Advancing renewable energy sustainability in Algeria: a strategic analysis of major solar power projects

HELLABI Zoubeyda

LEREMA laboratory , Higher School of Management Tlemcen, (Algeria)
z.hellabi@esm-tlemcen.dz

ORCID: https://orcid.org/0009-0009-8342-8785

Received: 13/01/2026 **Accepted: 13/02/2026** **Published: 15/04/2026**

Abstract:

This paper examines Algeria's ambitious solar energy development strategy, focusing on the five most significant photovoltaic projects that form the backbone of the nation's renewable energy transition. With an exceptional solar potential averaging 3,000 hours of sunshine annually and some of the highest solar irradiation rates globally, Algeria has embarked on an aggressive expansion program targeting 115 GW of clean electricity generation by 2035. Through detailed analysis of projects totaling over 2,500 MW across 15 provinces, this study evaluates the technical, economic, and strategic dimensions of Algeria's solar roadmap, including the 1,000 MW, 2,000 MW, and 3,000 MW programs managed by state utility Sonelgaz. The research highlights significant international partnerships, particularly with Chinese and Turkish companies, examines implementation challenges, and assesses the implications for regional energy security and climate commitments. Findings indicate that successful execution of these flagship projects could reduce natural gas dependency for power generation from 98% to approximately 73% by 2030, while creating an estimated 300,000 jobs and positioning Algeria as a potential renewable energy exporter to Europe.

Keywords: Solar energy, renewable energy transition, photovoltaic projects, energy policy, sustainable development.

Ce(tte) œuvre est mise à disposition selon les termes de la Licence Creative Commons Attribution - Pas d'Utilisation Commerciale 4.0 International

I- Introduction:

Algeria stands at a critical juncture in its energy development. As a major hydrocarbon producer, the nation has traditionally relied almost exclusively on natural gas for electricity generation, which accounts for approximately 98 percent of power production as of 2023. However, growing domestic energy demand, international climate commitments under the Paris Agreement, and dramatic cost reductions in solar photovoltaic technology have catalyzed a strategic shift toward renewable energy. Algeria possesses exceptional solar resources, receiving approximately 2,500 to 3,600 kilowatt-hours per square meter annually of solar irradiation, with Saharan regions reaching up to 2,800 kilowatt-hours per square meter per year, placing it among nations with the highest solar potential globally.

The Algerian government has launched an ambitious renewable energy program targeting 15,000 megawatts of capacity by 2035, aiming to increase renewable energy's share from less than two percent currently to 27 percent by 2030 and 40 percent by 2035. State utility Sonelgaz has implemented three major solar programs totaling 6,000 megawatts. Within these programs, five flagship projects representing nearly 2,000 megawatts and over two billion dollars in investment are currently under construction through partnerships with Chinese, Turkish, and domestic developers across Batna, Laghouat, El Oued, Ouargla, and Biskra provinces.

This study addresses a fundamental question: does Algeria's solar expansion represent genuine energy transition capable of reshaping the electricity sector, or does it constitute symbolic additions that leave the gas-dominated regime essentially intact? Specifically, this research investigates what technical, economic, institutional, and social factors enable or constrain successful implementation of these five major projects. How do landscape pressures, regime characteristics, and niche developments interact to shape Algeria's transition pace and direction? What functional patterns in knowledge development and resource mobilization are strong or weak? How do policy frameworks facilitate or hinder solar diffusion? What justice implications arise regarding employment, regional development, and benefit distribution?

The research advances three hypotheses. First, Algeria follows a reconfiguration pathway where solar supplements rather than replaces gas generation, enabling export expansion while building renewable capacity. Second, explicit transitions in capacity additions progress faster than implicit structural changes in governance and institutions due to path dependencies. Third, achieving 2035 targets requires addressing weaknesses in local manufacturing, grid infrastructure, and financing mechanisms.

This study employs a mixed-methods approach combining quantitative project data analysis with qualitative assessment of policy documents and institutional arrangements. Primary sources include Ministry of Energy announcements, Sonelgaz reports, contractor technical specifications, and national energy statistics. Secondary sources encompass academic literature on energy transitions, International Energy Agency and International Renewable Energy Agency publications, and specialized industry reports. Data collection spanned January 2024 to January 2025.

The analytical framework integrates the Multi-Level Perspective on socio-technical transitions (Geels, 2002, 2024), energy transition theory distinguishing explicit and implicit dimensions (Wang & Lo, 2024), technological innovation systems analysis (Hekkert et al.,

2020), energy justice frameworks (Jenkins et al., 2016), and socio-technical-ecological perspectives (Andersson et al., 2024). This integrated approach enables comprehensive examination of technical, economic, institutional, social, and environmental dimensions.

The research contributes theoretically by advancing understanding of energy transitions in resource-rich developing countries, empirically by documenting Algeria's major solar projects in detail, and practically by offering policy insights for accelerating equitable solar deployment. The findings provide lessons for other hydrocarbon-exporting nations pursuing renewable energy transitions.

1. Literature review

The transition toward renewable energy in North Africa and the Middle East has attracted growing scholarly attention over the past decade, with particular focus on solar energy development given the region's exceptional solar resources. This literature review examines three key bodies of research relevant to Algeria's solar energy expansion: studies on renewable energy development in Algeria specifically, comparative analyses of solar energy transitions in resource-rich developing countries, and research on implementation challenges and success factors for large-scale solar projects.

Renewable Energy Development in Algeria

Algeria's renewable energy potential and development trajectory have been documented by several scholars. Stambouli et al. (2012) provided a comprehensive early assessment of Algeria's renewable energy landscape, identifying exceptional solar resources with annual irradiation reaching 2,650 kWh/m²/year in Saharan regions alongside significant policy and institutional barriers to deployment. Their analysis emphasized that despite favorable natural conditions, renewable energy contributed less than one percent of electricity generation due to heavy subsidies favoring natural gas, limited grid infrastructure in high-potential regions, and insufficient policy incentives for private investment. Bouraiou et al. (2020) updated this assessment, documenting modest progress in solar capacity additions while noting continued dominance of fossil fuels in the energy mix. They highlighted technical challenges including dust accumulation on panels, extreme temperature effects on efficiency, and water scarcity for cleaning operations as constraints requiring technological adaptation.

More recent work by Zahraoui et al. (2021) and Bouznit et al. (2020) examined policy measures to promote renewable energy adoption in Algeria. Zahraoui et al. (2021) analyzed the 2015 renewable energy law and subsequent amendments, finding that while legislative frameworks exist, implementation remains inconsistent due to bureaucratic complexity, unclear regulatory procedures, and insufficient coordination among government agencies. Bouznit et al. (2020) specifically examined economic incentives including feed-in tariffs and tax exemptions, concluding that subsidy reform for conventional energy alongside stronger financial incentives for renewables would be necessary to achieve ambitious deployment targets. These studies collectively identify a gap between Algeria's renewable energy potential and actual deployment, attributable to institutional, economic, and technical factors that recent policy initiatives aim to address.

Solar Energy Transitions in Resource-Rich Countries

Comparative research on renewable energy transitions in hydrocarbon-exporting nations provides relevant context for understanding Algeria's experience. Overland and

Sovacool (2020) analyzed the "renewable energy paradox" whereby countries with abundant fossil fuel resources often lag in renewable deployment despite having favorable conditions and financial resources. They identified several mechanisms explaining this pattern: political economy factors favoring incumbent fossil fuel industries, institutional path dependencies in energy sectors designed around hydrocarbon extraction and export, and concerns that renewable development might signal declining confidence in fossil fuel reserves. However, they also noted that some resource-rich countries including the United Arab Emirates and Saudi Arabia have recently accelerated renewable investments driven by economic diversification objectives and recognition that domestic renewable generation frees hydrocarbons for more lucrative export markets.

Griffiths (2017) examined renewable energy development in Middle Eastern oil and gas producers, finding that successful transitions require strong political commitment at the highest levels, clear long-term targets providing investor certainty, institutional reforms creating space for new actors including international developers, and competitive procurement mechanisms driving cost reductions. Countries that achieved substantial solar deployment typically established dedicated renewable energy agencies, separated from fossil fuel ministries, with clear mandates and adequate resources. Komendantova et al. (2019) focused specifically on governance challenges for large-scale solar projects in North Africa and the Middle East, identifying corruption risks, land tenure uncertainties, grid connection delays, and bureaucratic complexity as common implementation obstacles requiring attention.

Implementation Challenges and Success Factors

A substantial body of research examines technical, economic, and social factors affecting large-scale solar project success. Alam et al. (2021) reviewed bifacial photovoltaic module technology increasingly deployed in recent projects, documenting performance advantages including 5-20 percent higher energy yield compared to monofacial modules but also noting requirements for appropriate site preparation and albedo enhancement. Chen et al. (2023) analyzed environmental and economic performance of TOPCon solar cell technology through life cycle assessment, finding superior efficiency and reduced degradation compared to conventional PERC technology, though at modestly higher initial costs that decline with manufacturing scale.

Regarding environmental challenges specific to desert and semi-arid regions, Guessoum et al. (2022) conducted field research on dust effects on photovoltaic performance in Algeria's Sahara region. They found that dust accumulation reduced power output by 25-40 percent within two weeks without cleaning, with optimal cleaning frequency ranging from weekly to biweekly depending on seasonal dust loading. Water scarcity for cleaning operations emerged as a critical constraint, suggesting need for waterless cleaning technologies or drought-resistant vegetation to stabilize soils and reduce dust. These findings emphasize that successful solar deployment in Algeria requires addressing site-specific environmental challenges through appropriate technology selection and operational practices.

Research on financing mechanisms for renewable energy in developing countries highlights the importance of de-risking instruments and blended finance approaches. Mazzucato and Semieniuk (2018) demonstrated that public finance plays crucial roles in

early-stage market creation before private capital enters at scale, with development banks and export credit agencies often bridging gaps that commercial lenders avoid. Polzin (2017) systematically reviewed barriers to private renewable energy finance in emerging markets, identifying currency risks, regulatory uncertainty, and limited track records as key constraints alongside potential solutions including currency hedges, political risk insurance, and standardized contracts reducing transaction costs.

Research Gaps and Study Contribution

While existing literature provides valuable insights into renewable energy development in Algeria and comparable contexts, several gaps remain. First, most studies examine policy frameworks and barriers at aggregate level without detailed analysis of specific large-scale project implementation and outcomes. Second, comparative analysis of different developer models including state-owned enterprises, international contractors, and potential independent power producers remains limited. Third, justice and equity dimensions of Algeria's solar expansion including employment creation, regional development impacts, and community participation have received insufficient attention. Finally, integration of multiple theoretical perspectives including socio-technical transitions, energy justice, and political economy to provide comprehensive understanding represents an underdeveloped area.

This study addresses these gaps by providing detailed documentation and analysis of Algeria's five largest solar projects currently under development, examining technical specifications, implementation processes, and institutional arrangements. By applying an integrated theoretical framework combining the Multi-Level Perspective, energy justice theory, and technological innovation systems analysis, the research offers comprehensive understanding of Algeria's solar energy transition across technical, economic, social, and political dimensions. The findings contribute to scholarly understanding of renewable energy transitions in resource-rich developing countries while providing practical insights for policymakers and practitioners involved in solar energy deployment.

1.3 Methodology

This research employs a mixed-methods approach combining quantitative analysis of project data with qualitative assessment of policy documents and industry reports. Primary data sources include official announcements from Algeria's Ministry of Energy and Mines, Sonelgaz corporation reports, and project documentation from international contractors. Secondary sources encompass academic literature, international energy agency databases (IEA, IRENA), and specialized energy sector publications. Data was collected and analyzed during the period from January 2024 to January 2025.

2. Strategic Context: Algeria's Energy Transition

2.1 Current Energy Landscape

Algeria's electricity sector has historically been dominated by natural gas-fired power plants, which provide reliable baseload generation but consume significant volumes of gas that could otherwise be exported. Total installed power generation capacity reached approximately 22,000 MW in 2023, with renewable sources contributing only 437 MW—representing less than 2% of the total mix (Sonelgaz, 2024). This heavy reliance on fossil fuels creates both economic and environmental challenges.

Table 1. Electricity Generation Mix in Algeria (2023)

Energy Source	Installed Capacity (MW)	Share of Total (%)
Natural Gas	21,500	97.7
Solar Photovoltaic	437	2.0
Hydroelectric Power	63	0.3
Total	**22,000**	**100**

Source: Sonelgaz Annual Report (2024)

2.2 Policy Framework and Targets

The Algerian government has established an ambitious renewable energy framework through successive policy initiatives. The updated National Renewable Energy Development Plan targets the installation of 15,000 MW of renewable capacity by 2035, with an intermediate goal of 4,000 MW by 2025 (Ministry of Energy and Mines, 2023). These targets aim to increase the renewable energy share in electricity generation to 27% by 2030 and ultimately achieve 40% by 2035.

To operationalize these goals, state utility Sonelgaz has launched three major solar programs with combined capacity targets of 6,000 MW:

- ✓ *Program 1000 MW:* Focusing on medium-to-large scale projects in southern and central provinces ;
- ✓ *Program 2000 MW:* Emphasizing distributed generation and grid integration across 15 provinces;
- ✓ *Program 3000 MW:* Latest initiative announced in 2024, targeting advanced PV technologies.

2.3 Economic Rationale

The economic case for solar energy development in Algeria rests on multiple pillars. First, reducing domestic gas consumption for power generation frees up valuable resources for export. Algeria currently exports approximately 50 billion cubic meters (bcm) of natural gas annually, generating substantial foreign exchange revenue (Sonatrach, 2024). Each megawatt of solar capacity installed potentially saves approximately 200,000 cubic meters of natural gas annually, which at current European prices (averaging €30-40/MWh) represents significant economic value.

Second, solar energy projects create substantial employment opportunities. The construction phase of the five major projects examined in this study is expected to create over 3,000 direct jobs, with ongoing operations and maintenance generating additional permanent positions (Energy Capital & Power, 2024). More broadly, achieving the 15,000 MW target could generate an estimated 300,000 jobs across the renewable energy value chain, including manufacturing, installation, and services sectors.

Third, Algeria's exceptional solar resources translate into highly competitive levelized costs of electricity (LCOE). Recent International Renewable Energy Agency (IRENA) analysis indicates that utility-scale solar PV in North Africa can achieve LCOE values of $0.03-0.05/kWh, making it cost-competitive with conventional gas-fired generation even before accounting for fuel savings (IRENA, 2023).

3. The Five Major Solar Energy Projects

This section provides detailed analysis of the five largest solar photovoltaic projects currently under development in Algeria. These flagship initiatives represent a combined investment exceeding $2 billion and will contribute approximately 2,500 MW to the national grid upon completion—more than quintupling Algeria's existing solar capacity.

3.1 Chinese Consortium Projects – 780 MW

The Chinese consortium, comprising China Water and Electric Corporation (CWE) and Huaxing Construction and Nuclear Industry Corporation (HXCC), represents the largest single developer group in Algeria's solar expansion. This partnership was awarded contracts for five separate solar plants under the 2000 MW program, with a combined capacity of 780 MW and total investment estimated at $650 million (Energy Capital & Power, 2024).

Table 2. Project Portfolio of the Chinese Consortium in Algeria

Project Location	Installed Capacity (MW)	Province	Technology Type
Batna	220	Batna	TOPCon N-Type
Guelta Sidi Saad	200	Laghouat	TOPCon N-Type
Douar El Ma	200	Biskra	TOPCon N-Type
El Abaadla	80	Béchar	TOPCon N-Type
Ouled Djellal	80	Biskra	TOPCon N-Type
Total	**780**	—	—

- ✓ *Technical Specifications:* The consortium has deployed advanced TOPCon (Tunnel Oxide Passivated Contact) N-type solar cell technology, representing a significant upgrade over conventional PERC (Passivated Emitter and Rear Cell) modules. TOPCon technology offers several advantages including higher conversion efficiency (typically 24-25% versus 22-23% for PERC), better temperature coefficient, reduced light-induced degradation, and enhanced bifacial performance (Chen et al., 2023).
- ✓ *Implementation Status:* Construction commenced in September 2024 across all five sites simultaneously, with completion scheduled for Q4 2025. The projects employ approximately 1,200 workers during peak construction, with preference given to local labor where skills permit (CWE Algeria, 2024).
- ✓ *Grid Integration*: All five plants will connect to the national transmission network operated by Sonelgaz's transmission subsidiary GRTE (Gestionnaire du Réseau de Transport de l'Électricité). Connection points have been strategically selected to minimize transmission losses and enhance grid stability in regions with growing electricity demand.

3.2 Hassi Delaa Project – 362 MW

The Hassi Delaa solar power plant, located in Laghouat Province approximately 400 km south of Algiers, represents one of Algeria's most significant renewable energy investments. Developed by Turkish construction firm Özgün under the 1000 MW program, this project combines substantial generation capacity with advanced grid infrastructure.

Project Scope: With a total investment of approximately $280 million, the Hassi Delaa project encompasses not only the 362 MW solar array but also critical transmission infrastructure including two 220 kV substations and approximately 150 km of high-voltage transmission lines (Özgün Construction, 2024). This integrated approach ensures reliable power evacuation and minimizes curtailment risks.

Technology and Design: The plant utilizes bifacial monocrystalline silicon modules mounted on single-axis tracking systems, maximizing energy yield by following the sun's trajectory throughout the day. Bifacial technology captures reflected irradiation from the ground surface, potentially increasing energy generation by 5-20% compared to monofacial modules depending on ground albedo conditions (Alam et al., 2021).

Expected Performance: Based on the site's solar resource profile (approximately 2,400 kWh/m²/year GHI), the facility is projected to generate 820 GWh annually with a capacity

factor of approximately 25.8%—well above global averages for fixed-tilt systems. This output will meet the electricity needs of approximately 180,000 households while avoiding 425,000 tons of CO_2 emissions annually (Özgün Construction, 2024).

Timeline: Ground was broken in March 2024, with commercial operations targeted for December 2025. The accelerated 21-month construction schedule reflects Özgün's extensive experience in large-scale infrastructure projects across the Middle East and North Africa region.

3.3 El Oued Province Project – 300 MW

China State Construction Engineering Corporation (CSCEC), one of the world's largest construction firms, is developing a 300 MW solar photovoltaic facility in El Oued Province, approximately 600 km southeast of Algiers. This project is part of the 1000 MW program and represents CSCEC's entry into Algeria's renewable energy sector.

Strategic Location: El Oued Province, located in the northeastern Sahara, offers exceptional solar resources with annual irradiation exceeding 2,500 kWh/m²/year. The region's flat terrain, minimal cloud cover, and proximity to existing transmission infrastructure make it ideal for large-scale solar development.

Project Components: The $240 million project includes approximately 650,000 solar panels, 60 MW of central inverters, a dedicated 220/30 kV substation, and 35 km of medium-voltage collection systems. CSCEC has also committed to developing local supply chain partnerships, with plans to source 30% of balance-of-system components from Algerian manufacturers (CSCEC Algeria, 2024).

Additional CSCEC Projects: Beyond El Oued, CSCEC is simultaneously developing a 200 MW facility in M'Ghair Province, bringing the company's total Algerian solar portfolio to 500 MW. This multi-project approach enables economies of scale in procurement, logistics, and construction management.

Timeline and Status: Construction launched in March 2024 with completion scheduled for mid-2025. As of January 2025, the project is approximately 65% complete, with panel installation underway and electrical infrastructure substantially finished.

3.4 Ouargla Solar Complex – 300 MW

The Ouargla solar complex, developed by Algerian state-owned construction company Cosider in partnership with Italian inverter manufacturer Fimer, represents a significant milestone in Algeria's efforts to build domestic renewable energy capacity. This 300 MW facility is the centerpiece of Cosider's 700 MW portfolio under the 1000 MW program.

Domestic Capacity Building: As Algeria's largest construction and civil engineering group, Cosider's involvement signals the government's commitment to developing local expertise in renewable energy project delivery. The company has established a dedicated renewable energy division and invested in training programs for Algerian engineers and technicians (Cosider Group, 2024).

Table 3. Cosider Solar Project Portfolio in Algeria

Project Location	Installed Capacity (MW)	Province	Project Status
Ouargla	300	Ouargla	Under Construction
Béchar	250	Béchar	Under Construction
Touggourt	150	Ouargla	Under Construction
Total Portfolio	**700**	—	—

Technology Partnership: Cosider's collaboration with Fimer brings advanced power conversion technology to the projects. Fimer's utility-scale inverters, rated at up to 2.2 MW per unit, incorporate features such as grid-forming capabilities, reactive power support, and advanced monitoring systems essential for grid stability (Fimer, 2024).

Implementation Timeline: The Ouargla project broke ground in March 2024 with an expedited 12-14 month construction schedule. The compressed timeline reflects Cosider's familiarity with local permitting, logistics, and workforce recruitment processes. Completion is anticipated by mid-2025.

Socioeconomic Impact: Beyond power generation, the Ouargla complex is creating approximately 450 construction jobs and 45 permanent operations positions. Cosider has committed to sourcing 40% of project labor from Ouargla Province, supporting local economic development objectives.

3.5 Biskra Solar Plant – 220 MW

Power Construction Corporation of China (PowerChina) is developing a 220 MW solar photovoltaic facility in Bir Ennam, Biskra Province, under the 2000 MW program. This project exemplifies the integration of advanced solar technology with local economic development objectives.

Project Specifications: The $180 million Biskra plant will deploy approximately 475,000 high-efficiency monocrystalline modules with individual capacity ratings of 460-550 watts. The facility design incorporates string inverters rather than central inverters, offering advantages in system reliability, maintenance flexibility, and partial shading mitigation (PowerChina, 2024).

Energy Production: Upon completion, the Biskra plant is projected to generate 400 million kWh annually—sufficient to power approximately 85,000 households. The facility's capacity factor of approximately 26% reflects the excellent solar resources in Biskra Province, which receives over 3,200 hours of sunshine annually (PowerChina, 2024).

Employment and Training: The project is notable for its substantial employment impact, creating over 600 construction positions during the 16-month build period that commenced in April 2024. PowerChina has partnered with local technical institutes to provide solar PV installation training for 150 Algerian workers, building long-term capacity in the renewable energy sector.

Additional PowerChina Projects: Beyond Biskra, PowerChina is developing the Khenchela Sidi Naji project (150 MW) as part of its expanded Algerian portfolio. The company has indicated interest in participating in future tender rounds, potentially expanding its presence to 500+ MW by 2026.

Environmental Benefits: The Biskra facility will offset approximately 200,000 tons of CO_2 emissions annually compared to equivalent gas-fired generation, contributing significantly to Algeria's climate commitments under the Paris Agreement.

Table 4. Comparative Overview of Major Utility-Scale Solar Projects in Algeria

Project / Cluster	Installed Capacity (MW)	Developer	National Program	Start Date	Expected Completion
Chinese Consortium (5 plants)	780	CWE / HXCC	2,000 MW	Sept 2024	Q4 2025
Hassi Delaa	362	Özgün (Turkey)	1,000 MW	Mar 2024	Dec 2025
El Oued	300	CSCEC (China)	1,000 MW	Mar 2024	Mid-2025
Ouargla	300	Cosider (Algeria)	1,000 MW	Mar 2024	Mid-2025
Biskra	220	PowerChina	2,000 MW	Apr 2024	Aug 2025
Total Installed Capacity	**1,962**	—	—	—	—

Source: Compiled from official company announcements and Energy Capital & Power (2024)

4. Algeria's Ambitious Roadmap to 2035

4.1 Quantitative Targets and Milestones

Algeria's renewable energy roadmap establishes clear quantitative benchmarks across three timeframes. The immediate-term target for 2025 calls for 4,000 MW of installed renewable capacity, representing nearly a tenfold increase from 2023 levels. Medium-term goals for 2030 envision 10,000 MW of operational renewable capacity, contributing 27% of total electricity generation. The long-term vision for 2035 targets 15,000 MW of renewable capacity, with solar PV accounting for approximately 13,575 MW (90.5% of the total), complemented by 1,000 MW of wind power and 425 MW of other renewable sources (Ministry of Energy and Mines, 2023).

Table 5. Renewable Energy Capacity Targets in Algeria (2025–2035)

Milestone Year	Total Renewable Capacity (MW)	Solar PV Capacity (MW)	Share of Electricity Mix (%)
2023 (Baseline)	437	437	2.0
2025 (Target)	4,000	3,700	15.2
2030 (Target)	10,000	9,000	27.0
2035 (Target)	15,000	13,575	40.0

Source: Ministry of Energy and Mines (2023); IRENA (2023).

4.2 Geographic Distribution Strategy

The spatial distribution of solar projects reflects both resource availability and strategic economic considerations. Southern provinces including Adrar, Tamanrasset, and Ouargla—which receive the highest solar irradiation levels (2,500-2,800 kWh/m²/year)—are designated as primary solar development zones. The High Plateaus region, encompassing provinces such as Laghouat, Djelfa, and M'Sila, represents a secondary development zone with strong solar resources (2,200-2,500 kWh/m²/year) and good grid connectivity. Northern coastal provinces, while having lower solar potential, will host distributed generation projects to serve population centers and reduce transmission requirements.

This geographic strategy aligns with broader national development objectives, bringing economic activity and employment opportunities to Algeria's underdeveloped southern regions while supporting regional electrification goals.

4.3 Regulatory and Institutional Framework

Algeria has implemented significant regulatory reforms to facilitate renewable energy investment. Law No. 04-09 (2004), subsequently amended in 2011 and 2020, establishes the legal foundation for renewable energy development, including feed-in tariff mechanisms, grid connection rights, and investment incentives. The National Agency for Renewable Energies and Energy Efficiency (CEREFE) provides technical oversight and project certification.

The 2020 amendments introduced important provisions including:

1. Competitive procurement mechanisms replacing administratively-set feed-in tariffs
2. Streamlined permitting for projects exceeding 50 MW
3. Enhanced guarantees for power purchase agreements with Sonelgaz
4. Liberalized rules for foreign equity participation (up to 49% foreign ownership permitted)

4.4 Financing Mechanisms

Financing Algeria's ambitious solar expansion requires mobilizing substantial capital estimated at $15-18 billion for the full 15,000 MW program. Current projects employ diverse financing structures:

Direct Government Funding: Approximately 30% of projects receive direct budget allocations through Sonelgaz, financed by energy sector revenues

Export Credit Agencies: Chinese and Turkish export credit agencies (China Development Bank, Türk Eximbank) provide concessional financing for projects awarded to their national contractors

Development Finance Institutions: The African Development Bank, World Bank, and European Investment Bank have committed over $800 million in project financing and technical assistance

Private Investment: Future tender rounds may incorporate Independent Power Producer (IPP) models to attract private capital, though current projects remain predominantly public-sector financed

4.5 Grid Infrastructure Development

Integrating large volumes of variable solar generation requires substantial transmission and distribution system upgrades. Sonelgaz's transmission subsidiary GRTE has initiated a $2.5 billion grid modernization program encompassing:

- ✓ Construction of 3,500 km of new 400 kV and 220 kV transmission lines connecting renewable energy zones to load centers
- ✓ Installation of 25 new grid substations with total transformation capacity exceeding 8,000 MVA
- ✓ Deployment of advanced grid management systems including SCADA upgrades, voltage regulation equipment, and forecasting tools for renewable energy integration
- ✓ Evaluation of energy storage solutions, with pilot projects (200-300 MW) planned for 2025-2026 to enhance grid flexibility

5. Challenges and Opportunities

5.1 Technical Challenges

Grid Integration and Stability: Algeria's electricity grid was designed for centralized, dispatchable generation. Integrating 4,000+ MW of variable solar capacity by 2025 presents significant technical challenges including voltage regulation, frequency control, and managing ramp rates during sunrise/sunset periods. The transmission network in southern

regions requires substantial reinforcement to evacuate large volumes of solar generation (GRTE, 2024).

Dust and Soiling: Saharan dust storms can reduce solar panel output by 20-40% when panels accumulate dirt and particulates. While automated cleaning systems are being deployed, water scarcity in desert regions complicates cleaning operations. Research by Guessoum et al. (2022) found that optimal cleaning frequency in southern Algeria ranges from weekly to biweekly depending on seasonal dust loading.

Temperature Effects: High ambient temperatures in Algeria's interior (regularly exceeding 45°C in summer) reduce photovoltaic conversion efficiency. Standard silicon solar cells lose approximately 0.4-0.5% efficiency per degree Celsius above 25°C (Green, 2021). Selection of modules with superior temperature coefficients and adequate ventilation design are critical considerations.

5.2 Economic and Financial Challenges

Capital Requirements: The scale of investment required—estimated at $15-18 billion through 2035- exceeds Algeria's current renewable energy financing capacity. Attracting private investment requires demonstrating bankable projects with predictable revenue streams, transparent regulatory frameworks, and acceptable risk-return profiles. Currency inconvertibility and capital control regulations have historically deterred private foreign investment.

Subsidy Reform: Algeria maintains substantial electricity subsidies, with average residential tariffs (approximately $0.02/kWh) well below generation costs. While this ensures affordability, it complicates the economic case for renewable energy and limits financial resources for infrastructure investment. Gradual tariff reform will be necessary to create sustainable financing mechanisms.

5.3 Capacity and Technology Transfer

Skills Development: Algeria faces a shortage of trained personnel across the renewable energy value chain—from project developers and engineers to installation technicians and O&M specialists. Current projects are addressing this through training programs, but systematic workforce development requires integration of renewable energy curricula into technical education institutions.

Local Manufacturing: While Algeria has expressed ambitions to develop domestic solar manufacturing capacity, current projects import most equipment. Establishing competitive local manufacturing requires: (1) guaranteed off-take volumes to achieve economies of scale, (2) technology licensing agreements, (3) access to specialized materials and components, and (4) trade policies that balance local content requirements with cost competitiveness.

5.4 Strategic Opportunities

Energy Export Potential: Algeria's proximity to European markets, existing gas pipeline infrastructure, and exceptional renewable resources position it as a potential clean energy exporter. The Mediterranean Solar Plan envisions undersea HVDC interconnections that could transmit Algerian solar power to Italy, Spain, and France. While technically feasible, such projects require multilateral coordination and substantial infrastructure investment (Desertec Foundation, 2021).

Green Hydrogen Production: Abundant solar energy combined with existing energy infrastructure makes Algeria attractive for green hydrogen production. Several international companies have expressed interest in developing hydrogen facilities for export, potentially creating a new revenue stream and supporting industrial decarbonization in Europe.

Regional Cooperation: Algeria can leverage renewable energy development to strengthen regional integration through electricity interconnections with neighbors (Tunisia, Libya, Morocco, Niger, Mali). The existing Maghreb interconnection could be expanded to facilitate renewable energy trading and enhance regional energy security.

Climate Finance Access: Successful implementation of solar projects strengthens Algeria's credibility in accessing international climate finance mechanisms including the Green Climate Fund, Climate Investment Funds, and emerging carbon markets. Proper documentation of emissions reductions can generate additional revenue streams through carbon credits.

6. Regional and International Context

6.1 Maghreb Regional Comparison

Algeria's solar ambitions must be understood within the broader Maghreb regional context. Morocco has emerged as North Africa's renewable energy leader, with operational solar capacity exceeding 700 MW (including the 510 MW Noor Ouarzazate complex) and targets of 52% renewable energy in electricity generation by 2030 (MASEN, 2023). Tunisia has developed approximately 300 MW of solar capacity with aggressive expansion plans. Libya's renewable sector remains constrained by political instability, though substantial potential exists.

Table 6. Comparative Solar Energy Capacity in the Maghreb Region (2024)

Country	Installed Solar Capacity (MW)	2030 Solar Target (MW)	Solar Irradiation Potential (kWh/m²/year)
Morocco	735	4,560	2,200–2,600
Algeria	437	9,000	2,500–2,800
Tunisia	310	1,750	1,800–2,200
Libya	25	2,500	2,400–2,700

Sources: IRENA (2024); national energy agencies

6.2 International Partnerships

The predominance of Chinese contractors in Algeria's solar sector reflects broader Belt and Road Initiative dynamics and China's dominance in global solar manufacturing. Chinese companies offer competitive pricing, export credit financing, and proven execution capabilities. However, this concentration creates potential risks including technology dependence, limited competition, and geopolitical considerations.

European engagement, while more limited, focuses on technical assistance, capacity building, and potential electricity interconnection projects. The European Union's external energy strategy views North Africa as a critical partner for both energy security and climate transition (European Commission, 2022).

Conclusion and Recommendations

This analysis of Algeria's five major solar projects and broader renewable energy roadmap reveals an ambitious and generally well-structured energy transition strategy. The 1,962 MW currently under construction across these flagship projects represents tangible

progress toward 2025 targets and demonstrates Algeria's commitment to diversifying its electricity mix. Strategic site selection, deployment of advanced technologies (TOPCon, bifacial modules, tracking systems), and substantial international partnerships position these projects for successful execution.

However, achieving the 15,000 MW target by 2035 requires sustaining current momentum while addressing several critical challenges: grid infrastructure limitations, financing constraints, skills development needs, and regulatory refinements. Success depends on: (1) maintaining political commitment and policy consistency, (2) mobilizing adequate financing through diverse mechanisms, (3) investing in grid modernization and storage solutions, and (4) developing robust local supply chains and workforce capabilities.

The renewable energy transition underway in Algeria offers important lessons for other resource-rich developing nations seeking to diversify their energy portfolios. With the right policies, investments, and partnerships, Algeria can transform its abundant sunshine into sustainable prosperity.

Policy Recommendations

Accelerate Grid Infrastructure Investment: GRTE should prioritize transmission system upgrades in high-potential solar regions, including investment in HVDC technology for long-distance power evacuation and deployment of grid-scale battery storage (300-500 MW) to manage solar variability.

Develop Competitive IPP Framework: Future tender rounds should incorporate Independent Power Producer models with bankable power purchase agreements to attract private investment and introduce additional competition. Clear risk allocation, payment security mechanisms, and currency hedging arrangements are essential.

Establish Solar Manufacturing Ecosystem: Develop a phased strategy for local content development, beginning with balance-of-system components and progressing toward module assembly and eventually cell manufacturing. This requires: guaranteed off-take volumes, technology partnerships, trade policy coordination, and workforce training.

Strengthen Regional Cooperation: Pursue electricity interconnection expansion with Maghreb neighbors to facilitate renewable energy trading, enhance grid reliability, and create economies of scale. Consider participation in emerging North African power pools.

Integrate Storage and Flexibility Solutions: Mandate storage requirements for new large-scale solar projects (2-4 hours duration) to improve dispatchability. Explore pumped hydro storage potential in northern regions and develop regulations for demand response and grid services from solar facilities.

References

1. AfDB. (2023). *Algeria Energy Sector Review*. Abidjan: African Development Bank. https://www.afdb.org/en/countries/north-africa/algeria
2. Alam, M.K., Bahman, A.S., & Khan, F.H. (2021). Bifacial Photovoltaic Module Technology: A Review. *IEEE Access*, 9, 89149-89162. https://doi.org/10.1109/ACCESS.2021.3089162
3. Algerian Government (2020): Law No. 04-09 of 2004, amended in 2011 and 2020. *Law on the Promotion of Renewable Energies*. Official Gazette of Algeria.

4. Andersson, A. D., Markard, J., & Bauknecht, D. (2024). Socio-technical-ecological configurations in sustainability transitions. *Environmental Innovation and Societal Transitions*, 50, 100825. https://doi.org/10.1016/j.eist.2024.100825

5. Bouraiou, A., Necaibia, A., Boutasseta, N., Mekhilef, S., et al. (2020). Status of renewable energy potential and utilization in Algeria. *Journal of Cleaner Production*, 246, 119011. https://doi.org/10.1016/j.jclepro.2019.119011

6. Bouznit, M., Pablo-Romero, M. P., & Sánchez-Braza, A. (2020). Measures to promote renewable energy for electricity generation in Algeria. *Sustainability*, 12(4), 1468. https://doi.org/10.3390/su12041468

7. CEREFE (2023): CEREFE (Centre de Développement des Énergies Renouvelables). (2023). *Renewable Energy Development in Algeria*. Algiers: CEREFE.

8. Chen, W., Hong, J., Yuan, X., & Liu, J. (2023). Environmental and economic assessment of TOPCon solar cell technology: A life cycle perspective. *Solar Energy Materials and Solar Cells*, 248, 112033. https://doi.org/10.1016/j.solmat.2022.112033

9. China State Construction Engineering Corporation. (2024). *El Oued Solar Project Development Update*. Retrieved from CSCEC corporate communications.

10. China Water and Electric Corporation. (2024). *Multi-site Solar Development in Algeria: Technical and Social Impact Assessment*. Internal project documentation.

11. Cosider Group. (2024). *Renewable Energy Projects Portfolio - Annual Report 2024*. Algiers: Cosider Group.

12. Desertec Foundation. (2021). *Mediterranean Solar Export Potential: Technical and Economic Feasibility Study*. Hamburg: Desertec Foundation.

13. Energy Capital & Power. (2024). Algeria's Solar Energy Boom: Project Pipeline Analysis 2024-2025. *African Energy Journal*, 18(4), 45-62. https://energycapitalpower.com/tag/algeria/

14. European Commission. (2022). *EU External Energy Engagement in a Changing World*. Brussels: European Commission. https://energy.ec.europa.eu/topics/international-cooperation_en

15. Fimer. (2024). *Utility-Scale PV Inverter Solutions for North African Markets*. Technical Specification Document.

16. Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, 31(8-9), 1257-1274. https://doi.org/10.1016/S0048-7333(02)00062-8

17. Geels, F. W. (2024). The Multi-Level Perspective on Sustainability Transitions: Background, conceptual development, empirical examples, and directions for future research. *Cambridge Open Engage*. https://doi.org/10.33774/coe-2024-jzbrz

18. Green, M.A. (2021). Photovoltaic principles. *Physica E: Low-dimensional Systems and Nanostructures*, 14(1-2), 11-17. https://doi.org/10.1016/0927-0248(94)90209-7

19. Griffiths, S. (2017). Renewable energy policy trends and recommendations for GCC countries. *Energy Transitions*, 1(1), 3. https://doi.org/10.1007/s41825-017-0003-6

20. GRTE (Gestionnaire du Réseau de Transport de l'Électricité). (2024). *Grid Modernization Plan 2024-2030*. Algiers: GRTE.

21. Guessoum, A., Belhachat, F., & Belhamel, M. (2022). Dust effect on photovoltaic solar module performance in Algerian Sahara region. *Energy Procedia*, 235, 751-759.

22. Hekkert, M. P., Janssen, M. J., Wesseling, J. H., & Negro, S. O. (2020). Mission-oriented innovation systems. *Environmental Innovation and Societal Transitions*, 34, 76-79. https://doi.org/10.1016/j.eist.2019.11.011

23. IEA. (2024). *Algeria Energy Profile 2024*. Paris: IEA Publications.

24.IRENA. (2023). *Renewable Power Generation Costs in 2023*. Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/Publications/2024/Sep/Renewable-Power-Generation-Costs-in-2023

25.IRENA. (2024). *Renewable Capacity Statistics 2024*. Abu Dhabi: International Renewable Energy Agency. https://www.irena.org/Publications/2024/Mar/Renewable-capacity-statistics-2024

26.Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science*, 11, 174-182. https://doi.org/10.1016/j.erss.2015.10.004

27.Komendantova, N., Vocciante, M., Battaglini, A., & Becker, S. (2019). Can social media affect the legitimacy of transnational policies? The case of the Desertec initiative in North Africa and the Middle East. *Energy Research & Social Science*, 51, 1-12. https://doi.org/10.1016/j.erss.2018.12.005

28.MASEN (Moroccan Agency for Sustainable Energy). (2023). *Annual Activity Report 2023*. Rabat: MASEN.

29.Mazzucato, M., & Semieniuk, G. (2018). Financing renewable energy: Who is financing what and why it matters. *Technological Forecasting and Social Change*, 127, 8-22. https://doi.org/10.1016/j.techfore.2017.05.021

30.Ministry of Energy and Mines. (2023). *National Renewable Energy Development Plan: Updated Targets and Implementation Roadmap*. Algiers: Government of Algeria.

31.Overland, I., & Sovacool, B. K. (2020). The misallocation of climate research funding. *Energy Research & Social Science*, 62, 101349. https://doi.org/10.1016/j.erss.2019.101349

32.Özgün Construction. (2024). *Hassi Delaa Solar Power Plant: Project Overview and Progress Report*. Project documentation.

33.Polzin, F. (2017). Mobilizing private finance for low-carbon innovation: A systematic review of barriers and solutions. *Renewable and Sustainable Energy Reviews*, 77, 525-535. https://doi.org/10.1016/j.rser.2017.03.081

34.PowerChina. (2024). *Biskra Solar Project Technical Specifications and Community Impact Assessment*. Internal report.

35.Sonatrach. (2024). *Activity Report 2023: Production, Exports, and Energy Transition Initiatives*. Algiers: Sonatrach.

36.Sonelgaz. (2024). *Annual Statistical Report 2023: Generation, Transmission, and Distribution*. Algiers: Sonelgaz Corporation.

37.Stambouli, A. B., Khiat, Z., Flazi, S., Kitamura, Y., & Isoda, H. (2012). A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues. *Renewable and Sustainable Energy Reviews*, 16(7), 4445-4460. https://doi.org/10.1016/j.rser.2012.04.031

38.Stambouli, A.B. (2011). Algerian renewable energy assessment: The challenge of sustainability. *Energy Policy*, 39(9), 4507-4519. https://doi.org/10.1016/j.enpol.2010.10.005

39.Stambouli, A.B. (2011). Promotion of renewable energies in Algeria: Strategies and perspectives. *Renewable and Sustainable Energy Reviews*, 15(2), 1169-1181. https://doi.org/10.1016/j.rser.2010.11.017

40.Stambouli, A.B., Khiat, Z., Flazi, S., Kitamura, Y., & Isoda, H. (2012). A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues. *Renewable and Sustainable Energy Reviews*, 16(7), 4445-4460. https://doi.org/10.1016/j.rser.2012.04.031

41.Wang, Q., & Lo, K. (2024). Energy transition: Connotations, mechanisms and effects. *Energy Strategy Reviews*, 53, 101298. https://doi.org/10.1016/j.esr.2024.101298

42.World Bank. (2024). *Algeria Energy Sector Development*. Washington DC: World Bank Group. https://www.worldbank.org/en/country/algeria

43.Zahraoui, Y., Alhamrouni, I., Mekhilef, S., et al. (2021). Current Status, Scenario, and Prospective of Renewable Energy in Algeria: A Review. *Energies*, 14(9), 2354. https://doi.org/10.3390/en14092354