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Utilisation and Challenges of Solar Photovoltaic Technology in the Salt Industry of Rajasthan: A Case Study of Didwana Region

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ABSTRACT

The salt industry in Rajasthan, particularly in the Didwana region, plays a crucial role in India's production of edible and industrial salt. These salt works require continuous electricity for pumping brine, operating shallow crystallizer pans, lighting, and auxiliary processing units. Currently, much of this energy demand is met through diesel generators or limited grid connections, which are expensive, unreliable, and environmentally unfriendly. Solar photovoltaic (PV) technology offers a promising alternative by harnessing abundant solar radiation in Rajasthan to meet the dispersed and daytime-peaking energy needs of salt operations. However, the saline and dusty environment of salt pans presents several unique challenges for PV deployment. Salt-laden dust can accumulate on module surfaces, reducing efficiency, while moisture and high salinity accelerate corrosion in modules, mounting structures, and electrical components. Additionally, seasonal flooding or soft soil in some pans can affect foundation stability, and scattered loads across large salt fields complicate the design of PV distribution and control systems. This study examines the potential utilisation of solar PV systems in the salt industry, identifying both opportunities and constraints. It compares different PV technologies, including mono-facial, bifacial, and thin-film modules, assessing their suitability under high-albedo salt-crust conditions and variable moisture levels. The research highlights practical mitigation strategies, such as corrosion-resistant C5-rated mounting structures, elevated module placement, glass-glass modules for bifacial gain, RO-water cleaning to reduce soiling, and appropriate O & Mschedules. The findings suggest that with careful design, technology selection, and maintenance practices, solar PV can significantly reduce operational costs, decrease diesel consumption, and enhance sustainability in Rajasthan's salt industry. In particular, bifacial glass-glass modules perform best on dry salt crusts, while thin-film or mono-facial modules provide reliable output during wet or muddy periods. This study underscores the importance of site-specific planning and offers a roadmap for integrating solar PV into the energy-intensive salt production process in Rajasthan.

Keywords: *Solar Photovoltaic, Salt Industry, Didwana, Corrosion, Renewable Energy, Sustainability.*

Introduction

Rajasthan offers exceptional solar resource and has become a focal region for large-scale solar deployment, which is directly relevant for decarbonising energy in land-intensive industries such as salt production [1], [2]. This section situates the salt sector within the state's solar opportunity and explains why Deedwana merits a PV-focused case study. Rajasthan's western districts record very high daily insolation and large tracts of available land that supported projects such as the Bhadla Solar Park [1], [2]. The state's renewable policy environment and investment incentives further strengthen the case for on-site and near-site solar systems for industrial uses [2].

Literature Review Synthesis

This review summarises global and Indian studies on solar-driven salt production, brine management and freshwater needs to frame technology choices for Deedwana.

- **Solar saltfield design and optimisation**: computerised brine-mass modelling and pond-series design improve yield and salt quality in large solar saltfields and are recommended for site-specific layout and hydrological control [3].
- **Solar desalination and stepped solar stills**: active solar stills and stepped designs provide low-cost freshwater for workers and processing in salt farming regions; stepped stills were shown to deliver cost-effective potable water to salt-farming communities in India's salt-producing areas [4], [5].
- **Brine concentration using waste heat**: solar evaporation rates can be augmented by modest heat inputs to increase brine concentration and salt output, though chemical control and scaling must be managed for downstream processes [6].

Together these studies indicate two practical pathways for salt operations: (a) optimise classical solar evaporation fields (layout, brine routing and quality control) and (b) integrate small-scale solar thermal or PV-driven desalting for potable and process water [3], [4], [5], [6].

Case Study Analysis Deedwana Region

This section summarises available evidence about Deedwana's suitability for PV adoption and identifies where empirical gaps remain for a rigorous site plan. Deedwana lies in Rajasthan's arid central/north region where state studies identify strong solar potential applicable to decentralised industrial power needs [1], [2]. Existing literature provides general saltfield design and operational guidance but does not report site-level production, energy use or water balance for Deedwana specifically, creating an evidence gap that must be filled by field surveys and energy audits [3], [4].

Findings and Practical Implications

- **Geographical context:** Rajasthan's western and central areas deliver high annual insolation and extended sunshine days that favour PV generation [1], [2].
- **Current salt production methods**: Global and Indian documentation treat solar salt production as staged pond evaporation with series/parallel brine routing and crystallisers; optimisation tools improve productivity and salt quality [3].
- **Energy requirements and gaps**: No peer-reviewed data in the supplied corpus quantifies Deedwana's electrical loads for pumping, processing, or washing—field measurement is required; therefore site-level energy audits are an immediate methodological priority (insufficient evidence).
- **PV potential for operations**: At the state level, studies conclude that rooftop, ground-mounted, and floating PV can increase local generation and reduce grid dependence; estimated high insolation supports PV capacity factors favourable for daytime process loads and battery pairing for limited off-sun needs [1], [2], [10].
- **Consequence**: detailed local baseline data (hourly loads, pond layouts, brine flows, water demand) must be collected before sizing PV capacity and storage or choosing hybrid thermal/PV options (insufficient evidence).

Technical Challenges and Mitigation

This section summarises arid-site technical constraints for PV in saltfields and evidence-based mitigation options drawn from the literature.PV performance in arid salt-producing sites faces four principal challenges: elevated operating temperature effects, soiling and dust deposition, sand abrasion and module degradation, and water availability for cleaning or thermal management [7], [8], [9]. Each is discussed with documented mitigation.

- **Elevated temperature:** Evidence shows atypical temperature-irradiance interactions in Western Rajasthan can alter DC power temperature coefficients and must be modelled using local field data during design [7].
- **Mitigation**: thermal management (rear or front cooling) can recover output; experimental FW (front-water) cooling delivered ≈9% relative efficiency improvement in Indian field trials and models [11].

- **Soiling and dust deposition:** Studies in India demonstrate dust can reduce module transmittance and output by large percentages seasonally, with maximum observed drops near 24% in certain months [8].
- **Mitigation:** planned cleaning schedules, low-abrasion wet cleaning where water is available, and anti-soiling coatings; cleaning frequency must be balanced with water scarcity concerns and operational cost.
- **Sand abrasion and arid durability:** PV module testing programmes prescribe sand and dust storm tests for arid climates because mechanical abrasion and UV exposure accelerate glass/coating damage [9].
- **Mitigation**: choose modules certified for arid testing, install protective glazing where justified, and maintain replacement plans for degraded modules.
- **System design and performance enhancement:** Tracking, bifacial layouts and thermal management substantially increase yield in desert analogues (case simulations reported single-axis trackers and active cooling giving 30–50% incremental gains under specific configurations) [10].
- **Mitigation:** quantify trade-offs—increased yield versus higher CAPEX, O&M and soiling sensitivity—before selecting trackers or bifacial modules [10].
- **Water for cleaning and process needs:** Stepped solar stills and small active desalters can supply potable water to salt-farm labourers at low cost and reduce risks associated with water scarcity [4], [5]. Where brackish or saline inputs exist, solar-driven desalting and brine reuse strategies should be integrated into the saltfield water balance [5], [6].

A combined technical programme for Deedwana should therefore include selection of arid-rated PV modules, thermal/cooling options for temperature control, a cleaning strategy matched to local water availability (potentially supplied by solar stills), and performance modelling using local irradiance and soiling inputs [7], [8], [9], [10], [11], [4], [5].

Policy Economics Recommendations

This section synthesises Rajasthan policy incentives, economic feasibility evidence and stakeholder recommendations drawn from regional policy summaries and economic case studies.

- **Opening**: Rajasthan’s policy packages and investment promotion schemes provide exemptions and financial incentives intended to attract renewable investments and reduce project operating costs, which can materially improve PV project bankability for industrial users [13], [14]. Economic case studies of small salt plants elsewhere show that mini-plant investments can be economically viable under favourable assumptions, supporting the need for a local techno-economic study for Deedwana [15].

Key Policy and Economic Points

- **State incentives**: The Rajasthan Investment Promotion Scheme and Integrated Clean Energy Policy include electricity duty exemptions, stamp-duty reliefs, reimbursement mechanisms and wheeling/banking incentives for captive renewable projects that can lower levelised costs for on-site PV [13], [14].
- **Technology choice and life cycle**: Life-cycle assessments support comparing module technologies for environmental impacts; choice should consider local manufacturing, recycling pathways and environmental metrics alongside performance in arid climates [16].
- **Feasibility practice**: Published salt-plant feasibility work shows standard financial indicators (NPV, IRR, B/C ratio) can be favourable for small salt plants when local demand, CAPEX and operating assumptions align; a Deedwana feasibility must model: CAPEX (modules, inverters, mounting), O&M (cleaning, replacement), energy storage (if needed), and avoided energy costs under existing tariffs and incentives [15].

Recommendations for Stakeholders

- **For industry**: commission detailed energy and water audits at Deedwana, model PV sizing with local irradiance and soiling profiles, and pilot a hybrid solution combining ground PV with small desalters/stepped stills for workforce water needs [3], [4], [5], [7], [8].

- **For policymakers** : apply available RIPS/Integrated Policy incentives to reduce upfront costs for captive PV at saltworks and prioritise water allocation mechanisms that enable responsible cleaning regimes without stressing local supplies [13], [14].
- **For researchers** : collect continuous field data (GHI, soiling rates, pond evaporation, brine flows), run brine-mass optimisation tools and cost-benefit models tailored to Deedwana, and test arid-rated modules and cooling methods under local conditions [3], [7], [9], [11].

Conclusion

combining Rajasthan's policy support with rigorous site surveys, arid-aware PV design, and integrated water solutions offers a credible pathway to decarbonise salt production in Deedwana while improving worker welfare and operational.

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