The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2025

Volume 38, Pages 625-629

IConTES 2025: International Conference on Technology, Engineering and Science

Performance Evaluation of the Andasol-1 Solar Power Plant in Algerian Climatic Conditions

Hicham Kadraoui
University of Abou Bakr Belkaid

Abstract: The generation of electricity from renewable sources is imperative in order to fight against the environmental and economic problems associated with fossil fuel utilization. The entire world energy sector is experiencing a rapid transformation towards renewable and sustainable energy sources, and a promising technological advancement in this regard is concentrated solar power (CSP), with a notable example being parabolic trough solar power plants. In this paper, we investigate the operational efficiency of the Andasol-1 parabolic trough solar power plant with 50 MWe output power in various Algerian desert locations, i.e., the Béchar, Ghardaïa, and Tamanrasset regions. A thorough examination of the Andasol-1 plant's technical characteristics is made, and an extensive economic and energy analysis is conducted based on System Advisor Model (SAM) software. Our study results reveal that the Tamanrasset region seems to be the most suitable area for CSP exploitation, with a capacity factor of 47.4% and a levelized cost of electricity (LCOE) of 0.130 €/kWh.

Keywords: Concentrated solar power, Parabolic trough, Andasol-1, LCOE, SAM simulation

Introduction

The world's energy scenario has changed considerably in recent times, with an accelerating transition to renewable and sustainable energy sources. CSP (concentrated solar power) has been one of the most promising technologies in this field, with prospects for efficient electricity production and thermal energy storage (Abdul Hai Alami et al., 2023).

Parabolic trough solar power plants represent one of the most advanced and widely installed CSP systems. They utilize parabolic reflectors for the concentration of solar radiation onto a receiver tube, warming up a transfer fluid, typically oil or molten salt that consequently generates steam to drive a turbine for electricity generation (El Boujdaini et al., 2019). Among the main advantages of such systems is the possibility of incorporation of thermal energy storage systems, as in the cases of power plants Nevada Solar One in the US and Andasol-1 in Spain.

The Andasol 1 central solar power plant is a pioneering commercial solar thermal power plant in Europe with a capacity of 50 MW. It uses parabolic trough technology with a solar field aperture of about 510,000 m², consisting of 7,488 curved glass collectors organized in 312 rows following the sun's movement. The solar field uses a heat transfer fluid (Dowtherm A) heated up to approximately 393°C, which generates steam to drive a Siemens 50 MW steam turbine. A key technical feature is its thermal energy storage system, consisting of 28,500 tons of molten salt (60% sodium nitrate and 40% potassium nitrate), which enables about 7.5 hours of full-load power generation even without sun, allowing near-continuous electricity supply (Solar Millennium AG, 2005).

Financially, the total construction cost was about €310 million (2008), equivalent to approximately $531 million in 2020 dollars, with a levelized cost of electricity (LCOE) estimated at around $0.29/kWh. The project started operation in 2008 and benefits from feed-in tariffs under Spanish renewable energy law, with substantial funding support including a €116.7 million loan from the European Investment Bank. The plant produces about 179-180 GWh per year, enough to supply electricity to up to 200,000 people, with an expected lifespan of at least 40 years (National Renewable Energy Laboratory. (2022, October 20).

In spite of the established success of Concentrated Solar Power (CSP) technologies in various global environments, there is a significant research gap regarding their operational performance under arid conditions (Ikhlef & Larbi, 2024). The Algerian desert, although endowed with rich solar resources, is a challenging but suitable land for the implementation of CSP technologies. Factors such as high solar irradiance, extreme temperature fluctuations, and dust deposition present opportunities and challenges to CSP technologies (Ihaddadene, Nabila, et al.2023).

Our research aims to fill the aforementioned research gap by undertaking a systematic examination of the operational efficiency of the Andasol-1 Concentrated Solar Power (CSP) plant under varying geographical conditions in the Algerian desert. By employing the System Advisor Model (SAM) software, a comprehensive examination of the facility's technical and economic performance will be conducted at three Algerian sites: the Bechar, Ghardaïa and Tamanrasset regions. The selection of the three sites is informed by the heterogeneous climatic and environmental conditions, thereby enabling an in-depth evaluation of the feasibility of CSP installation in arid desert environments.

Method

This study examines the adaptability and performance of the Andasol-1 concentrated solar power plant in three regions of the Algerian desert: Bechar, Ghardaïa, and Tamanrasset. These locations were selected based on several factors, the most important of which are solar radiation intensity, climatic variability, and geographical diversity. These areas were chosen specifically because they have higher levels of solar radiation than others. (Table 1) shows the geological and climatic data for these areas.

Table 1. Regional meteorological and geological parameters

Parametre	Bechar	Ghardaia	Tamanrasset
Latitude (°N)	31,57	32,49	22,89
Longitude (°E)	-2,14	3,67	5,57
Altitude (m)	772	530	1377
DNI (kWh/m²)	2925	2650	2812
GHI (kWh/m²)	2251	2180	2382
Température ambiante (°C)	21,9	22,5	22,8
Vitesse du vent (m/s)	4,0	3,8	3,6

Table 2. Technical input data: Comparison with Andasol-1 power plant parameters

Variable	SAM Input	Andasol-1
Climate	Bechar TMY3, Ghardaïa TMY3, Tamanrasset TMY3	Andasol-1, Espagne
Field aperture	510,000 m²	520,000 m²
Irradiation at design	950 W/m²	700 W/m²
Field HTF fluid	Therminol VP1	Therminol VP1
Design loop outlet temp	391°C	393°C
Number of SCA per loop	8	4
Collector (SCAs)	EuroTrough ET150	EuroTrough ET150
Receivers (HCEs)	Schott PTR-70	Schott PTR-70
Capacity - Design gross output	50 MW	50 MW
Cycle thermal efficiency	0.356	~0.381
Aux heater outlet set temp	391°C	391°C
Full load hours of TES	7.5 hr	28,500 t salt for 7.5 peak load hours
Tank height	14 m	14 m

The technical and economic analysis was carried out using the System Advisor Model (SAM) software. This program was developed by the US Department of Energy's National Renewable Energy Laboratory (NREL) and is a widely used tool for evaluating the performance of renewable energy projects. What sets SAM apart is its ability to simulate energy production and estimate the financial viability of projects. The program is relatively easy to use, but it requires some experience in the field of renewable energy to achieve accurate results. The study ultimately aims to understand the applicability of concentrated solar power technologies in harsh desert environments and how these plants can contribute to meeting the growing demand for energy. research aims to fill the aforementioned research gap by undertaking a systematic examination of the operational efficiency of the Alvarado Concentrated Solar Power (CSP) plant under varying geographical conditions in the Algerian desert.

Results and Discussion

Using hourly climate series (2013-2022) from the NSRDB data for the selected region, including Direct Normal Irradiance. Because July has the longest periods of sun irradiation of the year, we especially selected this month to display the best results. By choosing the July monthly average, we concentrated on the most promising and successful time frame, which is the best scenario every year. Based on the DNI beam irradiance (Figure 1), it can be observed that Tamanrasset s site exhibits the superior solar resource with peak DNI reaching 900 W/m² at solar noon, compared to 850 W/m² at Ghardaïa and 650 W/m² at Béchar. The solar resource availability spans 15 hours (05:00-20:00) at all sites, with productive DNI levels (>200 W/m²) extending from 06:00-19:00. Tamanrasset maintains DNI >800 W/m² for 5 consecutive hours (09:00-14:00), optimal for sustained high-temperature operation and thermal storage charging.

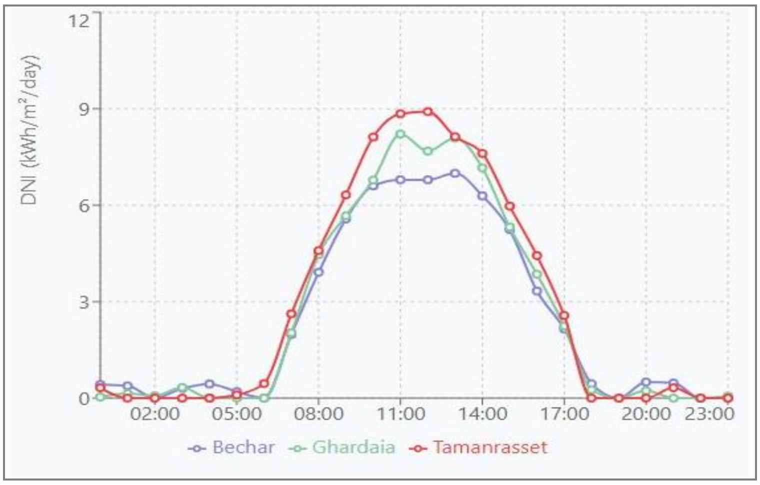

Fig 1. DNI variations over time (hours) in July: 2013-2022 Average data.

Financial Results

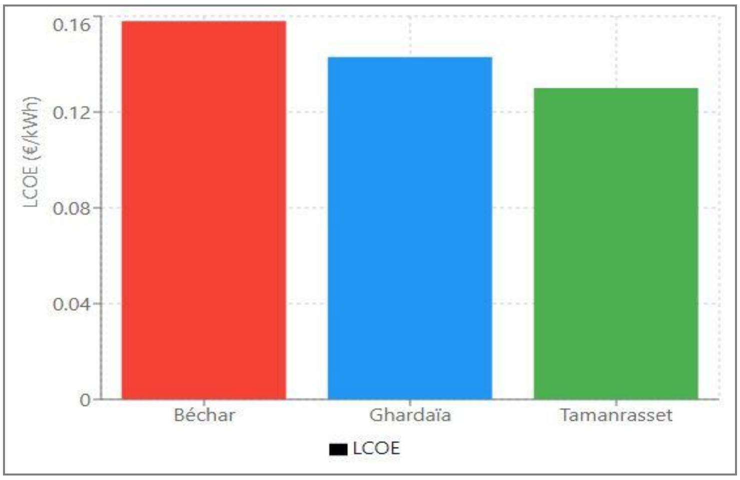

Figure 2. The levelized cost of electricity (LCOE)

The levelized cost of electricity (LCOE), which shows varying cost trends for various sites, is shown in (Figure 2). The Tamanrasset site has the lowest LCOE of 0.130 €/kWh and is therefore the most advantageous economically. The Ghardaïa region, with an LCOE of 0.143 €/kWh, comes in second. On the other hand, the Bechar site has lower production levels, resulting in a higher LCOE of 0.158 €/kWh. The economic subtleties inherent in these specific places' power producing capacities are highlighted by this observed variation.

SAM Model Validation

A validation investigation that contrasts the outcomes of the SAM software simulation with the Andasol 1 power plant's real performance is shown in (Table 3). It shows how much the verified data from the Andasol 1 power plant differs from the estimated values from the SAM simulation. Not to be overlooked is the fact that the Tamanrasset site performs noticeably better than the Spanish site. The arid terrain of the Tamanrasset location and the availability of more precise weather data are responsible for this.

Table 3. Technology cost comparaison (Algeria, 2022)

Technology	LCOE (€/kWh)	Capacity Factor	Storage Capability
CSP Parabolic Trough	0.130	61%	Integrated (7.5h)
PV + Battery Storage	0.125	25%	External (4h typical)
Natural Gas CCGT	0.065	85%	None
Onshore Wind	0.055	35%	None

While CSP remains more expensive than conventional fossil technologies, the integrated storage capability and dispatchable generation characteristics provide system-level value not captured in simple LCOE comparisons. Conclusion

Conclusion

The transition to renewable energy is a strategic step for environmental sustainability and a financially prudent decision in the long term. Our comprehensive analysis of the performance of the Andasol-1 Parabolic Trough Solar Power Plant in the diverse terrains of the Algerian desert underscores the feasibility of solar power in arid regions. By carefully adjusting the input parameters of Andasol-1, we have successfully minimized the Levelized Cost of Electricity (LCOE) and maximized annual energy production. Our study shows that Tamanrasset emerges as the most promising location among the evaluated sites, offering the best balance of energy yield and cost efficiency, closely followed by Bachar and Ghardaïa. These findings confirm that Parabolic Trough technology has significant potential to increase renewable electricity production in the Algerian desert, providing a solid blueprint for future solar energy projects in similar environments. These results strengthen the argument for expanding solar energy infrastructure in Algeria and contribute to the global narrative of transitioning to clean and economically advantageous energy sources.

Scientific Ethics Declaration

* The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

Conflict of Interest

* The author declares that there is no conflicts of interest

Funding

* This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Türkiye on November 12-15, 2025.

References

Alami, A. H., Olabi, A. G., Mdallal, A., Rezk, A., Radwan, A., Rahman, S. M. A., ... Abdelkareem, M. A. (2023). Concentrating solar power (CSP) technologies: Status and analysis. *International Journal of Thermofluids, 18*, 100340.

El Boujdaini, L., Ouali, H. A. L., Mezrhab, A., & Moussaoui, M. A. (2019). Techno-economic investigation of parabolic trough solar power plant with indirect molten salt storage. In *2019 International Conference of Computer Science and Renewable Energies (ICCSRE)* (pp. 1-7). IEEE.

Ihaddadene, R., Jed, M. E. H., & Ihaddadene, N. (2023). Assessing the effectiveness of a PV power plant and its subfields in Algeria: Case study Tamanrasset. *Energy for Sustainable Development, 77*, 101348.

Ikhlef, K., & Larbi, S. (2024). Evaluating the performance of parabolic trough solar power plants in Algerian deserts: A case study of Andasol-1. *Journal of Renewable Energies (Revue des Energies Renouvelables), 27*(2), 283-295.

National Renewable Energy Laboratory. (2022, October 20). *Andasol 1 – Concentrating solar power projects*. SolarPACES. Retrieved from https://solarpaces.nrel.gov/project/andasol-1

Solar Millennium AG. (2005). *The parabolic trough power plant Andasol 1 to 3*. Retrieved from http://large.stanford.edu/publications/power/references/docs/Andasol1-3engl.pdf

Author(s) Information

Hicham Kadraoui
University of Abou Bakr Belkaid, Tlemcen Algeria.
Automatic Laboratory of Tlemcen (LAT), University of Tlemcen, Algeria.
Contact e-mail: hicham.kadraoui@univ-tlemcen.dz

To cite this article:

Kadraoui, H. (2025). Performance evaluation of the Andasol-1 solar power plant in Algerian climatic conditions. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 38,* 625-629.