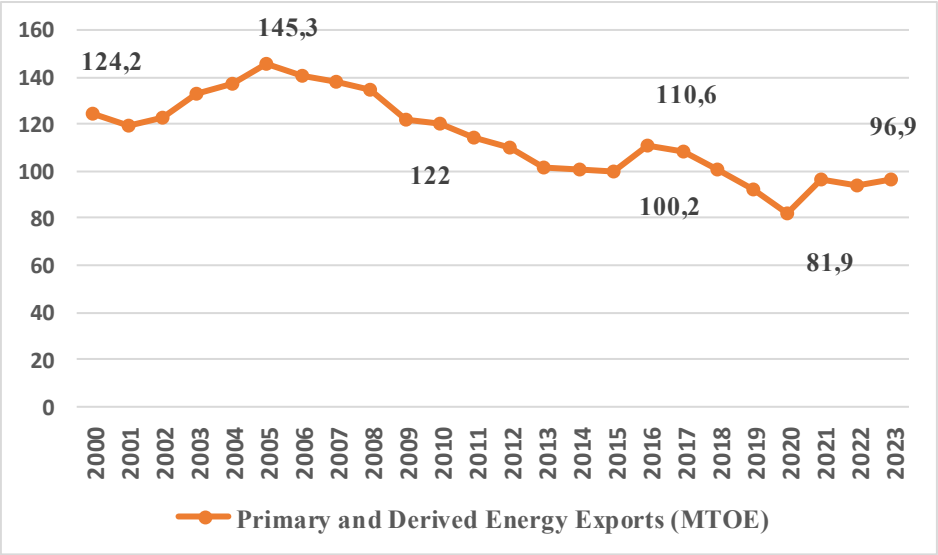
At the same time, international competition has intensified with the emergence of new players, such as the United States, thanks to its shale gas production, thereby reducing Algeria's market share. Global economic shocks, such as the 2009 financial crisis and the COVID-19 pandemic in 2020, have also exacerbated this trend, leading to a historic low in exports at 81.9 MTOE in 2020, before a moderate recovery in 2023.

In comparison, Qatar and Saudi Arabia have managed to navigate this context more effectively. Qatar reached approximately 114 billion USD in hydrocarbon exports in 2022, 75% of which came from gas, mainly LNG, thanks to strategic investments (Qatar Central Bank, 2023). Meanwhile, Saudi Arabia maintained high export levels while pursuing economic diversification, with oil still accounting for more than 40% of its GDP in 2023 (Arab News, 2023).

For Algeria, this decline in exports has direct repercussions on state revenues, further increasing its economic dependence on hydrocarbons. The energy transition is becoming a strategic priority. Subsidy reforms, infrastructure modernization, and greater integration of renewable energies are essential to reduce this dependence and strengthen economic resilience.

The contraction of exports highlights a growing vulnerability: Algeria is caught between rising domestic demand and shrinking external revenues, a situation that risks weakening both its balance of payments and its fiscal position. Unlike its Gulf counterparts, Algeria has not yet translated its hydrocarbon wealth into diversified export capacities or robust sovereign funds, leaving it more exposed to external shocks. This underscores the urgency of accelerating structural reforms and diversifying both the energy mix and the economic base.

Figure 3. Evolution of primary and derived energy exports (2000-2023)



Source: Prepared by the authors based on MEM reports.

2. Dependence on hydrocarbons and economic vulnerabilities

This section analyzes Algeria's structural dependence on hydrocarbons while examining the resulting economic vulnerabilities. It explores production dynamics, the impact of global price volatility, and the challenges associated with economic resilience. Beyond the descriptive trends, the focus is placed on structural weaknesses, governance issues, and the strategic implications of this dependence.

2.1. Production dynamics and pressure on resources

The Algerian economy relies primarily on hydrocarbons, which account for more than 90% of domestic energy consumption and constitute the bulk of national exports. This high dependence generates multiple vulnerabilities: price fluctuations in international markets, the gradual depletion of fossil fuel resources, and the continuous rise in domestic energy demand. Unlike countries such as Norway, which have invested hydrocarbon rents in sovereign wealth funds, Algeria has not developed comparable mechanisms to mitigate resource volatility.

2.1.1. Reserves and platforms: stability and declining production

Although Algeria's proven oil and natural gas reserves have remained stable since 2016, production has slowed. This decline is due to a lack of investment in infrastructure and the aging of existing facilities. The apparent stability of reserves therefore masks an incapacity to

transform potential into effective output, which reflects governance and policy shortcomings. Table 1 illustrates this situation, showing that oil reserves remained at 12.2 billion barrels and natural gas reserves at 4,504 billion m³ between 2016 and 2023.

In 2016, Algeria had 52 active platforms, but this number dropped to only 22 in 2020, likely due to the oil crisis and budgetary constraints. The rebound in 2021–2022 was short-lived, with the number of platforms falling back to 73 in 2023, highlighting continued uncertainty regarding operational stability. This volatility reveals a structural problem: instead of long-term investment planning, Algeria reacts to short-term price cycles, unlike Qatar or Saudi Arabia, which have consolidated investment strategies despite global downturns.

Tableau 1. Evolution of Reserves and Active Platforms in Algeria (2016-2023)

Years	2016	2017	2018	2019	2020	2021	2022	2023
Proven Crude Oil Reserves (Billion Barrels)	12,2	12,2	12,2	12,2	12,2	12,2	12,2	12,2
Proven Natural Gas Reserves (Billion m³)	4504	4504	4504	4504	4504	4504	4504	4504
Active Platforms	52	50	50	42	22	77	132	73

Source: Compiled by the authors from OPEC Statistical Bulletin (OPEC, 2020–2024 editions).

2.1.2. Hydrocarbon production: A marked decline and a moderate recovery

Hydrocarbon production in Algeria experienced a significant decline between 2016 and 2020 before initiating a modest recovery. This decline is largely attributed to structural factors such as the maturity of oil fields, a lack of investment in new wells, and the impact of the COVID-19 pandemic. It also reflects technological stagnation: while other producers have modernized extraction techniques and diversified towards offshore or unconventional resources, Algeria's reliance on aging onshore fields increases vulnerability.

Table 2 illustrates this trend. Crude oil production dropped from 1.146 million barrels per day in 2016 to 898,700 in 2020, before a partial recovery to 973,000 in 2023. A similar trend is observed for natural gas, which fell from 93.15 billion m³ in 2016 to 85.11 billion m³ in 2020, before rising to 104.27 billion m³ in 2023. The number of completed wells also fell sharply, confirming limited exploration dynamics.

These figures confirm that Algeria's problem is not the lack of reserves, but the inability to convert them into sustainable production capacity. The country risks falling into a "resource paradox": abundant resources but declining energy security due to poor institutional performance. This underscores the urgent need for ambitious investment policies and structural reforms.

Tableau 2. Evolution of Hydrocarbon Production and Completed Wells in Algeria (2016-2023)

Years	2016	2017	2018	2019	2020	2021	2022	2023
Number of Completed Wells	292	332	277	265	160	113	149	155
Crude Oil Production (1,000 barrels/day)	1146,3	1058,7	1040,1	1023,2	898,7	911	1020	973
Natural Gas Production (Billion m^3)	93,15	94,77	95,89	90,30	85,11	105,04	100,51	104,27

Source: Compiled by the authors from OPEC Statistical Bulletin (OPEC, 2020–2024 editions).

2.2. Economic fragility and external vulnerability

The Algerian economy remains heavily dependent on hydrocarbons, making it vulnerable to external shocks such as global price fluctuations and geopolitical crises. This dependence not only constrains growth but also weakens macroeconomic sovereignty, since fiscal stability and foreign reserves are directly tied to energy exports.

2.2.1. Hydrocarbon revenues and exports

Hydrocarbons remain a crucial pillar of Algeria's public finances and foreign trade. However, fluctuations in revenue and export volumes reveal a structural vulnerability in the sector.

Between 2016 and 2023, oil export revenues fluctuated with international prices, ranging from a low of $18.64 billion in 2016 to a peak of $32.54 billion in 2022. At the same time, export volumes declined, with crude oil exports falling from 668.7 thousand barrels/day in 2016 to 483 thousand in 2023. This indicates that Algeria is increasingly dependent on favorable prices rather than production capacity, which is a fragile model.

Gas exports also fell slightly from 53.97 billion m^3 in 2016 to 52.33 billion m^3 in 2023, despite recovery after the COVID-19 slowdown. Competition from LNG suppliers such as the United States and Qatar has reduced Algeria's market share, showing that its traditional pipeline-based strategy is less competitive in the new global gas market.

The contrast with Norway, which has buffered volatility through its sovereign wealth fund, illustrates Algeria's structural weakness: revenues are consumed in the short term instead of being reinvested to sustain long-term stability.

Tableau 3. Hydrocarbon export revenues and oil & natural gas volumes (2016–2023)

Years	2016	2017	2018	2019	2020	2021	2022	2023
Oil export revenue (Billion $)	18,64	22,35	26,08	22,67	13,18	23,35	32,54	26,11
Sahara blend price ($/Barrel)	44,28	54,12	71,44	64,49	42,12	70,89	104,24	83,64
Oil exports (1000 Barrels/Day)	668,7	632,5	571	584,2	438,7	446	477	483
Natural gas exports (Billion m³)	53,97	53,89	51,42	42,77	39,45	54,75	48,92	52,33

Source: Elaborated by the authors based on OPEC Statistical Bulletin (OPEC, 2017–2024 editions) and Annual Reports of the Bank of Algeria (2020–2024 editions).

2.2.2. Foreign exchange reserves and budget deficits

The strong correlation between oil revenues and macroeconomic indicators reflects Algeria's economic vulnerability. As shown in Table 4, Foreign exchange reserves fell from $114.14 billion in 2016 to $42 billion in 2020, before a fragile recovery to $96 billion in 2023. Budget deficits followed a similar pattern, peaking at -13.6% of GDP in 2016 and remaining significant at -5.2% in 2023.

This cyclical dependence reveals that Algeria lacks robust fiscal buffers. Unlike Gulf countries that established stabilization funds, Algeria relies on short-term adjustments, exposing its budget to recurrent crises. The country remains caught in a rentier model where fiscal health mirrors hydrocarbon cycles, leaving little room for counter-cyclical policies.

Tableau 4. Foreign exchange reserves and budget deficit (2016-2023)

Years	2016	2017	2018	2019	2020	2021	2022	2023
Foreign exchange reserves (Billion $)	114,14	97,33	79,88	62	48	44,72	60,99	96
Budget deficit (% of GDP)	-13,6	-8,8	-5,6	-9,6	-12	-7	-2,9	-5,2

Source: Elaborated by the authors based on the Annual Reports of the Bank of Algeria (2020–2024 editions).

3. Energy transition: Opportunities and challenges

The energy transition represents a major strategic issue for Algeria, which faces excessive dependence on hydrocarbons and fluctuations in global energy markets. This deep transformation of the national energy model is based on three essential pillars: the development of renewable energies, the improvement of energy efficiency, and economic diversification. The goal is to ensure sustainable energy security while fostering resilient

economic development. However, this ambition faces contradictions: while policy discourse emphasizes diversification, budgetary choices and institutional inertia continue to favor hydrocarbons.

3.1. Objectives and challenges of the energy transition

Algeria, where hydrocarbons account for approximately 91% of national exports and 97% of energy production, is vulnerable to fluctuations in oil and gas prices. In this context, the energy transition aims to achieve progressive autonomy by diversifying energy sources and reducing the impact of external crises.

One of the fundamental objectives is the diversification of the energy mix. Algeria aims to gradually reduce the share of hydrocarbons by integrating more renewable energies, including solar, wind, hydro, biomass, and geothermal energy. By 2030, renewable energies should account for 30% of the national energy mix (Ministry of Energy and Mines, 2024). Yet, these targets have often been revised or postponed in the past, raising doubts about their effective implementation. Unlike Morocco, which has already reached more than 37% renewables in its installed capacity in 2023, Algeria lags behind in concrete achievements.

Another key challenge is the reduction of greenhouse gas emissions, in line with commitments made at COP21 in Paris. The adoption of cleaner technologies and the improvement of energy efficiency are levers to achieve this. However, efficiency policies remain weak: the residential sector is characterized by high energy waste, and subsidies distort consumption patterns. Without a profound reform of energy pricing, efficiency measures are unlikely to succeed.

Algeria must also ensure the security of its energy supply. The transition will help compensate for the depletion of hydrocarbon reserves by developing alternative resources capable of meeting rising demand. Economic diversification is another pillar: renewable-related industries could reduce dependence on oil rents and stimulate innovation. Finally, the transition is expected to create green jobs. Nevertheless, job creation projections often remain theoretical, as the renewable energy sector is not yet sufficiently structured to absorb a large workforce, unlike the hydrocarbon industry.

3.2. Renewable energy potential in Algeria

Algeria has exceptional potential in renewable energy, particularly due to its solar and wind resources. Effectively harnessing these resources represents a strategic advantage for ensuring the country's energy sustainability and reducing its dependence on fossil fuels.

Solar energy is the country's main renewable resource. With an average sunshine duration of 3,000 to 3,500 hours per year and solar irradiation ranging between 1,700 and 2,650 kWh/m², Algeria is among the most favorable regions in the world for solar energy production (Oulimar et al., 2024). The Algerian Sahara, with its vast desert expanses, provides an ideal space for the large-scale installation of photovoltaic and thermal solar power plants. Since the 1980s, Algeria has initiated efforts in favor of solar energy, notably with the creation of the Renewable Energy Province and the adoption of the South Plan in 1988. However, despite these initiatives and the establishment of a favorable legislative framework, the share of solar energy in the energy mix remains limited, requiring increased investment and better utilization of available resources (RADP, 1999).

Wind energy is another promising renewable resource. Certain regions of the country, particularly the High Plateaus and the Southwest, have favorable wind speeds, reaching up to

6 meters per second (m/s) in Adrar. These conditions are ideal for the development of wind farms that can diversify the energy mix and complement the contribution of solar energy.
Beyond solar and wind, other renewable sources such as hydropower and geothermal energy also offer interesting prospects. Furthermore, technological advances in energy storage, biogas, and smart grids will enable better integration of renewable energies into the national energy network. International partnerships with leading clean technology countries, such as Germany and China, play a key role in acquiring expertise and adapting innovations to the country's specific needs (Khan & Dhakal, 2022).

3.3. Economic, institutional, and technological constraints

Despite its advantages, the energy transition in Algeria faces several constraints. Economic limitations are a major obstacle, as both public and private investments remain concentrated in the hydrocarbon sector, which remains the main driver of the national economy. The lack of dedicated financing for renewable energies hinders their development, making it necessary to develop incentive strategies to attract investments and create a favorable economic environment for innovation.
Institutional and regulatory challenges also pose a barrier. Although Algeria has adopted several legislative measures, such as Law No. 99-09 on the promotion of renewable energies and the National Energy Management Plan, their implementation remains insufficient. The effectiveness of regulatory frameworks depends heavily on political will, legal stability, and the capacity of institutions to support economic actors in this transition (RADP, 1999).
Technological obstacles represent another challenge. The lack of local capabilities in the production and maintenance of renewable energy equipment limits the country's autonomy in this field. Dependence on technology imports increases costs and hinders the development of a local industrial ecosystem dedicated to clean energy. It is therefore essential to strengthen research and innovation, promote specialized training, and develop synergies between academic institutions, research centers, and industrial players.

3.4. Perspectives

The energy transition in Algeria is both an economic and environmental necessity. By implementing a coherent strategy and mobilizing adequate resources, the country can turn current challenges into opportunities for sustainable development. The diversification of the energy mix, the strengthening of local capacities, and the improvement of the regulatory framework are key levers that will enable Algeria to ensure its energy security while aligning with the global shift toward clean energy. With a clear vision and coordinated actions, this transformation can become a driver of long-term economic growth and resilience.

4. The role of natural gas in the energy transition

As part of the global energy transition, natural gas stands out as a strategic resource. With its economic, environmental, and geopolitical advantages, it plays a crucial role in helping Algeria diversify its energy mix while meeting the growing needs of its population and supporting its sustainable development ambitions.

4.1. Natural Gas: A Strategic pillar and the challenges of the energy transition

Natural gas holds a central place in Algeria's energy mix. Due to its lower carbon footprint compared to coal and oil, it is considered an ideal transitional energy source for reducing greenhouse gas emissions.

For Algeria, this resource has a dual significance: ensuring national energy stability and supporting economic growth. With 99% of the country's electricity production relying on natural gas, it is essential for meeting the needs of industries and households. However, this dependency presents challenges regarding sustainability and technological innovation (Bouznit & Pablo-Romero, 2021).

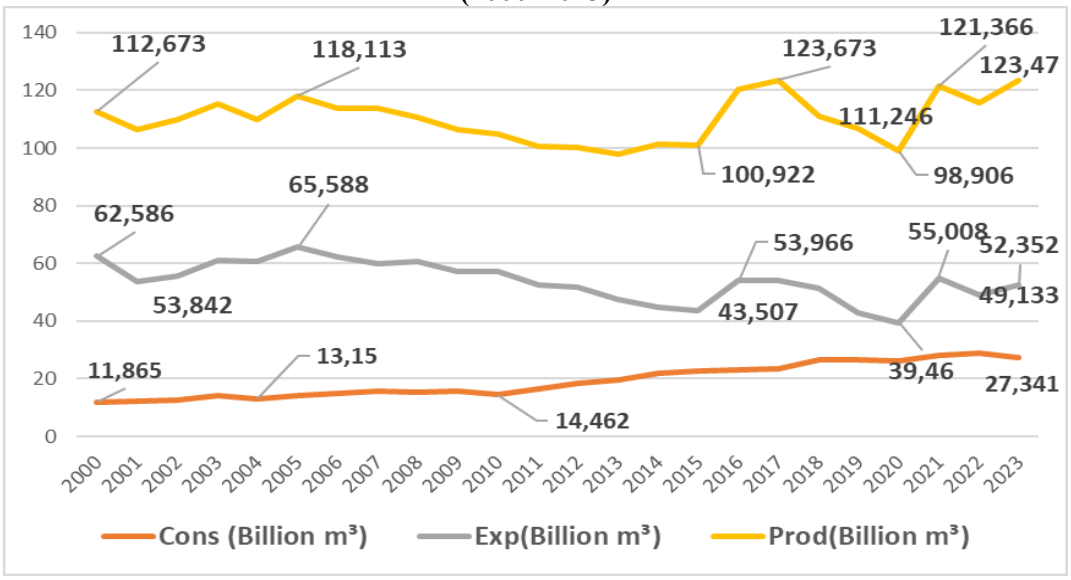
To optimize its role in the energy transition, several strategic actions are necessary. The development of advanced technologies, such as carbon capture and storage, is crucial for reducing emissions associated with natural gas use. Simultaneously, the gradual integration of renewable energies, particularly solar energy, would allow significant volumes of natural gas to be freed up for export. For example, the project aiming to produce 15,000 MW of solar photovoltaic energy by 2035 reflects this complementary strategy (International Energy Agency, 2021).

However, this strategy entails major challenges: attracting significant investments, modernizing existing infrastructure, and balancing the increase in domestic demand with export ambitions.

4.2. Natural gas dynamics: Domestic consumption, production, and exportation

The figure below illustrates the simultaneous trends in domestic consumption, production, and exports of natural gas in Algeria from 2000 to 2023.

Figure 4. Evolution of natural gas consumption, production, and exportation in Algeria (2000–2023)



Source: Compiled from MEM (Ministry of Energy and Mines) reports.

A sustained increase in domestic consumption is observed, rising from 11.865 billion m³ in 2000 to 28.932 billion m³ in 2022, with an average annual growth rate of 4.4%. This increase reflects the combined effects of industrialization, demographic growth, and expanded access to energy.

Conversely, natural gas production has experienced significant fluctuations. It peaked at 123.673 billion m³ in 2017 before dropping to 98.906 billion m³ in 2020, mainly due to disruptions caused by the COVID-19 pandemic. A notable recovery was recorded in 2023, with production reaching 123.47 billion m³, illustrating efforts to revive the energy sector.

Natural gas exports have followed a general downward trend despite occasional fluctuations. After peaking at 65.588 billion m³ in 2005, they declined to 49.133 billion m³ in 2022. This decline results from increasing domestic demand pressure and unfavorable conditions in the global market.

The analysis of these trends highlights several challenges. The constant rise in domestic consumption puts significant pressure on the country's export capacity, potentially compromising foreign exchange earnings. Moreover, production fluctuations, particularly between 2017 and 2020, reveal the vulnerability of Algeria's energy sector to economic and health crises. Finally, if domestic consumption continues to grow at the same pace, the volumes available for export could further decrease, weakening national economic security.

4.3. Strategic measures for sustainable balance

To ensure a sustainable balance between domestic consumption, production, and natural gas exports, adopting multidimensional strategic measures is essential.

4.3.1. Optimizing domestic consumption

Due to massive energy subsidies, domestic energy demand remains particularly high, exerting growing pressure on export capacity. The gradual removal of subsidies, especially for industrial users, is a recent measure aimed at promoting a more rational use of energy resources. For example, the Decree of 10 Rabie Ethani 1446, published in Official Journal No. 74, ends generalized subsidies for certain user categories, paving the way for better resource allocation (Ministry of energy and mines, 2024).

Fiscal incentives can also encourage energy-saving practices, such as installing solar water heaters or improving building thermal insulation. Additionally, public awareness and education campaigns on energy efficiency can play a crucial role in fostering responsible long-term behaviors.

4.3.2. Developing renewable energies

Diversifying the energy mix through renewable energy is essential to reducing dependence on natural gas for electricity production. Algeria has exceptional solar potential, with annual sunshine duration exceeding 3,000 hours in some regions (Renewable Energy Development Center, 2023). According to the National Energy Efficiency Program, the goal is to achieve cumulative energy savings of 93 million tons of oil equivalent by 2030, mainly through thermal insulation, solar water heaters, and hybrid solar power plants (Ministry of energy and mines, 2023).

A significant example is the project to produce 15,000 MW of solar photovoltaic energy by 2035, which could free up substantial volumes of natural gas for export.

4.3.3. Strengthening technological and infrastructure capabilities

To maintain steady energy production, investing in advanced technologies such as carbon capture and storage and the exploration of unconventional gas is crucial. These technologies help reduce environmental impact while optimizing available resources. Additionally, developing energy storage infrastructure, such as battery storage and other technologies, is essential to ensure stable production, especially given the intermittency of renewable energy sources.

4.4. Natural gas: A geopolitical lever for Algeria

Natural gas plays a central role in Algeria's energy strategy, acting as an economic driver and a geopolitical tool. As Africa's leading natural gas exporter and a major supplier to the European Union, Algeria leverages its strategic position to strengthen its international influence.

4.4.1. Algerian gas and the European Union: A strategic partnership

With Europe accounting for nearly 90% of Algeria's gas exports, energy relations between Algeria and the European Union are crucial. Algeria exports gas mainly through the Transmed (Algeria-Tunisia-Italy), Medgaz (Algeria-Spain), and, historically, the GME (Maghreb-Europe Pipeline), although the latter has been inactive since 2021 due to tensions with Morocco. In the context of the European Union's efforts to diversify its energy sources and reduce dependence on Russian gas, Algeria is seen as a strategic supplier. However, maintaining this role depends on increasing production capacity, improving infrastructure, and attracting foreign investments (Mediterranean Energy Observatory, 2024).

4.4.2. Energy cooperation with Africa: An emerging dynamic

In Africa, Algeria plays an important role in energy cooperation. The Trans-Saharan Gas Pipeline project, linking Nigeria to Algeria via Niger, is a prime example. This project aims to establish a strategic energy corridor between sub-Saharan Africa and Europe. While it offers promising economic opportunities for the involved countries, it faces challenges such as regional instability and high costs. If well-developed, the TSGP could enhance Algeria's role as a regional energy hub and promote greater cooperation among southern countries (Sonatrach, 2023).

4.4.3. Geopolitical and strategic challenges

Algerian natural gas is a strategic asset but also a source of geopolitical constraints. To maintain its influence, Algeria must diversify its partnerships by exploring Asian and South American markets while consolidating its European presence. Additionally, regional instability and competition from producers like Qatar and the United States pose significant challenges. Managing these issues requires proactive energy diplomacy, supported by infrastructure modernization and a balanced export strategy (International Energy Agency, 2024).

4.4.4. Opportunities and challenges of the global energy transition

In the context of the energy transition, Algeria could leverage its natural gas potential to develop liquefied natural gas projects and integrate advanced technologies, such as carbon capture and storage. These initiatives would help reduce the carbon footprint of gas production while enhancing Algeria's market competitiveness. However, this requires substantial investments and a revision of national energy policies (International Energy Agency, 2023).

5. Strategies and perspectives for sustainable energy security

Algeria, rich in fossil resources, recognizes the need to adopt diversified strategies to ensure sustainable energy security. This involves not only improving energy efficiency but also diversifying the energy mix, modernizing infrastructure, strengthening international cooperation, and increasing investment in research and innovation.

5.1. Strengthening energy efficiency policies

Improving energy efficiency is essential to reduce dependence on fossil resources and promote the sustainability of Algeria's energy system. Policies adapted to the context of developing countries can serve as inspiring models.

For example, Saudi Arabia, as part of its "Vision 2030" program, implemented the Saudi Energy Efficiency Program in 2012, aiming to improve energy efficiency across multiple sectors, including residential buildings. This program introduced thermal insulation standards and other measures to reduce household energy consumption. According to Krarti and Ihm (2017), strict application of the energy efficiency code in Saudi residential buildings could save up to 1.7 TWh per year and reduce peak demand by 468 MW annually.

In the United Arab Emirates, the "UAE Energy Strategy 2050," launched in 2017, aims to cut electricity and water consumption by 40% by 2050. This strategy includes initiatives such as building regulations and renovations, wastewater management, energy efficiency, urban lighting, and private solar energy production (Khan, M. R., & Dhakal, S., 2022).

In Mexico, the "Luz Sustentable" program, launched in 2011, replaced incandescent bulbs with subsidized compact fluorescent lamps (CFLs), generating significant savings for households. According to the World Bank (2014), this program distributed approximately 45.8 million CFL bulbs, leading to a reduction in residential electricity consumption (World Bank, 2014).

In Iran, targeted subsidies for energy-efficient appliances and the increasing use of natural gas in transportation have helped reduce internal consumption. According to a publication by the International Energy Agency in 2018, these measures improved the country's energy efficiency (International Energy Agency, 2018).

These experiences highlight the importance of specific tools, such as adopting building standards, financial incentives for energy-efficient equipment, promoting alternative fuels, and strengthening public-private partnerships for innovative solutions like smart meters. However, these policies can only succeed with large-scale awareness campaigns and effective governance. By adapting these strategies to its context, Algeria could transform its energy model, reduce its dependence on hydrocarbons, and address the challenges of the energy transition.

5.2. Diversification of the energy mix

Diversifying energy sources is essential to reduce dependence on hydrocarbons and ensure the sustainability of Algeria's energy system. Renewable energies, particularly solar and wind, must play a predominant role in the national energy mix. This requires increased investments in clean energy projects, supported by public-private partnerships, as well as the effective implementation of the national renewable energy program, with quantified short-, medium-, and long-term objectives. Institutional reform is also crucial to strengthen governance mechanisms and attract foreign investments in clean technologies (Cherif & Lanza, 2021).

According to the National Research Program on Energy Security, Algeria aims to increase the share of renewable energies to about 27% of national electricity production by 2030 (Ministry of Energy and Mines, 2023). This ambitious program plans to install 15,000 MW of renewable energy by 2035, including an initial phase of 3,000 MW dedicated to solar photovoltaic energy. This first phase includes the construction of 15 solar power plants totaling 2,000 MW across 12 provinces, as well as the "Solar 1000" project, which aims to install an additional 1,000 MW in five provinces, with capacities ranging between 50 and 300 MW (Sonelgaz, 2022).

Sonelgaz Group plays a key role in this transformation by leading several of these projects. At the same time, the Trans-Saharan Gas Pipeline project, linking Nigeria to Europe via Algeria and Niger, stands as a major initiative to strengthen energy security and diversify energy sources.

Tableau 5. Projected evolution of Algeria's energy mix

Energy Source	Current Share in 2023 (%)	Projected Share in 2030 (%)
Hydrocarbons	97	70
Renewable Energies	3	27
Others	0	3

Source: Ministry of energy and mines (2024).

This diversification of the energy mix will not only reduce dependence on hydrocarbons but also lower greenhouse gas emissions, contributing to Algeria's international commitments in the fight against climate change.

To achieve these goals, it is crucial to implement incentive policies such as subsidies for clean technologies, guaranteed purchase prices for electricity generated from renewable sources, and tax benefits for investors. Additionally, strengthening institutional capacities and training a skilled workforce in the renewable energy sector are key elements in ensuring the success of this energy transition.

5.3. Modernization of energy infrastructure

The aging energy infrastructure in Algeria compromises the performance and sustainability of the system. Modernizing it through smart grids and connected meters is essential to improve reliability, energy efficiency, and reduce losses.

5.3.1. Challenges of energy infrastructure in Algeria

In Algeria, technical and commercial electricity losses amount to about 15% of the energy injected into the grid, revealing significant inefficiencies. The heavy reliance on hydrocarbons and the lack of flexibility in the electricity grid hinder the integration of renewable energies.
To enhance the energy infrastructure, it is essential to modernize transmission and distribution networks by replacing outdated lines, installing advanced transformer stations, and automating networks. At the same time, adopting smart technologies such as connected meters, real-time energy management centers, and predictive maintenance sensors is crucial. Finally, digitalization and data management through analytical tools will optimize consumption and reduce outages.

5.3.2. International lessons and implications for Algeria

Several countries facing similar energy challenges as Algeria have implemented modernization strategies with significant results. These experiences provide valuable insights for optimizing Algeria's electricity grid and reducing technical losses.

a. International Experiences

- Saudi Arabia, through its Saudi Smart Grid Program under Vision 2030, deployed over 10 million smart meters, reducing technical losses from 14% to 8% in five years, with an investment of $50 billion (Saudi Electricity Company, 2022).
- Egypt implemented a large-scale grid modernization program supported by international institutions between 2015 and 2022, reducing losses from 15% to 10% with an investment of $10 billion and the implementation of real-time management systems (World Bank, 2022).
- Iran gradually modernized its grid by installing 5 million smart meters and strengthening network management, reducing technical losses from 16% to 12% between 2010 and 2021 (Tavanir Company, 2021).

b. Prospects for Algeria

Algeria, by leveraging these experiences, can accelerate the modernization of its electricity infrastructure by integrating advanced solutions. The large-scale deployment of smart meters, combined with the creation of real-time grid management centers and automation of infrastructures, would be an effective lever for optimizing energy efficiency.
Additionally, strengthening technological partnerships with leading countries in smart grids would accelerate this transition. With a planned investment of $20 billion, these initiatives aim to reduce technical losses from 15% to 7% by 2030, positioning Algeria as a major player in regional energy modernization (Zerouti M., Bouchetara M., & Fadel S., 2021).

5.4. International Cooperation and Financing for the Energy Transition

Algeria must strengthen its international cooperation to accelerate its energy transition, particularly in financing and technology transfer. These levers are essential for diversifying the energy mix and modernizing infrastructures. On the financial front, several international funds can support this transition. The Green Climate Fund finances climate projects in developing countries, while the Sustainable Energy Fund for Africa, led by the African

Development Bank, supports sustainable energy infrastructure. Additionally, the World Bank and other multilateral institutions provide funding for renewable energy and energy efficiency, allowing Algeria to access crucial financial resources for its energy infrastructure projects.
Regarding technology transfer, Algeria benefits from strategic partnerships with several international players. The European Union, through programs such as Horizon Europe, supports renewable energy research. China invests in solar technologies and green hydrogen, while Germany, through the Algerian-German Energy Partnership (Energiepartnerschaft), contributes expertise in training and adapted technologies.

These initiatives are part of Algeria's energy roadmap, which is based on enhanced international cooperation and the integration of technological innovations (Yaïci, 2024).

5.5. Local innovation and development for a sustainable energy transition

Algeria faces a dual challenge: ensuring its energy security while initiating a transition to a more sustainable model. To achieve this, it is essential to stimulate local innovation, alongside international cooperation, by investing in research and fostering green entrepreneurship.
Financing remains a central pillar. Institutions such as the Green Climate Fund, the World Bank, and the African Development Bank offer support mechanisms for sustainable energy projects. These opportunities allow Algeria to diversify its funding sources and attract investments in key sectors such as solar energy, green hydrogen, and energy efficiency.
Technology transfer is also a crucial aspect of this transition. Countries like Germany, China, and the European Union play a leading role in providing specialized training and adapted technologies. Programs like Horizon Europe and energy partnerships strengthen the integration of new technologies in Algeria, enabling it to meet local needs while benefiting from global best practices.
Local innovation is another cornerstone of the energy transition. Algeria has implemented several initiatives to encourage research and development, notably through the National Research Program on Energy Security. Institutions such as the Renewable Energy Development Center (CDER) focus on energy solutions adapted to local climatic conditions. International models, such as the Fraunhofer Institute in Germany or the Institute for Solar Energy and New Energies in Morocco, provide inspiring examples of successful applied research.
Green entrepreneurship represents a strategic lever. The National Agency for the Promotion of Research and Technological Development (ANVREDET) encourages the creation of startups specializing in clean technologies. However, stronger support is needed to maximize the impact of these initiatives, particularly to facilitate the industrial transfer of know-how and accelerate the large-scale deployment of local innovations.
Finally, a successful energy transition requires an inclusive approach. The retraining of workers from the hydrocarbons sector to renewable energies and ensuring equal access to electricity in rural areas are challenges to be addressed to guarantee a just and sustainable transformation. Raising awareness of energy issues and training a qualified workforce are essential conditions to succeed in this transition.
Thus, Algeria has multiple opportunities to achieve its energy transition, provided that it strengthens synergies between research, innovation, and international cooperation. By

combining global best practices with a tailored local innovation strategy, Algeria can build a resilient and sustainable energy system.

Conclusion

The analysis conducted in this article highlights the multiple and interconnected challenges that Algeria must address to ensure its energy security and successfully transition to a sustainable energy model. Although the country has remarkable energy potential, particularly due to its vast natural gas reserves, it remains heavily dependent on hydrocarbons, making it vulnerable to global price fluctuations and geopolitical tensions. This situation exposes the Algerian economy to significant risks, particularly in terms of financial stability, economic growth, and energy sovereignty. In a global context marked by the progressive decarbonization of economies and the acceleration of the energy transition, diversifying the energy mix becomes an unavoidable necessity to ensure long-term energy security.

Natural gas, as a relatively cleaner and more flexible energy source, represents a strategic lever to initiate this transition. It provides Algeria with a short- and medium-term solution to meet growing energy demand while reducing its national carbon footprint. However, the shift to a more sustainable energy model cannot materialize without a genuine sectoral reform focused on modernizing infrastructure and integrating renewable energies. Algeria has significant solar and wind energy resources, particularly in the southern regions, and must fully exploit this potential to reduce its dependence on fossil fuels. The country's energy policy must therefore be redirected towards a massive development of renewable energies, relying on proactive legislation and strong support for technological innovation.

The challenges facing Algeria are numerous and extend beyond mere technical aspects. Managing budgetary constraints, overcoming institutional obstacles, and the need to reform energy governance are among the top priorities. To succeed in this transition, the country must adopt an integrated approach, balancing the diversification of energy sources, the optimization of domestic consumption, and the development of strategic partnerships at regional and international levels. Algeria's involvement in regional energy cooperation projects, such as the development of energy corridors or rural electrification through renewable solutions, represents a promising avenue to strengthen its energy security while supporting its socio-economic development.

Ultimately, Algeria stands at a decisive crossroads. It must find the right balance between its economic imperatives, environmental challenges, and social priorities to build a resilient and inclusive energy future. This energy transition must be carried out in a concerted manner, involving all stakeholders, from public institutions to private companies, as well as civil society and international partners. This process will require a bold strategic vision based on informed choices and well-adapted public policies, enabling Algeria to transform its energy challenges into opportunities for sustainable development. In this regard, the country has all the necessary assets to assert its role as a leader in the regional and global energy landscape while consolidating its energy sovereignty and ensuring the stability of its economy.

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