Reassessing Energy Security in Algeria: Insights from Solar Energy

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Abstract:

Energy security in Algeria is often discussed through the lens of hydrocarbon abundance, yet persistent structural vulnerabilities, rising domestic demand, fiscal dependence on fossil fuels, and exposure to price volatility, challenge this perception. This study reassesses Algeria's energy security by examining the role of solar energy as a strategic economic and infrastructural alternative. Using a qualitative–analytical approach supported by secondary data from national strategies and international energy statistics, the study situates solar energy within the multidimensional framework of energy security, encompassing availability, affordability, accessibility, and environmental acceptability. The findings indicate that while Algeria possesses exceptional solar potential and has launched multiple renewable energy programs, the effective contribution of solar energy to energy security remains limited. Installed capacity and actual generation remain modest relative to potential, constrained by regulatory inertia, financing bottlenecks, and grid integration challenges. The study concludes that solar energy can enhance Algeria's long-term energy security only if embedded within coherent structural reforms rather than treated as a symbolic complement to fossil fuels.

Keywords: Energy Security; Solar Energy; Renewable Energy; Algeria.

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I- Introduction:

Energy security has evolved from a narrow concern over supply adequacy into a multidimensional economic and strategic issue encompassing price stability, system resilience, environmental sustainability, and long-term development prospects. In this broader framework, secure energy systems underpin macroeconomic stability, fiscal planning, and sustained economic growth.

Algeria represents a paradoxical case. Despite its status as a major hydrocarbon producer, the national energy system remains structurally vulnerable due to heavy dependence on fossil fuels, rapidly growing domestic consumption, and exposure to external price shocks. Simultaneously, Algeria benefits from one of the highest solar irradiation levels globally, positioning solar energy as a theoretically viable pillar of energy diversification. However, resource endowment alone does not guarantee energy security. The persistence of implementation gaps, governance constraints, and infrastructural limitations raises critical questions regarding the real capacity of solar energy to mitigate Algeria's energy vulnerabilities.

The Main Question:

Given Algeria's high solar potential yet persistent structural vulnerabilities, it becomes essential to assess whether and how solar energy can realistically strengthen the country's energy security. This raises the main question: **To what extent does solar energy contribute to energy security in Algeria?**

1. The theoretical framework of the study

In this section, we establish the theoretical framework linking solar energy to energy security. We first clarify the concept of solar energy and its economic, social, and environmental relevance, before defining energy security as a multidimensional concept encompassing availability, accessibility, affordability, and environmental acceptability. We then outline the theoretical mechanisms through which solar energy can contribute to energy security by reducing fossil fuel dependence, decentralizing energy production, and enhancing system resilience.

1.1. Solar Energy: Concept and Economic Relevance

1.1.1. Definition of solar energy

Considered a primary source of renewable energy as it is available throughout the year and directly falls on the Earth's surface. Tropical and equatorial regions are more exposed to solar energy, receiving about 2500 kilowatts/m2 per hour annually. Regions in Africa the Arabian Peninsula, and Latin America are most exposed to solar radiation.

The term Solar energy refers to the consumption of electric energy produced from the solar rays, which travel through electromagnetic waves at a speed of 200,000 km/second, and are divided into: (Khiati & Talem, 2024, p. 385)

Ultraviolet rays: Representing 6% to 7% of solar radiation, with wavelengths ranging from 400 to 700 nanometers.

Visible light rays: Including violet, yellow, green,blue, orange, and red rays, with wavelengths ranging from 400 to 700 nanometers,

Infrared rays: Their role includes heating the atmosphere and the Earth's surface, evaporating water, and controlling wind movement, with wavelengths reaching 700 nanometers.

Key elements of solar energy include:

Concentrated solar power (CSP): uses the heat from sunlight to generate electric power from conventional steam-driven turbines, using lenses or mirrors and tracking systems to concentrate a large area of sunlight into a small beam. It is about 25% more expensive than photovoltaic solar energy but is non-competitive with gas-powered energy production.

Photovoltaic Solar Energy: Captures sunlight using photovoltaic cells, representing technologies that directly convert solar rays into electrical energy based on the photovoltaic effect. (Khiati & Talem, 2024, pp. 385-386)

1.1.2. Social Energy Dimensions (solar energy pdf)

- **Solar Energy and the Economic Dimension**

Economic development is strongly dependent on the availability of reliable and modern energy services, which are essential for enhancing productivity, stimulating investment, and generating employment beyond the primary sector. Limited access to energy constrains opportunities for savings, entrepreneurship, and income generation, thereby restricting economic growth prospects.

Solar energy plays an increasingly important role in supporting economic development and is prioritized within the strategic energy policies of many countries. By enabling decentralized energy production, solar energy facilitates the establishment of small enterprises, supports agricultural activities, and promotes private sector development

The contribution of solar energy to sustainable economic development can be summarized as follows: (Hasan, Hossain, & Kabir, 2023, p. 18)

- Solar energy represents an inexhaustible and freely available renewable resource.
- The relatively simple and safe nature of solar technologies reduces operational risks and limits material and human losses.
- Solar energy projects promote job creation, stimulate local investment, and support economic activities in both agricultural and industrial sectors, while contributing to more rational energy consumption amid demographic growth.

- **Solar Energy and the Social Dimension**

Solar energy also addresses key social challenges by improving access to energy services, which is a critical factor in poverty reduction and social inclusion. Insufficient access to energy marginalizes vulnerable populations and limits their ability to improve living standards. Globally, a significant share of the population either lacks access to modern energy services or relies on traditional fuels, particularly in rural areas.

The dependence on conventional biomass fuels for cooking and heating has adverse effects on both public health and the environment. Moreover, stark disparities persist in energy consumption levels between developed and developing countries, reinforcing global inequality.

Solar-based applications, such as photovoltaic systems, solar water heaters, and energy solutions for agricultural processing, contribute to employment creation and poverty alleviation. In remote and isolated regions, solar energy reduces geographic isolation, supports local development, and provides an effective alternative to centralized electricity systems. Additionally, solar energy can supply essential infrastructure, including schools, health centers, and hospitals, particularly in desert and rural areas. The adoption of green building practices powered by solar energy reduces the costs of grid extension and

conventional power infrastructure, while promoting regional equity and encouraging investment in renewable energy sectors (Laib & Aaraba, 2021)

– **Solar Energy and the Environmental Dimension**

From an environmental standpoint, Environmental security is intrinsically linked to national security. The impact of solar energy in promoting environmental sustainability is profound:

- **Reducing Carbon Footprint**: Solar energy is a clean, renewable resource that significantly reduces carbon emissions.

Lowering greenhouse gases mitigates climate change effects, which can cause resource scarcity, mass migrations, and conflicts.

For instance, a nation that heavily invests in solar energy can decrease its carbon emissions drastically, contributing to global efforts to combat climate change.

This reduction in emissions also lessens the likelihood of climate-induced natural disasters, which can have devastating impacts on national security by displacing populations and straining resources.

- **Preserving Natural Resources**: By reducing reliance on fossil fuels, solar energy helps preserve natural resources and ecosystems.

  This preservation is vital for long-term environmental sustainability and national security. Fossil fuel extraction often involves environmentally harmful practices such as deforestation, water pollution, and habitat destruction.

  Transitioning to solar energy mitigates these impacts, ensuring that natural resources remain intact and available for future generations.

  Additionally, the sustainable management of natural resources supports biodiversity, which is essential for maintaining healthy ecosystems that provide critical services, such as clean water and air.

- **Enhancing Public Health**: The adoption of solar energy also contributes to public health improvements, which indirectly supports national security.

  Fossil fuel combustion releases pollutants that degrade air quality, leading to respiratory illnesses and other health issues.

  By switching to solar energy, nations can reduce air pollution, resulting in a healthier population that is less burdened by medical costs and more capable of contributing to the economy and national defense. (TAMESOL, 2024)

1.2. Energy Security: Definition and Dimensions

1.2.1. Definition of Energy Security

Energy security, according to the International Energy Agency (IEA), is defined as the uninterrupted availability of energy sources at an affordable price. An influential approach to analyzing energy security has been the four As which are: availability, accessibility, environmental acceptability, and affordability. (German Council on Foreign Relations, 2025)

Energy security is commonly analyzed through several interrelated dimensions. Availability refers to the existence of sufficient domestic or external energy resources, including fossil fuels and renewable sources, capable of meeting current and future demand. Accessibility relates to the economic, political, and technological conditions that determine a country's ability to reliably access these resources when required. This dimension

encompasses infrastructure adequacy, market integration, geopolitical constraints, and regulatory frameworks.

Environmental acceptability reflects the societal and regulatory assessment of the negative externalities associated with different energy sources. It captures public tolerance for environmental impacts such as pollution, greenhouse gas emissions, ecosystem degradation, and biodiversity loss, and increasingly shapes energy policy choices in the context of climate change. **Affordability**, in turn, concerns the cost of energy for consumers and producers, including price stability, cost competitiveness across energy sources, and the financial sustainability of energy supply systems.

Over recent decades, the factors threatening national energy security have become more numerous and complex. Risks now arise not only from physical scarcity, but also from climate change, geopolitical competition over energy resources, armed conflicts, natural disasters, unreliable supply chains, excessive dependence on a limited number of energy sources or suppliers, deliberate manipulation of energy markets, and cyberattacks targeting critical energy infrastructure.

To mitigate these risks and ensure a secure and uninterrupted energy supply, countries may adopt a combination of strategic measures. These include diversifying energy sources and suppliers to reduce import dependence, improving energy efficiency to curb demand pressures, strengthening the digital resilience of energy systems, and investing in research and development to support new technologies and energy uses. Ongoing energy transitions and broader sustainability agendas offer potential solutions to energy security challenges, while simultaneously introducing new vulnerabilities.

In the context of the global shift toward low-carbon energy systems, future energy security concerns are increasingly linked to the structure of green supply chains. Ensuring secure, resilient, and carbon-neutral energy systems will require diversification not only in energy sources, but also in ownership, technologies, and sourcing across the entire energy value chain. (Asia Pacific Energy Research Centre, 2007, p. 7)

From the perspective of the World Bank Group, energy security refers to a country's ability to produce and utilize energy in a sustainable manner and at reasonable cost, in order to support economic and social development. Specifically, energy security is viewed as a critical condition for facilitating economic growth and, through this channel, contributing to poverty reduction. At the same time, it directly enhances quality of life by expanding access to modern and reliable energy services.

However, the meaning and priorities of energy security are not uniform across countries. They vary according to structural characteristics such as the level of economic development, the availability of domestic energy resources, and the country's role in global energy demand. On this basis, countries may be broadly categorized according to their development status, energy endowment, and exposure to international energy markets.

For energy-producing countries, energy security is closely linked to the ability to secure stable, long-term, and profitable markets for their natural resources, as these

revenues often constitute a central pillar of their economies. In contrast, for industrialized economies, energy security primarily concerns the continuity and reliability of energy supply, which is essential for sustaining economic activity and maintaining high living standards. For low-income countries, energy security represents a fundamental prerequisite for development, as access to energy increases productivity, raises incomes, and improves outcomes in health, education, and economic integration.

Despite these differences, all countries share a common interest, across producers and consumers, and between developed and developing economies, in ensuring that global energy systems support economic growth in a sustainable and resilient manner. Persistent inequalities in access to electricity and modern energy services continue to pose a major challenge, particularly in developing regions, where energy poverty remains a barrier to inclusive development.

In recent years, international attention to energy security has intensified due to rising and volatile energy prices, particularly in oil and gas markets. Although current price levels differ from historical peaks, increased volatility has heightened concerns about macroeconomic stability and long-term supply security. Such price fluctuations pose risks to the global economy as a whole, but their impact is disproportionately severe for low-income, energy-importing countries, which often lack the fiscal capacity to absorb price shocks.

Energy-importing countries are therefore increasingly concerned not only with short-term price volatility, but also with the long-term availability of secure and affordable energy supplies. At the same time, energy-exporting countries have benefited from elevated price levels through increased export revenues. Nevertheless, prolonged high energy prices may ultimately weaken global economic growth, potentially undermining trade relations between exporters and importers, despite limited evidence of such effects to date. (The World Bank Group, 2005, p. 5)

1.2.2. The Significance of Energy Security

Energy's development was a concern regarding the continuation of its supply among producers and consumers, making maintaining this continuity a challenge in and of itself. In addition, a variety of factors have contributed to the ongoing search for energy security, the most notable of which are: (Bašová, 2018, p. 151)

Protecting national economies from unanticipated challenges posed by natural gas suppliers;

The primary requirement for the security of the state and its population is the provision of the bare minimum of energy on its territory;

Disruptions in energy supply because an immediate drop in production and an increase in energy prices, which causes an increase in the consumer price index;

Energy Security falls under Human Security because it plays a direct role and contributes to food security, water security, and climate security in general;

Global energy supply networks are under severe strain. It is an urge to shift to low-carbon supply systems rather than traditional ones that cause anxiety and doubt about the success of this transition.

The growing interest in energy security points to three distinct dimensions: an economic one based on the ability of the household sector to meet energy needs; a material dimension based on approved infrastructure based on its energy efficiency; and a political dimension based on the ability of the government to meet energy needs. Then, following my conduct concerning energy guidance.

1.2.3. Threats to Energy Security:

Threats to the energy sector can be natural, technological, or human caused, and can damage, destroy, or disrupt energy systems (Resilient Energy Platform). A community that is energy-secure will incorporate resilient systems and approaches that can prevent, mitigate, or allow for adaptation to threats and changing conditions. Examples of threats to the energy sector include:

Natural Disasters: Severe weather events like droughts and storms are projected to become more intense and destructive. These events can decrease or disrupt supplies and negatively impact energy infrastructure. In the United States, severe weather is the number one cause of power outages. Cyberattacks: The energy sector is becoming more automated, digitized, and interconnected. Cyberattacks are becoming more common and could pose a greater threat as the energy sector becomes more modern and connected. Geopolitics: Interstate conflicts can threaten energy security. For example, the 1973 oil crisis resulted from an embargo by the Organization of Petroleum Exporting Countries on the United States (U.S. Department of State). Political instability in fuel producing nations can impact energy prices. Fuel Price Fluctuations: Changes in fuel prices (e.g., related to market or other factors) can threaten energy security through impacting a nation's or community's ability to purchase fuels. Long-Term Climatic Changes: Changing environmental conditions like air temperature, water temperature, and water availability can cause stress to energy systems. • Rising temperatures increase the demand for air conditioning, most significantly impacting summer peak energy demands • Water is necessary for energy production. Hydroelectric systems depend on flow, and some electricity production systems need water for cooling. Reduced precipitation or increased water temperatures can impact supply by limiting power plant capacity. Snowpack melt changes (i.e., the timing of melt and runoff in the spring or summer) changes peak production for hydroelectric systems • Changes in sea levels or storm surges can impact energy infrastructure close to shorelines, due to flooding. (Cox, Beshilas, & Hotchkiss, 2019, pp. 1-2)

1.3. Theoretical Link: Solar Energy and Energy Security

The Role of Solar Panels in Enhancing Energy Security

- **Reducing Dependence on Fossil Fuels**

Solar panels are game-changers when it comes to cutting down on fossil fuel use. They tap into the sun's energy, which is free and abundant, reducing the need for oil, coal, and gas. This shift is not just about going green; it's about securing a steady, local energy source. By relying more on solar, countries can promote energy independence and shield themselves from the volatile global fossil fuel market.

- **Decentralizing Energy Production**

Solar panels are popping up everywhere, rooftops, fields, and even parking lots. This spread-out energy production means power is generated closer to where it's used, slashing transmission losses. Plus, if one system goes down, others can pick up the slack, making the whole grid more reliable. It's like having a backup plan that kicks in when you need it most.

- **Increasing Resilience Against Energy Disruptions**

Imagine a storm knocks out the power grid. With solar panels, especially those paired with battery storage, homes and businesses can keep the lights on. These setups store extra energy for use when the sun isn't shining or during outages. They act like a safety net, providing power when the grid can't. This resilience is crucial during natural disasters or unexpected blackouts.

Solar energy isn't just a clean alternative; it's a strategic move towards a more stable and secure energy future. By embracing solar technology, we not only protect the environment but also build a more resilient energy system that can withstand the challenges of the modern world. (Solar N Plus, 2025)

2. The Reality of Solar Energy in Algeria

In this section, we examine the practical reality of solar energy development in Algeria by analyzing national renewable energy programs, regional implementation efforts, and the evolution of solar electricity capacity and generation. We review major policy initiatives, projects implemented in both northern and southern regions, and recent trends in installed capacity and output in order to assess the extent to which solar energy has moved beyond planning objectives toward effective deployment. This empirical overview provides the basis for evaluating whether Algeria's solar potential has translated into tangible contributions to its energy system.

2.1. National Renewable Energy strategy in Algeria

In response to rising energy intensity and growing domestic demand, the Algerian government has increasingly emphasized energy efficiency and renewable energy options. This policy orientation materialized in the launch of an ambitious national program aimed at developing renewable energies, especially solar power, and improving energy efficiency. The strategy focuses on expanding the use of inexhaustible resources to diversify energy sources and prepare the foundations of Algeria's future energy system (Stambouli, Khiat, Flazi, & Kitamura, 2012, p. 4450)

Recognizing the limitations of earlier initiatives, the government approved a revised and complementary national renewable energy development program (2015–2020–2040) in February 2015. This revision, partly triggered by the sharp decline in global oil prices, implicitly acknowledged the shortcomings of the initial program and reinforced the urgency of energy diversification.

The national renewable energy strategy, developed in coordination with the Centre for Renewable Energy Development (CDER), established several key objectives:

The deployment of approximately 22,000 MW of renewable energy capacity between 2011 and 2030, including 12,000 MW to meet domestic demand and 10,000 MW intended for export. The overarching goal is for renewable sources to account for 40 % of national electricity production by 2030, with solar energy contributing around 37 % and wind energy approximately 3 %.

The renewable energy program for the period 2011–2020 includes the construction of 60 solar photovoltaic and solar thermal power plants, wind farms, and supporting facilities aimed at strengthening the domestic solar energy industry.

Capacity targets envisage the installation of approximately 2,600 MW for the national market by 2020, with export potential of around 2,000 MW, increasing to 12,000 MW for domestic use and 10,000 MW for export by 2030.

In parallel, Algeria has announced plans to supply approximately 15,000 MW of solar energy by 2035, with the objective of substantially reducing dependence on hydrocarbons in electricity generation. This initiative is intended to stabilize growing domestic energy demand, support long-term export ambitions, and contribute to the diversification of the national economy beyond fossil fuels.

2.2. Solar Energy Deployment in Algeria's Southern Regions

Electricity demand has increased markedly in recent years, particularly in southern regions where climatic conditions and geographic isolation pose specific challenges. In response, Algeria has implemented several solar-based projects aimed at revitalizing the Great South, improving access to energy, water, and agricultural productivity (Ouaar & Ismael, 2021, p. 599)

- **Key initiatives include:**

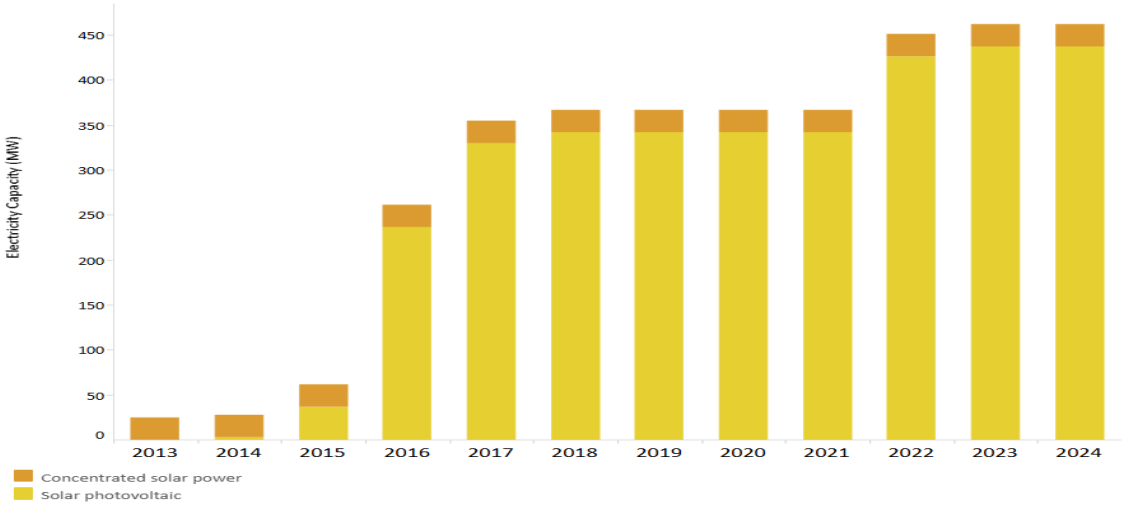
- Grid-connected photovoltaic systems in the state of Ghardaïa, where solar panel fields feed electricity directly into the national grid. This configuration allows all generated energy to be absorbed by the grid, effectively functioning as a storage system with unlimited capacity.
- Upgrading photovoltaic solar lighting systems in the state of Adrar, focusing on evaluating the performance of different lamp technologies and ensuring reliable electricity supply under high-temperature and high-irradiation conditions.
- Photovoltaic pumping systems in desert environments, particularly in the Adrar region, where abundant groundwater resources support agricultural expansion. These systems are designed to provide irrigation and drinking water using solar-powered pumps, in collaboration with CDER under Euro-Mediterranean cooperation programs (MEDA).
- Solar-powered irrigation projects in Temacine (state of Ouargla), where photovoltaic pumping systems are planned to irrigate approximately 14 hectares of palm groves and greenhouses, offering a practical solution in areas without access to the electricity grid.
- The Hassi R'Mel hybrid project, aimed at integrating solar energy into gas-based power generation, reflecting an intermediate approach to the energy transition.
- Smart solar stations for electricity supply and irrigation in the state of Laghouat, targeting isolated communities that rely on groundwater as their primary water source. These projects combine photovoltaic electricity generation with efficient water use to support irrigation and domestic needs.
- Integration and optimization of photovoltaic lighting using white semiconductor LEDs, reflecting efforts to reduce electricity consumption through energy-efficient lighting technologies.
- Solar cooling projects based on absorption technology in the state of Biskra, exploring the use of solar thermal energy for refrigeration and air conditioning, particularly for food preservation and residential comfort in hot climates.

Therefore, Algeria has expressed a commitment to strengthening the industrial use of solar energy, particularly within the framework of Great South development strategies and

the 2030 horizon. This includes expanding the electricity interconnection network between northern regions and southern desert areas such as Adrar, and facilitating the installation of large renewable energy plants in In Salah, Adrar, Timimoun, and Béchar, with full integration into the national electricity system (Ouaar & Ismael, 2021, p. 601)

2.3. Solar electricity generation/capacity in Algeria 2013-2023

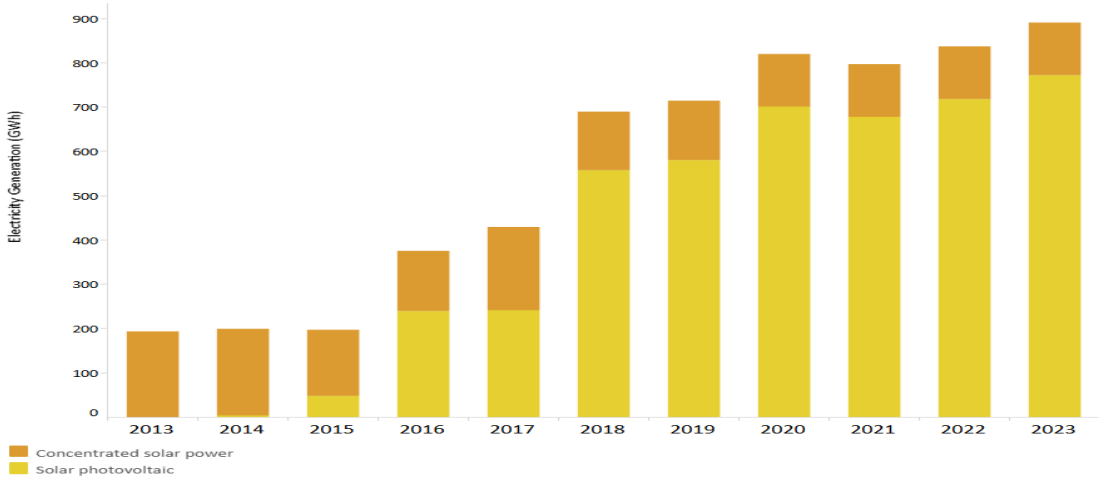
Fig 1: Solar electricity capacity in Algeria 2013-2023



Source: IRENA Renewable Energy Statistics 2025

Figure 1 illustrates the trajectory of Algeria's installed solar electricity capacity from 2013 to 2024, distinguishing between photovoltaic (PV) and concentrated solar power (CSP) technologies. Capacity expanded rapidly after 2015, driven almost entirely by PV projects, reflecting early government incentives and declining technology costs. However, growth stagnated between 2017 and 2021, highlighting structural impediments: limited access to long-term financing, slow regulatory approvals, and weak grid infrastructure capable of accommodating intermittent solar generation. Post-2022, capacity growth resumed, yet the overall scale remains modest compared with Algeria's abundant solar potential. When combined with Figure 2, which depicts actual solar electricity generation, a clear divergence emerges: installed capacity does not consistently translate into electricity output. This gap signals that technical factors alone do not explain underperformance; rather, it points to governance inefficiencies, financing bottlenecks, and inadequate integration into the national grid. In essence, Algeria's solar sector demonstrates that while PV technology is deployable, systemic barriers regulatory, financial, and infrastructural continue to constrain the effective exploitation of its solar resources.

Fig 2. Solar electricity generation in Algeria 2013-2023



Source: IRENA Renewable Energy Statistics 2025

Figure 2 illustrates the evolution of solar electricity generation in Algeria between 2013 and 2023, disaggregated by photovoltaic (PV) and concentrated solar power (CSP) technologies. The data reveal a clear acceleration of solar generation after 2016, driven almost exclusively by photovoltaic deployment. While CSP accounted for most solar generation in the early years, its contribution remains limited and relatively stagnant over time. This shift reflects both global cost trends favouring PV and domestic constraints related to capital intensity, operational complexity, and system integration. Despite recent growth, total solar electricity generation remains modest relative to Algeria's overall power production, underscoring the persistence of structural barriers to large-scale renewable integration.

2.4. Overview of Solar Energy Projects in Algeria

Several solar-related projects have been implemented in Algeria, contributing, albeit modestly, to the country's sustainable development objectives:

2.4.1. Rural Electrification of Remote Southern Villages (1998):

Launched in 1998 and led by Sonelgaz, this program aimed to provide off-grid solar electricity to isolated communities in southern Algeria that were not connected to the national power network. The project delivered basic solar-powered lighting services to approximately 1,000 households across four southern provinces, Tamanrasset, Adrar, Illizi, and Tindouf, using state-funded resources. While limited in scale, the initiative demonstrated the feasibility of solar energy for decentralized rural electrification in remote areas.

2.4.2. Hassi R'Mel Hybrid Gas–Solar Power Plant (2011):

Commissioned on 14 January 2011, the Hassi R'Mel hybrid power plant represents Algeria's most prominent utility-scale solar-related project. Developed through a partnership between the Algerian company NEAL and the Spanish firm ABENER, the project involved an investment of approximately €350 million. The plant has a total installed capacity of 150 MW, of which 120 MW is generated from natural gas and 30 MW from solar thermal energy, and is fully integrated into the national electricity grid. Despite being frequently cited as a flagship renewable project, the plant remains predominantly gas-based, highlighting the continued dominance of fossil fuels in Algeria's electricity generation mix (Aouadj, Zebirate, Smail, & Saidi, 2021)

Table (1): Government Targets for Renewable Energy Capacity Deployment in Algeria (2015–2030)

	First phase 2015-2020	Second phase 2021-2030
Solar cells	3000	10575
Wind	1010	4000
Solar heat	-	2000
Cogeneration	190	250
Biomass	360	640
Geothermal Heat	05	10
Total	4525	17475

source : Renewable Energies Program of the Ministry of Energy and Mines. (https://www.cder.dz)

Table 1 further shows that Algeria's renewable electricity development strategy is structured around two implementation phases:

- **Phase I (2015–2020):** This phase targeted the deployment of approximately 4,525 MW of renewable electricity capacity, with solar photovoltaic technologies accounting for the largest share (around 3,000 MW). The emphasis during this period was primarily on initiating large-scale solar deployment and establishing a preliminary renewable energy base.
- **Phase II (2021–2030):** The second phase focuses on expanding grid infrastructure, notably through the development of transmission links between northern demand centers and southern desert regions such as Adrar. This grid expansion is intended to enable the installation of large renewable power plants in In Salah, Adrar, Timimoun, and Béchar, and to ensure their integration into the national electricity system. Within this phase, solar thermal technologies are also expected to become economically viable, supporting further diversification of solar generation technologies. According to the projections presented, solar energy is expected to account for more than 37 % of national electricity production by 2030.

Solar energy is exploited primarily through **thermal conversion technologies** to meet a range of residential, agricultural, and industrial needs. At the household level, it is used for **domestic water heating as well as space heating and cooling.** In the agricultural sector, solar thermal energy supports **crop drying and preservation processes.** Industrial applications include **seawater desalination** and the **production of distilled water** for specialized uses such as battery manufacturing, laboratory operations, and other technical applications.

Overall, Algeria possesses substantial renewable energy potential, particularly in solar energy, which occupies a central position in the country's long-term energy strategy and its stated objectives for 2030, as summarized in the following table:

Table (2): Government Targets for Renewable Energy Capacity Deployment in Algeria (2015–2030)

Energy type	2011-2020		2021-2030	
Photovoltaic Solar Energy	2011-2015	Projects completed with an estimated capacity of 800 MW	2021-2023	Projects completed with an estimated capacity of 200 MW
	2011-2013	Projects completed with an estimated capacity of 150 MW Completion of the Hassi R'Mel hybrid solar–gas power plant (150 MW total capacity, including 25 MW from solar energy)	2021-2030	Projects completed with an estimated capacity of 500 MW
	2011-2013	Two wind farms completed, totaling an estimated 1,200 MW	2016-2030	Projects completed with an estimated capacity of 1700 MW

source : Renewable Energy Development Center of Algeria. (http://portail.ceder.dz)

Despite the range of solar-related projects and strategic plans implemented, their cumulative contribution remains modest when measured against Algeria's resource endowment.

2.5. Long-Term Prospects for Solar Energy in Algeria

Investment in solar energy offers a dual advantage: it supports the achievement of energy supply objectives while contributing to environmental protection through the reduction of carbon emissions, without constraining economic development. Countries located within the so-called "Sunbelt" benefit from consistently high levels of global horizontal irradiation throughout the year, making solar technologies particularly viable. This group includes regions such as North Africa, the Middle East, Australia, southern Africa, China, and the southern United States, all of which possess favorable climatic conditions for large-scale solar deployment. Areas with an average annual solar irradiation exceeding 2,800 kWh/m² are considered optimal for solar energy exploitation (Maka & Alabid, 2022, p. 480)

Within this context, solar energy represents the most abundant renewable resource in Algeria, making its exploitation a strategic necessity. Algeria benefits from exceptionally high solar exposure: annual sunshine duration exceeds 2,000 hours across most of the national territory and may reach 3,900 hours in Saharan regions. The average daily solar energy received on a horizontal surface is approximately 5 kWh/m², corresponding to about 1,700 kWh/m² per year in northern regions and 2,650 kWh/m² per year in southern regions (Himri, Arif, Boudghene Stambouli, Himri, & Draoui, 2009, p. 100)

Algeria's vast land area, much of which consists of desert terrain, further strengthens its solar advantage. Annual solar energy inflows are estimated at approximately 169,400 TWh, a volume that is often cited as being several thousand times greater than the country's current annual electricity consumption. This substantial endowment underscores the strategic role solar energy could play in Algeria's long-term energy transition.

2.6. Can Solar Energy Secure Algeria's Energy Future?

Since the economic crisis of 1986, Algeria has sought to reduce reliance on fossil fuels in the state budget, and recent strategies have focused on optimizing the use of renewable energy, particularly solar power. A variety of large-scale projects and policy measures aim to strengthen the position of solar energy relative to fossil fuels. Investments in utility-scale solar projects are intended to generate significant electricity, supporting national demand while reducing dependence on diesel and natural gas. Simultaneously, the government promotes household solar adoption through incentives and facilitation programs for rooftop installations, signaling a dual strategy targeting both centralized and decentralized solar deployment.

As of 2021, Algeria's total solar generation capacity was approximately 400 MW, with the Tamanrasset project standing out as the largest solar facility in the country and among the largest globally, with an estimated capacity of 344 MW. Electricity demand in Algeria is growing at over 7% annually, underscoring the urgency of diversifying supply. In 2011, the government launched a renewable energy development program targeting 22,000 MW by 2030, 12,000 MW for domestic electricity and 10,000 MW for export. However, this program has not fully achieved its goals; the 2015 target of generating 40% of electricity from renewable sources by 2030 was revised downward to 27%, reflecting the challenges of translating policy ambitions into operational outcomes.

To accelerate renewable energy development, Algeria established the Renewable Energy and Energy Efficiency Directorate under the Prime Minister's Office in 2019 and the Ministry of Energy Transition and Renewable Energies in 2020. The ministry's roadmap targets a 30% share of renewable electricity by 2030, beginning with an initial provision of 1,000 MW (premier-ministre, 2023). Priority measures include the transport and housing sectors, with a 10% reduction in energy consumption by 2021 achieved through initiatives such as the installation of 100,000 solar water heaters, expected to yield up to 40% energy savings while supporting local industry. Further, national renewable energy plans seek to expand solar, wind, and natural gas utilization. On August 14, 2019, SKTM, a Sonelgaz subsidiary, signed agreements to construct nine hybrid photovoltaic-diesel power stations in southern Algeria, totaling 50 MW. (Gueddiri & Chemani , 2024, p. 173)

Despite these efforts, structural challenges continue to constrain solar energy's impact on Algeria's energy security. Installed capacity remains modest relative to the country's solar potential, and electricity generation often lags behind capacity, particularly during the 2017–2021 stagnation period. This suggests that solar energy, while growing, currently functions more as a complement than a substitute for fossil fuels. Short-term contributions to energy security are therefore limited, with solar primarily reducing incremental fossil fuel consumption rather than transforming the energy mix.

In the long run, solar energy has the potential to enhance Algeria's energy security significantly, provided that systemic barriers, financing, regulatory clarity, grid readiness, and technical capacity, are addressed. Coupled with grid modernization and storage integration, solar deployment could reduce exposure to fuel price volatility and environmental impacts. However, historical experience indicates a risk of treating solar as a

symbolic policy rather than a driver of structural reform: announced targets and pilot projects often outpace the implementation of supporting mechanisms, creating the appearance of progress without substantive system-wide transformation.

For solar energy to meaningfully secure Algeria's energy future, deployment must be embedded within a coherent reform strategy that strengthens governance, ensures financing continuity, and integrates renewable generation into national planning. Additionally, the success of the energy transition will depend on fostering an environment conducive to innovation and entrepreneurship, while developing competitive industrial sectors capable of engaging internationally. Only with such structural alignment can solar move beyond complementarity and become a transformative contributor to Algeria's energy security.

Conclusion

In this study. We conclude that solar energy, despite its abundance and strategic relevance, has not yet translated into a transformative improvement in Algeria's energy security. Our analysis shows that existing solar initiatives have contributed only marginally to electricity supply and remain insufficient to offset the country's structural dependence on fossil fuels. The persistent divergence between installed capacity and actual electricity generation indicates that technological deployment alone is inadequate to deliver meaningful energy security gains.

We find that the limited contribution of solar energy is primarily driven by structural and institutional constraints rather than by resource availability. Regulatory inertia, financing bottlenecks, fragmented governance, and insufficient grid readiness continue to restrict the effective integration of solar energy into the national energy system. As a result, solar energy currently functions more as a complementary source than as a structural substitute for hydrocarbons, reducing incremental fossil fuel use without fundamentally reshaping the energy mix.

We therefore argue that solar energy can meaningfully enhance Algeria's long-term energy security only if it is embedded within coherent structural reforms that ensure regulatory clarity, financing stability, grid modernization, and institutional coordination. Without addressing these systemic constraints, solar energy risks remaining a symbolic policy instrument rather than a driver of structural change. Ultimately, we find that Algeria's future energy security will depend less on its exceptional solar potential than on governance quality and the consistency of long-term strategic implementation.

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