



Reality and Prospects of Renewable Energy in the Context of Sustainable Development: From Internationalization to Localization – The Case of Algeria



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Received: 13/04/2025 ; Accepted: 11/09/2025

Abstract

Renewable energies are a means to spread more justice between the rich world and the poor countries, and it is not limited to those who live today, as the maximum use of the sun and wind today will not reduce the opportunities of future generations. On the contrary, when we rely on renewable energy, we will make the future of our children and grandchildren safer ".

Renewable energy, in all its types, is solar energy, wind energy, hydraulic energy, organic energy and other "natural" energies. It is indeed considered the hope of saving energy in the future, on the one hand because it is inexhaustible energies, and on the other hand because it is not polluting the environment, in addition to that, the application of technologies Modern generation of these types of energy will provide multiple job opportunities for young people.

Regarding Algeria, it has recently adopted renewable energies as an important and worthwhile source of energy saving, as this was considered a strategic choice for decision makers.

Keywords: renewable energy, low energy, sustainable development, environmental protection, Legal mechanisms.

Introduction:

Energy has consistently been a fundamental driver of human progress and socio-economic advancement throughout history. The prioritization of energy sources, the assurance of supply security, the pursuit of economically viable access, and the reliance on resources that do not compromise ecological equilibrium are imperatives that transcend national boundaries. Rather, they embody a collective global imperative that has only intensified with the depletion of inexpensive energy resources.

In this regard, contemporary challenges confronting the international community are predominantly characterized by climate change, escalating dependence on fossil fuels, and the imperative to provide equitable access to energy. Addressing these multifaceted challenges necessitates the establishment of long-term alliances and coherent policies, as numerous international entities have already initiated. These entities have acknowledged that unilateral measures are insufficient to guarantee energy security or fulfill the ambitious research agendas they have envisaged. Consequently, coordinated efforts, a unified strategic framework, and the allocation of substantial financial resources are critical to underpin high-caliber research and attract distinguished experts endowed with exceptional competencies and innovative perspectives. Conversely, significant capabilities continue to be

fragmented, with disparate stakeholders pursuing objectives that may either converge or diverge, ultimately resulting in suboptimal outcomes and aspirations that remain disconnected from tangible achievements.

Within the ambit of national energy policy, the mandate conferred upon the energy sector is to furnish all citizens with energy under optimal conditions, with respect to both quality and service continuity. Addressing these needs also necessitates the rationalization of energy supply costs to safeguard national resources. Given Algeria's extensive hydrocarbon reserves and the relatively low costs associated with their extraction compared to renewable energy alternatives, the nation's energy requirements have thus far been predominantly met through oil and natural gas. However, this reliance does not negate the strategic interest in renewable energies, given the intrinsic advantages they present.

In light of these advantages and specific economic pressures—particularly in terms of cost considerations—the role ascribed to renewable energy within the national energy policy framework is to fulfill the energy demands of remote regions that are not integrated into the electricity and natural gas networks. Several initiatives have been executed in this context, both within the energy sector and across other sectors of the national economy.

Technological advancements anticipated to drive down costs, the sustained dynamics of the global energy landscape, and the exigency of environmental preservation have collectively compelled Algeria to recalibrate its renewable energy strategy, underscoring an augmented commitment from public authorities to foster the development and proliferation of these energy sources.

The diverse legislative instruments ratified in recent years, including the "Energy Efficiency Law" and the "Renewable Energy Promotion Law within the Framework of Sustainable Development," embody the state's resolve to position renewable energy as a cornerstone of the nation's future energy architecture. These legislative measures are aimed at ensuring that renewable energy sources contribute substantively to the national energy matrix.

Research Problem: What is the status of renewable energy in Algeria compared to developed countries?

This study will attempt to address the following elements:

- **First:** The reality of renewable energy in the international community.
- **Second:** The reality of renewable energy in Algeria.

1. The Reality of Renewable Energy in the International Community

The international community has long recognized the need to regulate the use of renewable energy sources, culminating in numerous multilateral treaties and agreements. Many nations have also prioritized protecting human health, property, and the environment from the harmful effects of conventional energy consumption, leading to the adoption of national legislation that regulates the safe deployment of renewable energy technologies.

1. Factors and Challenges Influencing the Expansion of Renewable Energy Worldwide

Renewable energy has emerged as a primary global energy source outside of fossil fuels, offering a viable alternative for mitigating environmental impacts¹. Today, many countries, especially industrialized nations, are actively working to harness renewable energy to counter environmental degradation. Renewable energy sources are characterized by their recurrent and inherently sustainable occurrence in nature².

This section explores the factors that drive the expansion of the renewable energy sector, followed by an examination of the obstacles that hinder its expansion and proliferation.

1.1 Factors Supporting the Expansion of the Renewable Energy Sector

Several factors contribute to the expansion of the renewable energy sector, ensuring energy security for the future, promoting sustainable expansion, and encouraging increased investments in renewable energy technologies:

- 1) Governments that integrate financial support mechanisms into their national policies, providing long-term financing solutions for energy technologies. They balance subsidies between fossil fuel projects and renewable energy initiatives, redirecting a portion of revenues to support the renewable energy sector.
- 2) Policies implemented without bureaucratic hurdles, alongside economic models characterized by production abundance and accessible financing, maximize returns at the lowest possible cost.
- 3) Establishing incentive policies and preferential financing to create attractive investment opportunities.
- 4) Facilitating the transfer of technology, capacity building, job creation, and the establishment of markets for renewable energy technologies.
- 5) Setting clear strategic targets with defined timelines to enhance energy production at the national level.
- 6) Implementing environmental taxes on industries to discourage the use of fossil fuels and nuclear energy, promoting contributions to the renewable energy sector.
- 7) Enacting legislation that regulates energy consumption across sectors, guiding compliance with energy efficiency standards.
- 8) Establishing technical standards and mandating compliance across industries.
- 9) Adopting market-oriented energy policies that foster competitive markets, internalize externalities, and aim for energy security, environmental protection, and economic efficiency.
- 10) Raising societal awareness about pollution issues and highlighting renewable energy's role in resolving energy challenges.
- 11) Supporting policies that promote research, development, and commercialization of renewable energy technologies.
- 12) Introducing market diffusion strategies to absorb technology introduction costs, enhancing technical performance and driving industrial growth.

1.2. Barriers and Challenges to the Expansion and Adoption of Renewable Energy

Several barriers impede the expansion and widespread adoption of renewable energy, which can be grouped into five primary challenges:

1.2.1. Political and Legislative Barriers

The absence of cohesive policies guiding governments toward sustainable development impedes the widespread adoption of renewable energy. The sector remains somewhat unorganized, with limited strategic support for expansion and investment. Additionally, there is an evident lack of coordinated cooperation among relevant government and executive entities, such as policymakers, financial institutions, equipment suppliers, and end-users.

A significant obstacle in Algeria is the political instability that has persisted since 2019, leading to economic crises that affect policy decisions, especially in the energy sector. Algeria's energy sector is caught between its traditional fossil fuel-based model and the transition to renewable energy³.

1.2.2. Technological Barriers to Renewable Energy Technologies

Technological challenges arise in several areas:

- a) **Research and Development:** Some renewable energy technologies are still in development and have not reached full commercial maturity.

- b) **Expertise and Skills:** A shortage of technical expertise and local manufacturing capacity, particularly in regions like the Gulf Cooperation Council (GCC).
- c) **Strategic Implementation:** Imbalances in the effectiveness of renewable energy technologies at the local level hinder strategic deployment.
- d) **High Costs and Low Efficiency:** The high costs and relatively low efficiency of renewable energy technologies present significant barriers.
- e) **Financing and Financial Support:** Limited financial incentives, such as funding mechanisms, customs tax exemptions, and private sector involvement, hinder sectoral growth.

1.2.3. Economic and Financial Barriers:

- a) There is a significant gap between the price at which energy is sold and the average cost of its production.
- b) Renewable energy projects often entail high capital costs, exacerbated by increasing investment expenses, which pose challenges for investors seeking to recover their capital in a short period.
- c) The volatility of fuel prices, coupled with government subsidies for conventional fuels, can limit the expansion of the renewable energy sector and the resolution of climate pollution issues.
- d) The erroneous belief that investing in renewable energy projects constitutes a financial risk has led to a lack, or total absence, of financing mechanisms⁴.

1.2.4. Legal Barriers:

These barriers vary according to the legal systems of different countries. Generally, the absence of national energy regulations, licenses, and legal approvals hinders the widespread adoption of renewable energy. It also impedes investment and the regulation of behavior related to the lack of awareness about the importance of renewable energy.

1.2.5. Climatic and Environmental Barriers:

Climatic changes such as dust, clouds, water issues, and wind can disrupt energy generation, leading to hesitation in supporting the sector. This highlights the need for high-efficiency technologies capable of withstanding these environmental challenges and maintaining consistent performance.

2. The Role and Key Initiatives of the International Renewable Energy Agency (IRENA):

With growing global interest in renewable energy, a call for the establishment of an international agency emerged. In response, the **International Renewable Energy Agency (IRENA)** was founded in 2009⁵, with the goal of promoting the widespread and sustainable adoption of renewable energy sources. IRENA's charter identifies six types of renewable energy within its purview: biomass, geothermal energy, hydropower, tidal energy, solar energy, and aeolian (wind) energy.

Following several preparatory meetings in 2008, a draft charter was prepared, and IRENA's founding conference was held in Bonn, Germany, from January 24–27, 2009. At that time, 75 countries ratified the agency's charter. IRENA's organizational structure comprises three primary divisions:

- 1) **The General Assembly:** This is IRENA's decision-making body, with each member country represented by one vote. The Assembly meets annually at the agency's headquarters.
- 2) **The Council:** Comprised of at least 11 and up to 21 representatives from member states, the Council serves for two years and holds biannual sessions. It facilitates consultations and cooperation with member states, drafts programs and budgets, and presents reports to the General Assembly.
- 3) **The Secretariat:** Headed by a Director-General elected by a two-thirds majority of the General Assembly for a four-year term (renewable once), the Secretariat assists the Assembly and

Council in their functions, prepares work programs, and coordinates with international organizations⁶.

IRENA plays a pivotal role in shaping international strategies by providing support to all member states, particularly developing nations, and facilitating the localization of renewable energy technologies through collaborative frameworks that promote knowledge exchange. The agency's evaluations and readiness assessments help nations identify effective policies, attract investment, and foster partnerships, contributing to long-term transitions toward renewable energy. These reports offer analysis and recommendations across key areas, including business model development, policy creation, institutional and organizational capacity-building, resource and technology identification, and project financing.

At its third meeting, IRENA announced three major initiatives aimed at advancing renewable energy globally. These initiatives include:

- a) **Global Atlas for Renewable Energy:** This initiative represents the world's most extensive project for mapping and assessing solar and wind resources. The Atlas consolidates critical geospatial data on renewable energy potential and resource quality worldwide, supporting the development of actionable strategies for energy resilience. By integrating datasets and cartographic resources from diverse research institutions and private sector stakeholders, the Atlas provides a holistic, granular depiction of solar and wind energies availability⁷.
- b) **Establishment of a Global Renewable Energy Roadmap:** IRENA introduced a roadmap aimed at achieving global renewable energy goals by 2030.
- c) **Abu Dhabi Fund for Development (ADFD) Partnership:** The agency announced its first funding cycle in partnership with the ADFD, offering \$350 million in concessional financing over seven years for renewable energy projects in developing countries.

3. Pioneering Global Experiences in Renewable Energy and Their Potential Transfer to Algeria

This section provides an overview of key global experiences in harnessing renewable energy, with concise references to leading Arab and Western examples. We will assess how these experiences can be adapted to Algeria, with careful consideration of national particularities. Special attention will be given to Germany's renewable energy policies and mechanisms, exploring their applicability in the Algerian context, while accounting for national specificities.

3.1. Leading Experiences in Western Countries

3.1.1. The German Experience in Renewable Energy

Germany stands as a global pioneer in the renewable energy sector⁸, having committed to expanding renewable sources as alternatives to fossil fuels, particularly in central regions. The country's goal is to reduce greenhouse gas emissions by 80% by 2050, compared to 1990 levels⁹. In this pursuit, Germany implemented a series of legal measures¹⁰, beginning with the Renewable Energy Act (EEG) on January 1, 1991, followed by the Renewable Energy Sources Act in 2000. This legislation laid the foundation for the country's renewable energy projects, and several amendments have been made subsequently, with the most recent in 2014. The latest amendment aimed to integrate environmental considerations into sustainable development strategies, with a long-term vision extending to 2050.

Germany has defined two main objectives for its energy transition:

1. To reduce energy consumption by 10%.
2. To produce one million electric vehicles by 2020.¹¹

3.1.3. The Chinese Experience in Renewable Energy¹²

China has made significant strides in renewable energy, spurred by sound governmental policies. The country has prioritized investments in this sector, with hydropower as the largest renewable energy source, accounting for approximately 18% of China's total electricity supply. With 229 gigawatts of installed hydropower capacity, China is the world's largest producer, contributing nearly one-quarter of global hydropower generation.

Wind energy represents the second-largest renewable source in China, with installed capacity reaching 13.89 gigawatts by 2013. The Chinese wind energy market is the fastest-growing in the world. In terms of solar energy, China produced around 30% of the global photovoltaic supply in 2012¹³. In 2013, the country installed 12 gigawatts of photovoltaic solar capacity—50% more than any other country had installed in a single year before that time. Currently, China has approximately 19 gigawatts of installed solar photovoltaic capacity¹⁴.

Biomass energy, derived from wood and energy crops, plays a relatively small role but remains significant in specific sectors. Biomass is used for heat production, converted into biogas, or transformed into liquid fuels. China's government has plans to increase biomass usage, and the country ranks as the third-largest producer of ethanol fuel globally, contributing 2.5% of the world's total in 2012. Biomass energy capacity in China stands at nearly 10 gigawatts¹⁵.

3.1.3. The U.S. Experience in Renewable Energy¹⁶

The United States is the world's largest producer of carbon dioxide, contributing significantly to global greenhouse gas emissions. As a result, the U.S. has rapidly turned towards clean energy to address environmental threats to its population. Today, the U.S. is at the forefront of solar, wind, thermal, and other renewable energy technologies.

In the field of biofuels, particularly ethanol derived from corn, the U.S. has identified a significant opportunity for renewable energy investment. Ethanol production requires much less petroleum than gasoline, and its greenhouse gas emissions are 15–20% lower. U.S. car manufacturers have responded to the growing interest in biofuels; for example, General Motors currently produces nine vehicle models compatible with E85 fuel, a blend of 85% ethanol and 15% gasoline¹⁷.

In conclusion, the U.S. shift towards renewable energy will not only help address future challenges but also stimulate its economy through environmentally sustainable investments. These efforts meet societal needs for energy and employment, a central challenge for policymakers. Algeria, which has already outlined a renewable energy program extending to 2030, could benefit from adopting similar strategies, capitalizing on the economic and environmental potential of clean energy.

3.2. Pioneering Arab Experiences in Renewable Energy

The successful experiences of Arab countries in harnessing renewable energy can serve as ideal models for Algeria, given the numerous commonalities, particularly their fossil fuel-based economies¹⁸. Among these notable Arab examples in renewable energy exploitation are:

3.2.1. The Reality of Renewable Energy in the United Arab Emirates

3.2.1.1. The Experience of Dubai

Dubai launched an integrated energy strategy extending to 2030, allocating investments worth 60 billion AED over five years. Algeria can benefit from this experience by initiating an energy project aimed at diversifying energy sources and optimizing their use. This can be achieved by enhancing infrastructure through solar and water energy projects, which would significantly improve investment in renewable energies.¹⁹

3.2.1.2. The Experience of Abu Dhabi

Abu Dhabi established an institute dedicated to developing all fields of renewable energy, focusing particularly on technological aspects, with a financial allocation of 2.2 billion AED. Algeria could

leverage this pioneering experience by creating a specialized institute for research and development in renewable energy sciences and technologies²⁰.

3.2.2. The Reality of Renewable Energy in Saudi Arabia

Saudi Arabia's approach centers on attracting investments in the renewable energy sector, fostering competitiveness among its promising companies, and enhancing their capabilities. Approximately 25 companies were qualified under the project named "Doumat Al-Jandal," with assistance from the Kingdom's Renewable Energy Project Development Office. Additionally, Saudi Arabia has implemented a renewable energy program within a future vision extending to 2030, based on strategic planning and goal setting.

Algeria, in turn, can benefit from this experience by attracting investments related to the energy sector, which will undoubtedly contribute to diversifying the local energy mix and providing opportunities for employment and investment. Moreover, the Algerian state should strive to attract foreign investment in renewable energy to foster competition with promising national companies²¹.

3.2.3. The Reality of Renewable Energy in Tunisia²²

Tunisia relies almost entirely on fossil fuels to meet its energy needs, with over 94% of the country's installed capacity coming from fossil fuels. The remaining 6% is derived from renewable sources, primarily hydropower and aeolian energy. Wind power in Tunisia amounts to 233 megawatts, followed by hydropower at 62 megawatts. Solar energy contributes minimally, while other sources like geothermal energy and biomass remain underutilized. This situation has prompted Tunisia to undertake several major renewable energy projects, both completed and planned for the future. The most prominent include²³:

01. Implemented Projects

- **Hydropower Electricity Generation Project:** In 2007, the Tunisian Electricity and Gas Company (STEG) completed hydropower projects in Sidi Salem, Fernana, Nebour, Aroussia, Kesab, and Bou Hertma, with a total capacity of 62 megawatts.
- **Wind Energy Electricity Generation Project:** In 2009, STEG completed a wind energy project in Sidi Daoud in Al-Hawariya (Nabeul Governorate) with a capacity of 54.5 megawatts.
- **Solar Water Heating Project for the Residential Sector:** Implemented under the **PROSOL** program (2005–2012) to assist households in transitioning from fossil fuel-powered water heaters to solar-powered ones.

02. Projects Under Implementation

- **TuNur 1 Concentrated Solar Power Project:** Aiming for a capacity of 200 megawatts by 2028.
- **Bizerte Electricity Generation Project:** By the end of November 2013, efforts were underway to connect 144 megawatts—out of a planned 190 megawatts of wind energy capacity—by STEG in the region of Khabta in Metline.
- **El Akarit Concentrated Solar Power Project:** A public sector initiative aiming to produce 50 megawatts of electricity from concentrated solar power.

2. The Reality of Renewable Energy in Algeria

Algeria possesses significant renewable energy resources, particularly solar energy, which has the potential to replace oil and generate higher revenues than petroleum. This strategic asset ensures that Algeria's economy will not face threats from the depletion of oil reserves by 2025. Moreover, it provides a unique opportunity for the country to advance its industrialization and compete with

leading global economies—if it manages to capitalize on this energy through the implementation of a robust and strategic approach.

This section will explore Algeria’s legal framework for the promotion of renewable energy, the structures responsible for its development, and an assessment of the country’s national renewable energy capacities, discussed under the following headings:

1. The Legal Framework for the Promotion of Renewable Energy in Algeria

1.1. Legal Framework for the Promotion of Renewable Energy and Sustainable Development²⁴

1.1.1 Law No. 98-11

Law No. 98-11, which outlines the Five-Year Program on Scientific Research and Technological Development (1998–2000)²⁵, serves as the foundational legislative text supporting the adoption of renewable energy in Algeria. It marks the first genuine effort by the state to establish a legal framework encouraging the development of renewable energy. The law emphasizes the rational management and efficient use of energy resources, particularly through the support of renewable energy, all aimed at fostering sustainable development.

1.1.2 Executive Decree No. 04-92

Executive Decree No. 04-92²⁶ builds upon these efforts by encouraging the rational use of energy, specifically electricity, and organizing the investment market for renewable energy projects. The decree also regulates contracts within this field, positioning itself as a pivotal legal instrument governing Algeria’s renewable energy sector.

1.1.3. Law No. 04-09

Law No. 04-09²⁷ further promotes the use of renewable energy within the context of sustainable development, representing the first legislative text to explicitly link renewable energy with the concept of sustainability. This law introduced a series of provisions aimed at encouraging investments in the renewable energy sector²⁸, thereby supporting sustainable economic growth. By enhancing the contribution of renewable energy to the national infrastructure, the law plays a crucial role in advancing Algeria’s economic development.

The law also calls for the implementation of supportive measures to ensure a smooth energy transition, as outlined in the National Program for the Promotion of Renewable Energy. This program seeks to actualize the objectives set out in the legal framework through concrete and measurable outcomes²⁹.

However, despite the promising intentions behind this legislation, it has largely remained theoretical. Ambiguities in the law, combined with the absence of practical mechanisms to support industrial and economic stakeholders, have limited its impact. This has left much of the legal framework inactive, hindering its ability to promote the large-scale exploitation of renewable energy in Algeria.

Upon reviewing Algeria’s legal framework concerning renewable energy, it becomes clear that, while the country has a comprehensive set of laws in place, these legal instruments remain ineffective in practice. Despite reflecting the Algerian government’s clear intent to foster and promote the renewable energy sector, the framework has not been effectively translated into action. This is primarily due to several obstacles, the most significant of which is the lack of coordination among key actors in the energy sector³⁰. As a result, the legislation, though extensive, has yet to yield substantial progress in the field of renewable energy development.

1.2. Legal Framework for Promoting Renewable Energy and Environmental Protection

1.2.1 Law No. 99-09

Law No. 99-09³¹, related to energy management, establishes a set of measures aimed at rationalizing the use of renewable energy to reduce the environmental impacts of energy systems in Algeria. The

law focuses on optimizing energy usage to minimize the adverse effects of energy consumption on the environment, aligning with the country's environmental protection goals.

1.2.2. Executive Decree No. 2000-116

Executive Decree No. 2000-116³² details the management of Special Allocation Account No. 101-302, known as "The National Fund for Energy Control." This decree outlines the financial management of resources, including revenues from taxes and penalties set forth in Law No. 99-09. It serves as a financial instrument to support the energy efficiency initiatives prescribed by the law.

1.2.3. Law No. 02-01

Law No. 02-01³³ represents Algeria's first legislative framework for regulating the marketing of electricity generated from renewable sources. It promotes the use of renewable energy to support environmental protection and integrates renewable energy into the country's broader environmental policies.

1.2.4. Law No. 03-10

Law No. 03-10³⁴ enhances the existing legislative framework by promoting the use of cleaner technologies for the rational use of natural resources. The law emphasizes ecological considerations, specifically in the context of biodiversity, demonstrating the Algerian legislator's commitment to environmental preservation through sustainable resource management.

1.2.5. Presidential Decree No. 16-262

Presidential Decree No. 16-262³⁵ was enacted following Algeria's ratification of the Paris Agreement (COP 21), adopted at the 21st United Nations Climate Change Conference in Paris in December 2015³⁶. The agreement obliges the 195 signatory countries, including Algeria, to reduce emissions of ozone-depleting gases that contribute to global warming.³⁷

2. Structures for the Development of Renewable Energy in Algeria

This section outlines the key national institutions involved in advancing renewable energy in Algeria.

2.1. Ministry of Environment and Renewable Energy³⁸

Established in 2017, this ministry plays a critical role in renewable energy. Its main tasks in this sector include:³⁹

- a) Fostering a Sustainable Environmental Culture: By conducting targeted awareness-raising and educational activities.
- b) Building and Enhancing Waste Management Facilities: Extending waste collection, implementing selective sorting at the municipal level, and improving the efficiency of integrated waste management systems.
- c) Encouraging Public-Private Partnerships: In waste collection, sorting, and processing, while developing waste valorization sectors, including recycling activities. These efforts are vital for reducing imports, creating jobs, and generating wealth.⁴⁰
- d) Promoting a Circular Economy: By introducing regulations that encourage the emergence of a circular economy.
- e) Improving Citizens' Living Conditions: Ensuring Algeria contributes to global environmental protection efforts through renewable energy and energy efficiency programs.

2.2. Renewable Energy Development Center (CDER)

Founded on March 22, 1988, in Bouzaréah by the High Commissioner for Research, CDER's mission is to develop and implement scientific and technological research programs in all energy systems related to renewable energy. The center gathers information to identify necessary research projects, develops, executes, and evaluates programs, promotes technological advancement, and ensures scientific and technological oversight concerning renewable energy.

2.3. Experimental Station for Deep Desert Technologies

Also established on March 22, 1988, this station focuses on promoting, manufacturing, and testing solar technologies tailored for desert conditions.

2.4. Solar Energy Development Unit

Founded on January 9, 1988, this unit supports the government's energy efficiency policy by developing solar equipment. It conducts technical, economic, and engineering studies, builds prototypes for solar systems used in residential, industrial, and agricultural sectors, and manufactures thermal, electrical, and mechanical systems based on solar energy⁴¹.

2.5. Silicon Technology Development Unit

Affiliated with the Ministry of Higher Education and Scientific Research, this unit is tasked with promoting and developing silicon-based technology, which is fundamental for renewable energy applications.

2.6. Renewable Energy Conservation Authority

Established by Executive Decree No. 82-46 on January 23, 1982, this authority operates under the High Council for Scientific and Technical Research. It is responsible for preparing and implementing national scientific, technological, and industrial development plans related to renewable energy, as well as conducting research aimed at producing new energy sources.⁴²

2.7. National Agency for the Promotion and Rationalization of Energy Use (APRUE)

Operating under the Ministry of Energy and Mines, APRUE was created by Executive Decree No. 85-235 on August 25, 1985, in Algiers. The agency is tasked with developing strategies to meet rising energy demands, promoting rational energy use, and offering forward-looking energy proposals. Its mission was expanded by Executive Decree No. 04-314⁴³, which granted the agency additional responsibilities.

2.8. Renewable Energy Directorate

Founded in 1998 under the Ministry of Energy and Mines, this directorate is charged with developing and promoting renewable energy resources. One of its significant achievements is the establishment of a solar energy experimental station in the Sahara, focusing on research and development of solar and wind energy. The station's work includes developing solar thermal systems suited to the desert climate, which use solar energy for residential heating and generating electricity by powering turbines. Additionally, photovoltaic technology has been applied to convert solar energy into electricity.

Table 1: Solar Energy Applications in Algeria.

Photovoltaic Applications	Thermal Applications
Public electricity supply and housing	Domestic water heating
Photovoltaic electricity production	Water purification
Photovoltaic-powered water pumping	Solar concentration and drying
Photovoltaic power stations	Solar cooling systems

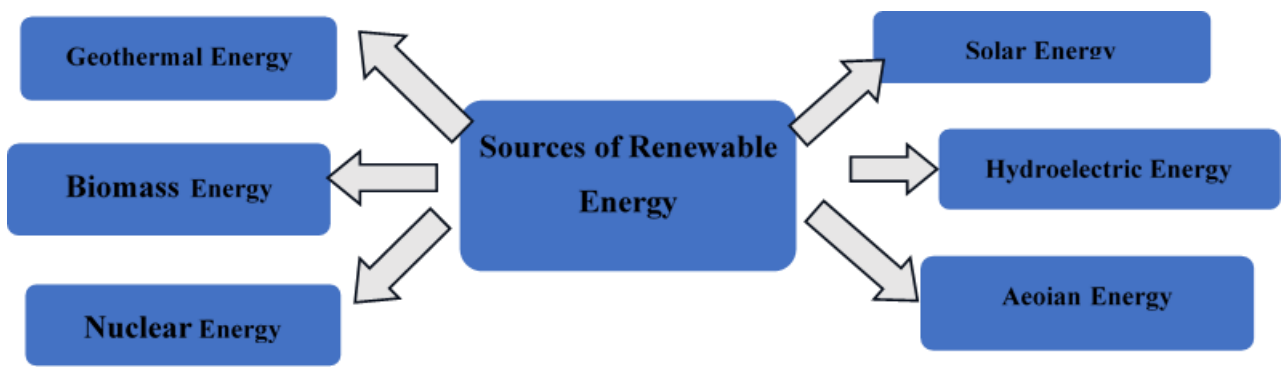
Source: Cherif Omar, *The Use of Renewable Energy and Its Role in Sustainable Local Development*.⁴⁴

3. Renewable Energy Capabilities in Algeria

3.1. National Potential for Renewable Energy Deployment

Algeria possesses a robust array of renewable energy sources, ranging from solar and hydropower to geothermal, aeolian, and biomass energies. This section delineates the substantial potential these resources represent for sustainable development within the nation.

Sources of Renewable Energy



Source: Younes Hawassi, Yazid Ben Soucha, Akram Chetih, Renewable Energies in Algeria as an Alternative for Sustainable Development⁴⁵

3.1.1. Solar Energy

Algeria's strategic geographical position confers upon it a significant advantage in solar energy production. The country is poised to transition from conventional energy reliance to becoming a prominent exporter of renewable energy, particularly targeting European markets. This shift is indicative of Algeria's potential to continuously expand its renewable energy production and exportation capabilities. The nation's solar irradiance is prodigious, exceeding five billion megawatt-hours annually, positioning it as a premier solar energy hub.

Illustrative data on the distribution of solar energy across Algeria is presented below:

Table 02: Distribution of Solar Energy in Algeria.

Desert	High Plateaus	Coastal	Region
86%	10%	4%	Area (%)
3,500	3,000	2,650	Sunshine Duration (Hours/Year)
2,650	1,900	1,700	Solar Irradiance (kWh/m²/Year)

Source: Ministry of Energy and Mines, *Renewable Energy Guide*, Algeria⁴⁶.

Photovoltaic conversion technology has emerged as a pivotal component in the transition toward sustainable energy systems, owing to its technological maturity and the extensive availability of solar irradiance on a global scale. Empirical evidence from localized implementations underscores the viability of photovoltaic systems in diverse applications, including water pumping, irrigation, and telecommunications infrastructure⁴⁷. Such versatility not only highlights the adaptability of solar technology in addressing energy demands but also its role in fortifying resilience within critical sectors. In an exemplary case, four strategically positioned wells, equipped with solar-panel roofing, were completed under the Sonatrach-Tassili initiative, with financial backing from the Italian energy conglomerate Eni. This pioneering endeavor, exploiting solar technology for well drilling in remote

arid regions, signifies a transformative step towards harnessing renewable resources, particularly within Algeria's southern expanse.

The success of this initiative hinged on extensive multi-sectoral collaboration, involving technical support from municipal bodies in Illizi and Djanet, as well as coordination with district-level authorities, the water management directorate, and the National Park Authority of Tassili. Such inter-institutional cooperation exemplifies a structured approach to sustainable development and a forward-looking, innovative project.⁴⁸

Algeria, with its extensive solar potential globally⁴⁹, stands at the forefront of the Mediterranean Basin⁵⁰ in renewable energy capacity:

- An estimated 169,440 terawatt-hours per annum of solar potential,
- Equivalent to 5,000 times the nation's current electricity consumption,
- And approximately 60 times the annual energy consumption of the European Union's original fifteen-member states, which is estimated at around 3,000 terawatt-hours.

3.1.2. Aeolian (Wind) Energy

In the domain of renewable energy development, wind energy presents itself as a dynamically variable resource, heavily influenced by local topography and meteorological conditions. Algeria, characterized by its bifurcation into northern and southern geographical zones, exhibits distinct climatic patterns that significantly influence wind resource potential. The southern region, notably the southwest, experiences wind speeds surpassing 4 m/s, occasionally exceeding 6 m/s in the Adrar vicinity⁵¹.

The strategic incorporation of wind energy within Algeria's national energy portfolio is recognized by experts as a pivotal investment. Economic projections posit that wind energy could generate annual revenues exceeding three billion euros, alongside creating numerous job opportunities and fostering a sustainable energy infrastructure. Historically, Algeria's wind energy consumption has been modest, with an initial capacity of merely 0.7 MW. This backdrop sets the stage for the ambitious five-year plan (2010-2014) aimed at augmenting Algeria's renewable energy capacity, particularly through the enhancement of local wind energy generation units.

The Algerian Renewable Energy Development Center (CDER) articulates a structured support mechanism for these units, providing the essential resources to invigorate the sector. The plan involves deploying 20 researchers and 360 academics across 30 local laboratories to intensify research and development activities. These initiatives are tailored to map high-wind-activity areas for potential wind farm development, with an overarching goal to achieve 3% of national electricity production from wind energy by 2015.

Internationally, the wind energy sector witnessed significant growth in 2009, as delineated by the Global Wind Energy Council (GWEC). The annual increase of 31% in installed capacity, amounting to an addition of 37.5 GW, brought the global total to 157.9 GW. China was instrumental in this expansion, doubling its wind capacity from 12.1 GW to 25.1 GW, while the United States expanded by 10 GW to reach an aggregate capacity of 35 GW. This surge underscores China's ascendancy as a global leader in wind energy, paralleled by substantial advancements in turbine manufacturing and the anticipation of a tenfold increase in capacity by 2020.⁵²

In its preliminary foray into wind energy, Algeria has invested 30 million euros in constructing its first wind farm, consisting of 10 turbines with an installed capacity of 10 MW in Adrar. This investment marks a significant milestone for the country, representing a tangible commitment to renewable energy integration. The French industrial group "Vergnet,"⁵³ known for its specialization in wind technology, was commissioned for this project, emphasizing international collaboration in

Algeria's renewable strategy. The site selection in Adrar, following detailed wind mapping studies, affirms the suitability of the region for wind energy development and sets a blueprint for future installations in wind-viable locations such as Tindouf.⁵⁴

3.1.3. Hydropower Energy

Despite substantial annual precipitation, Algeria's hydropower capacity remains underutilized, with only a fraction of the available water resources harnessed for energy production. Algeria's hydropower strategy focuses on integrating renewable energy capabilities into new dam constructions, equipping them with the necessary technologies to ensure a sustainable and resilient energy supply. Algeria receives approximately 65 billion cubic meters of rainfall annually, yet only 25 billion cubic meters are exploited, two-thirds of which is surface water. The remainder comprises groundwater, often concentrated in specific regions or lost through evaporation or rapid flow into the sea or aquifers.⁵⁵

Table 03: Hydropower Distribution by Region and Flow Characteristics.

Installed Capacity (MW)	Location	Power Stations
Strong Flow Stations		
71.5	Bejaia	Derguina
24		Imghil Imda
5.7	Mascara	Bouhanifia
15.6	Chlef	Oued Fodda
7.0	Ain Defla	Arib
100, 16	Jijel	Mansouria, Iragen
6.425	Bouira	Gouriats
4.228	Ain Temouchent	Tsala
3.5	Tlemcen	Beni Gzoul
Weak Flow Stations		
8.085	Tizi Ouzou	Souk El Jemaa
4.458, 2.7	Tizi Ouzou	Tizi Medan, Ighzer Nesbal
286 MW		Total

Source: Ministry of Energy and Mines, *Renewable Energy*⁵⁶

3.1.4. Geothermal Energy Resources:

Algeria is home to more than 200 geothermal hot springs, with the majority located in the northern part of the country. Notably, over two-thirds of these geothermal sources exceed 45°C, with the highest temperatures recorded at Hammam Meskoutine (98°C), Ain Oulman (118°C), and Biskra (119°C)⁵⁷. These thermal springs are largely attributed to the Jurassic limestone reservoirs found primarily across the northeastern and northwestern regions, with thermal outputs frequently exceeding 40°C.

Table 04: Potential Use of Alpine Basin Geothermal Water

Potential Applications	Water Temperature (°C)
Minimum temperature for cooling	70
Aquaculture	60
Mushroom cultivation	50
Urban heating (minimum requirement)	40
Fermentation	30
Fish farming	20

Source: Ministry of Energy and Mines.⁵⁸

The Alpine geothermal reservoir is being tapped at a flow rate exceeding 4 cubic meters per second, with water temperatures reaching 57°C.

3.1.5. Biomass Energy Capabilities:

Biomass represents an important component of Algeria's renewable energy portfolio, with its primary sources divided into two categories:⁵⁹

1. Forestry Resources:⁶⁰

Algeria's tropical forest cover is limited to approximately 10% of the national land area, comprising about 25 million hectares. The country's forest regions are divided into tropical and arid zones, with the latter covering over 90% of the national territory. Key energy-producing species within Algeria's forests include maritime pine and eucalyptus, which currently constitute only 5% of the country's total forest biomass.

2. Animal Waste:

Organic waste, particularly animal manure, holds significant potential for biogas production. Valorizing this waste through anaerobic digestion not only provides an environmentally sound waste management solution but also contributes to energy security.

3.1.6. Hydrogen Energy

Hydrogen is poised to play a transformative role in Algeria's energy transition. The global production of hydrogen is estimated at 65 million tons annually⁶¹, making it a crucial energy vector for future energy systems. Hydrogen is the most abundant element in the universe, and its fusion in stars, including the Sun, produces the heat and light necessary for life. While hydrogen does not exist freely in large quantities on Earth, it can be produced through various methods such as electrolysis, thermolysis, and solar-driven processes that mimic natural photosynthesis.⁶²

Hydrogen is widely recognized as an ideal fuel, offering substantial technical and environmental benefits. One kilogram of hydrogen produces three times the energy of an equivalent quantity of gasoline, making it an attractive alternative for a variety of sectors, including transportation⁶³.

2.1. The National Renewable Energy Program (2011–2030) .

Algeria has initiated a substantial shift toward sustainable energy over the last two decades, establishing frameworks for a renewable energy transition through the implementation of ambitious programs. Central to this strategy is the National Renewable Energy Development and Energy Efficiency Program, an extensive initiative designed to propel the country toward a green energy economy by 2030⁶⁴. Spanning from 2011 to 2030⁶⁵, this program aims to achieve an installed renewable capacity of approximately 22,000 MW, segmented into 12,000 MW dedicated to domestic electricity demand and 10,000 MW designated for export. Consequently, renewable energy forms a

foundational component of Algeria's long-term energy and economic policy, with expectations that by 2030, around 40% of Algeria's electricity production will be derived from renewable sources. Realizing this program will demand significant financial commitment, with the Algerian government pledging an investment of approximately \$60 billion, placing Sonelgaz in charge of executing this critical national initiative⁶⁶.

Algeria's pivot toward renewable energy is motivated by the urgent need for holistic and sustainable solutions to environmental challenges, as well as the conservation of fossil-based resources, including natural gas, petroleum, and coal. This strategic approach is bolstered by Algeria's immense solar energy potential; solar power alone is projected to constitute over 37% of national electricity generation by 2030. Wind energy, while a smaller contributor, is expected to comprise around 3% of the total electricity output. Additionally, a series of pilot projects focused on other renewable energy sources are underway to test and refine diverse technology applications⁶⁷.

Table 05: Projected Renewable Energy Installations under the National Program (2011–2030) in MW.

Total	Wind Power	Photovoltaics (PV)	Concentrated Solar Power (CSP)	Year
41	10	6	25	2013
557	50	182	325	2015
2,601	270	831	1,500	2020
12,000	2,000	2,800	7,200	2030

Source: Mokhtari Din, Fatima Zahra Zerouat, *Renewable Energy* ⁶⁸

Several significant projects are slated for completion in the first implementation phase (2011–2030), such as:⁶⁹

- A photovoltaic panel manufacturing plant in Rouiba Enara (Sonelgaz subsidiary), with an annual production capacity of 140 MW.
- A 10 MW wind farm in Adrar.
- A model photovoltaic plant in Ghardaia, incorporating four distinct photovoltaic technologies with a cumulative capacity of 1.1 MW.

Further strategic initiatives under consideration include:

- Concentrated Solar Power (CSP) plants with a combined capacity of 150 MW, with integrated thermal storage options.
- A silicon manufacturing plant to provide the primary raw material for photovoltaic (PV) cells.⁷⁰
- Geothermal power plants with an initial production capacity of 5 MW.

The National Renewable Energy Program stands as a pivotal component of Algeria's sustainable development ambitions, with broad-reaching economic, social, and environmental benefits. Key impacts include:⁷¹

- Development of a domestic renewable energy manufacturing industry, achieving an integration rate exceeding 80% through Algerian enterprises, supported by the creation of a network of local contractors for infrastructure and component manufacturing.
- Conservation of fossil fuels and a projected reduction in CO₂ emissions by approximately 900 million tons of CO₂ equivalent.
- Technology transfer and capacity building in renewable energy, enhancing the expertise of Algerian scientists, engineers, and technical personnel, with the ultimate goal of achieving full local implementation of renewable energy projects.

Table 06: Prospective Renewable Energy Exploitation for Clean Energy Production in Algeria.

2007	2008	2009	2010	2011	2012	2013	2014	2015	Years
0	30	30	100	100	100	100	170	170	Thermal Solar Power (MW)
0	0.149	0.140	0.442	0.413	0.384	0.369	0.572	0.532	Budget Allocation %
0	20	40	40	60	80	80	80	100	Wind Power (MW)
0	0.099	0.187	0.176	0.247	0.307	0.295	0.268	0.312	Budget Allocation %
50	100	150	200	250	300	350	400	450	New Resources (MW)
0.937	1.767	2.508	3.178	3.732	4.183	4.714	4.911	5.156	Budget Allocation %
1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	5.1	Photovoltaic Power (MW)
0.006	0.008	0.010	0.011	0.013	0.014	0.015	0.015	0.016	Budget Allocation %
51.1	151.6	222.1	342.6	413.1	483.6	534.1	654.6	725.1	Total (MW)
0.943	2.023	2.844	3.808	4.402	4.888	5.392	5.766	6.016	Budget Allocation %

Source: Menaour Osirir, Salima Boudrie, *Renewable Energy Resources in Algeria and Sustainable Development*⁷²

This table illustrates that, despite Algeria's vast renewable potential, particularly in solar energy, current contributions to the national energy budget remain modest. Algeria's solar energy capacity is estimated to exceed that of the European Union by 60 times and the global average by roughly four times, providing ample opportunity for extensive solar deployment.⁷³

Conclusion:

In conclusion, renewable energy technologies present an equitable means to foster sustainable resource distribution worldwide, benefitting both present and future generations. Maximizing solar and wind energy deployment does not deplete opportunities for subsequent generations; on the contrary, it ensures a secure, sustainable legacy.

In Algeria, although substantial progress has been made, there is still considerable potential yet to be realized given the country's rich natural and energy resources. Key recommendations include:

- Enhancing scientific and technical exchanges between Algeria and leading renewable energy nations (e.g., Germany, China, USA) through regular conferences and collaborative research initiatives.
- Replacing a significant portion of conventional energy with eco-friendly renewables, particularly given Algeria's finite fossil fuel reserves. A sustainable green strategy would yield lasting benefits for the Algerian economy (e.g., job creation, improved economic efficiency) and the environment.
- Prioritizing flagship renewable energy projects that bolster Algeria's energy portfolio and profitability.
- Providing financial and logistical support to stimulate the renewable energy market, recognizing Algeria's comparative advantage within the Maghreb region.
- Investing in human capital by enhancing specialized training programs.

- Expanding technology and research efforts, particularly in the exploration of alternative energy sources.
- Strengthening legislation to promote renewable energy adoption and responsible fossil fuel use.
- Offering incentives for households that implement solar power solutions.

¹ Ali Ahmed Atika, Energy and Development in the Arab World, Arab Future Journal, Center for Arab Unity Studies, Beirut, Lebanon, Vol. 11, No. 122, 1989, p. 39.

² Ali Ahmed Atika, Op.Cit, p.39

³ Kloum Youssef and Ezzedine Massoud, Legal Mechanisms of Algeria's New Approach in Renewable Energy: A Comparative Study of Leading Global Experiences in Renewable Energy, Journal of Studies and Research of the Arab Journal of Humanities and Social Sciences, Vol. 13, No. 4, July 2021, 13th year, p. 633.

⁴ Kloum Youssef and Ezzedine Massoud, *ibid.*, p. 633.

⁵ In the presence of representatives from 139 countries and around 117 observers from local, regional, and international organizations, Germany, Austria, and the United Arab Emirates competed to host the headquarters of the IRENA agency in Bonn, Vienna, and Abu Dhabi, respectively. In the voting session, Germany and Austria withdrew, enabling the UAE to secure the headquarters of the International Renewable Energy Agency (IRENA), thereby becoming the first international organization to establish its headquarters in the Middle East. This decision strengthened IRENA's position as a global center for renewable energy. Accessed April 04, 2025.

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⁶ Mohamed Moustafa El-Khayyat, *Expert in Renewable Energy and Environment, International Renewable Energy Agency (IRENA)*, Accessed April 10, 2025.
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<http://arabic.people.com.cn/31657/8090427.html>

⁸ Kloum Youssef and Ezzedine Massoud, *ibid.*, p. 634.

⁹ Abbas Zahra, Ben Aouida Najwa, *Benefiting from the German Energy Transition to Advance Renewable Energy in Algeria*, *Economic Studies Journal*, Issue 38, August 2019, pp. 370-374.

¹⁰ Abbas Zahra, *ibid.*, p. 375.

¹¹ Abbas Zahra, *ibid.*, p. 377.

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¹⁴ Ghadawia, Maamar, *ibid.*, p. 156.

¹⁵ Ghadawia, Maamar, *ibid.*, p. 155.

¹⁶ Ghadawia, Maamar, *ibid.*, p. 156.

¹⁷ Ghadawia, Maamar, *ibid.*, p. 156.

¹⁸ Kloum Youssef and Ezzedine Massoud, *ibid.*, p. 633.

¹⁹ Kloum Youssef and Ezzedine Massoud, *ibid.*, p. 166.

²⁰ Maamari, Oussama, Aida Anwar, and Sally Mohamed El-Dinouri, *Towards Benefiting from Leading Arab Experiences in Renewable Energy Investment for Sustainable Development in Algeria*, *Journal of Finance and Business Economics*, Vol. 3, No. 1, June 2018, p. 186.

²¹ *ibid.*, same page.

²² Tahar Abdel-Raouf Belkouch, Mohamed Al-Aribi, *The Role of Renewable Energy in Achieving Sustainable Development Goals in Maghreb Countries: Insights from Leading International Experiences*, *The New Economy Journal*, Vol. 10, Issue 1, 2019, p. 374.

²³ Tahar Abdel-Raouf Belkouch, Mohamed Al-Aribi, *ibid.*, p. 375.

²⁴ Kloum Youssef, Ezzedine Massoud, *ibid.*, p. 338.

²⁵ Law No. 98-11 dated 08/02/1998, containing the Guiding Law and the Five-Year Program on Scientific Research and Technological Development 1998-2002, *Official Gazette* No. 62/98.

²⁶ Executive Decree No. 04-92, dated 03/25/2004, concerning the diversification of electricity production, *Official Gazette* No. 19/04.

²⁷ Law No. 04-09 dated 08/14/2004, *ibid.*, p. 09.

²⁸ Mostafawi, Aida, *Renewable Energy as an Alternative to Address Environmental Security Threats*, *Annals of the University of Algiers I*, Issue 33, Part 2, June 2019, p. 126.

²⁹ Mostafawi, Aida, *ibid.*, p. 127.

³⁰ Kloum Youssef and Ezzedine Massoud, *ibid.*, p. 631.

³¹ Law No. 99-09 dated 07/28/1999 concerning energy management, *Official Gazette* No. 51/99.

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³⁷ Kloum Youssef, Ezzedine Massoud, *ibid.*, p. 339.

³⁸ Ministry of Environment and Renewable Energies (Algeria), *Wikipedia*, Accessed March 10, 2025. <https://ar.wikipedia.org/wiki/>

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⁴⁵ Younes Hawassi, Yazid Ben Soucha, Akram Chetih,, *Renewable Energies in Algeria as an Alternative for Sustainable Development*, *Journal of Administrative and Economic Research*, Vol. 02, Issue 04, December 21, 2018, p. 237.

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⁵⁴ Said Ali Hattabi, *Energy and Mines: Environment: A Global Leap in Wind Energy Utilization*, *ibid.*, p. 109.

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