INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH
Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

TECHNO-ECONOMIC FEASIBILITY ANALYSIS OF A 50 MW MOLTEN SALT SOLAR TOWER POWER PLANT IN ORHOMURU-OROGUN, NIGERIA

JOHN A. FRIDAY[1*], IDIBIE E. EMUESIRI[1], BELLO A. SAMUEL[2]
[1]Mechanical Engineering, School of Engineering Technology/Federal Polytechnic Orogun, Nigeria, *(ORCID: 0000-0002-8220-7093)
[2]Science Lab Technology, School of Applied Sciences/Federal Polytechnic Orogun, Nigeria

ABSTRACT

Solar energy is a scientifically validated alternative to fossil fuels, with molten salt tower solar power being particularly suitable for energy storage due to its physical and thermal properties. Despite favorable climatic conditions, Nigeria and Sub-Saharan African countries have not widely adopted this technology, hence, the need for alternative energy solutions amid rising fossil fuel consumption and population growth. This study evaluates the techno-economic feasibility of a 50 MW molten salt tower solar thermal power plant in Orhomuru-Orogun, Delta State, Nigeria. The plant was designed based on a DNI of 1800 W/m² and incorporates climatic data from the NSRDB for accurate simulation inputs. Results showed that the Molten Salt Solar Tower power plant in Orhumuro, Orogun is feasible. The plant's first-year energy production: 562,887,360 ₵/kWh, 62.1% capacity factor, operating 12 hours daily. High electricity generation occurs in April, May, and June, exceeding 100 kW. Financial metrics include levelized PPA prices (28.90 ₵/kWh normal, 26.26 ₵/kWh real), levelized COE (28.53 ₵/kWh normal, 25.93 ₵/kWh real), investor IRR (11.00% in flip year and project end), NPV over project life ($8,792,008), and developer NPV ($10,470,116). The highest zenith angles are in December, November, and October, while the lowest are in June and July.

KEYWORDS - Azimuth angle, Direct Normal Irradiation (DNI), Molten salt thermal plant, National Solar Radiation Database (NSRDB), System Advisor Model (SAM), Techno-economic Assessment, Zenith angle.

1. INTRODUCTION

Solar energy technology has gained insight into this present age and has been listed as one of the mature renewable energy sources for electricity production. This is because solar energy system technology truncates the rapid destruction of the earth's ozone layer due to carbon dioxide emissions from non-renewable fuels on burning which results in contamination of the immediate environment. Hence, there is a need to shift from a non-renewable energy supply. Solar energy systems have been recognized as a viable alternative to non-renewable fuels, with concentrated solar power (CSP) technologies showing significant promise globally. Despite favorable weather conditions, Nigeria and Sub-Saharan Africa have not yet adopted CSP technology. Solar energy integration in Nigeria's energy infrastructure technical and economic feasibility studies is necessary. The rapid population growth in developing countries like Nigeria increases fossil fuel consumption, exacerbating issues, such as global warming, greenhouse gas emissions,

Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

food insecurity, and energy poverty. Therefore, substituting fossil fuels with renewable energy sources is crucial, although it remains a significant challenge in many African countries [1]. Immediate action is needed to improve energy and transportation systems in Africa using renewable resources, but developing countries like Nigeria face challenges due to low research funding and technical expertise. Solar energy, harnessed through photovoltaic (PV) systems and concentrated solar power (CSP), is a widely studied and promising solution [2]. Majidjamil emphasizes that the continuous use of fossil fuels has caused significant environmental damage, prompting governments to promote renewable energy sources like solar power, which is environmentally friendly and does not emit carbon monoxide [3]. Achieving sustainable, high-efficiency renewable energy is crucial for national development and mitigating climate change. Photovoltaic (PV) systems convert sunlight directly into electricity using non-mechanical processes, with three main technologies—monocrystalline silicon, polycrystalline silicon, and thin film—dominating the market. Bambokela highlights that while photovoltaic (PV) systems are clean and quiet, they lack thermal energy storage and have lower efficiency however, concentrated solar power (CSP) systems, store thermal energy and provide higher efficiency [4]. Bernard evaluated the techno-economic feasibility of a 6kW off-grid solar photovoltaic system for single households in Kumasi, Ghana, finding it cost-effective with a payback period of 15 years at $0.116/kWh, which reduces to 13 years when including a 600-litre water supply system. The study concluded that such systems are feasible for electricity and water supply in similar socio-economic and climatic conditions in developed countries [2]. Alireza analyzed the techno-economic feasibility of hybrid PV, diesel, and wind systems for rural electrification in Colombia, finding that hybrid configurations significantly reduce carbon emissions compared to diesel-only systems [5]. Aili compared off-grid renewable energy schemes in Windhoek, Namibia, finding that solar home systems and hybrid micro-grids can meet residential loads ranging from 1.7 kWh/day to 5.5 MWh/day, with costs influenced linearly by fuel price and load demand variations [6]. The feasibility study of a 10MW solar plant in Libya utilized NASA data to analyze solar irradiation across 22 locations, revealing the highest potential in the southern region with global irradiation ranging from 2100 to 2500 kWh/m². The study estimated maximum power generation at 22.06GW, with the highest energy production recorded in Al Kufrah (22067.13MWh) and the lowest in Al Jabal al Akhdar (17891.38MWh) [7]. MajidJamil studied a techno-economic feasibility analysis using SDM and MATLAB/SIMULINK for a solar photovoltaic power plant highlighting the importance of reliable components and accessible local technicians for maintenance to enhance performance [8]. A pilot biogas-solar photovoltaic system was implemented for farming communities in Botswana, using HOMER software for design and simulation, revealing high solar PV potential in the south-west region (Palapye) with annual yields of 1753-1899 kWh/kWp [9].

In CSP systems, the technology utilizes mirrors or lenses to reflect and concentrate sunlight onto a large area mechanism called a receiver. Hence, a high-temperature fluid in the receiver gets heated by the collected heat energy from the sunlight. Electricity is produced when the concentrated light is converted to heat energy. The heat can also be used to drive a heat engine, connected to an electrical power generator, or power a thermochemical reaction. However, the heat can also be utilized in diverse applications such as fuel steam engines, spinning turbine blades, etc., to generate electricity. In addition, concentrated solar energy is quite advantageous. Hence, giving high efficiency compared to photovoltaic systems. They possess high efficiency in power generation and are easily amenable to the generation of thermal energy for industrial applications, and that has made them very attractive for off-grid energy. Scientists have used numerous engineering simulation methods to analyze concentrated solar power (CSP) feasibilities and application systems for off-grid energy generation in different countries; hence below is the summary of some studies of CSP technology as reported hereunder. Taiea evaluated the thermal performance and design parameters of the Alkuraymat power plant, using a parabolic trough solar field with thermal energy storage. They used the System Advisor Model (SAM) with molten salt as the working fluid, finding it feasible to generate about 893.82 GWh annually with a 19.4% LCOE at 4.79 cents/kWh [9]. Ahmed analyzed CSP thermal power generation in Sudan using SAM, revealing that the nominated regions outperformed Spanish plants in energy output, capacity factor, and LCOE [10]. Gakkhar and Soni conducted a parametric assessment of CSP technologies, showing the highest direct investment cost at 0.0308 with a payback period of 0.0273 economic criteria [11]. John and Oyekale analyzed the techno-economic feasibility of a large-scale parabolic trough thermal power plant in Effurun-Warri, Nigeria, finding it technically feasible with a 35% capacity factor and an LCOE of 11.87₵/kWh, producing 78 GWh annually [1]. Mohamed conducted a cost analysis of a large solar plant in Egypt using SAM with parabolic trough concentrators and molten salt tanks, confirming the project's feasibility [12]. Althuwaini modeled the performance of a combined photovoltaic and CSP system using RETscreen software, estimating annual costs at USD 9.5 million for CSP and USD 20 million for PV [13]. MENENDEZ et al. (2021) analyzed the LCOE of CSP systems with public incentives versus private investment in Extremadura, Spain, finding that net electricity production reduces LCOE and increases investment value [14]. Krueger studied a small solar power plant in Thailand using SAM software, showing that storage technology improves CSP operation compared to PV, with potential price drops from 0.11-0.19 Euro/kWh to 0.05-0.08 Euro/kWh by 2020 [15]. Mardikaningsih assessed the techno-economic feasibility of solar-powered public street lighting using a B/C ratio methodology, finding it economically viable with lithium batteries and LED lights [16].

Molten salts are advanced solar technology used in power production and energy storage due to their high heat capacity and temperature. The molten salt reactors (MSRs) utilized molten salt as a coolant or fuel, offering advantages like improved thermal performance and safety. The technology is used in CSP plants and nuclear hybrid energy systems for efficient heat storage and transfer. However, its limitations include tritium production, corrosion, and the behavior of fission products in molten salts [17]. Molten salts are promising for high-temperature thermal energy storage (TES) and heat transfer fluid (HTF) in the next-generation concentrated solar power (CSP) plants due to their high thermal stability and low cost. However, severe corrosion of structural materials in contact with molten chloride salts is a big challenge, especially at an elevated temperature. Ding explored magnesium corrosion inhibition and alumina-forming Fe-Cr-Al alloys to mitigate molten salt drawbacks, finding significant corrosion resistance improvements [18]. Giaconia the reliability of molten salt as a heat transfer fluid in a CSP plant in Egypt [19], while Benes and Soucek highlighted the safety and efficiency benefits of molten salt reactors, despite challenges in material compatibility and fuel cleanup [20]. In 2008, Abengoa developed and tested an 8 MWhth Molten Salts pilot plant [21]. To evaluate the technology's feasibility for commercial use, achieving the first operational demo of indirect double tank storage by January 2009. The project focused on key aspects such as material corrosion, leakage points, performance efficiency, and thermal losses, providing valuable insights for future commercial-scale plants [22]. Boretti proposed that using higher-temperature fluids and advanced power cycles in CSP plants can significantly enhance efficiency and reduce costs, making CSP more competitive with other renewable technologies, especially in optimal locations like the Atacama Desert [23]. Parrado analyzed the Levelized Cost of Energy (LCOE) for a 50 MW CSP plant using various molten salt compositions for thermal energy storage (TES), highlighting Chile's potential for CSP growth compared to Spain and the USA [24]. Turchi found that molten salt power towers with the supercritical CO2 Brayton cycle could increase efficiency and reduce costs, though higher thermal storage costs might offset these benefits [25]. Gage evaluated molten chloride salt TES systems, proposing designs to reduce costs, but found the estimated cost of $60/kWhth still exceeds the Department of Energy's target [25].

The preceding literature review indicates that while parabolic trough CSP technology is widespread, it faces economic constraints. The review also highlights the System Advisor Model (SAM) as a crucial and widely used tool for designing and simulating CSP systems, likely due to its open-source nature and ability to account for minute-by-minute climatic variations. Consequently, feasibility studies on molten salt thermal plants have been conducted in various countries. However, to the best of the authors' knowledge, there is non-existent information on the techno-economic feasibility of a large-scale molten salt tower thermal plant for electricity generation in Orogun, Delta State, Nigeria, despite the region's favorable climatic conditions. This study aims to fill this gap using SAM software to evaluate the viability of a 50 MW Molten Salt Solar Tower power plant configuration in Orhomuru-Orogun, Nigeria. The specific objectives of the study are:

- To design a 50 MW molten salt solar tower power plant using the System Advisor Model (SAM) engineering software.
- To evaluate the impact of azimuth and zenith angles on energy production.
- To assess the techno-economic feasibility of the 50 MW molten salt solar tower power plant in the context of current market conditions in Nigeria.
- To analyze the annual energy production profile of the molten salt solar tower power plant, considering

INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH
Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

the ambient conditions of Orhomurun-Orogun, Delta State, Nigeria.

2. METHODOLOGY

2.1. SITE DESCRIPTION, PLANT SCHEME, AND DATA COLLECTION

Figure 1 depicts the schematic representation of the projected Molten Salt Solar Tower power plant configuration system. An array of parabola-shaped mirrors and an intertwined network of pipelines normally called solar receivers constitute the solar panel plant. However, the pipelines play a vital role in the power plant for transferring fluid from the corresponding solar collectors to the known power block which converts the collected thermal energy from the sun to electricity. Heat energy, storage tanks that utilize molten salt are used for thermal storage at excess heat transfer fluid for later use in electricity generation during the hours when solar irradiation is low or nonexistent. In this study, the power plant is an air-cooled steam power is an air-cooled steam power plant that operates on the Rankine cycle. The climatic parameters of Orhomuru-Orogun were obtained from the National Solar Radiation Database (NSRDB). Latitude, Longitude, and Average temperature of Orhomuru-Orogun were collected from the NSRDB to validate the system advisor model engineering tool built-in data for this location. Global Horizontal Irradiation (kWh/m^2/day) and Average wind speed (m/s) were also considered in the modeling.

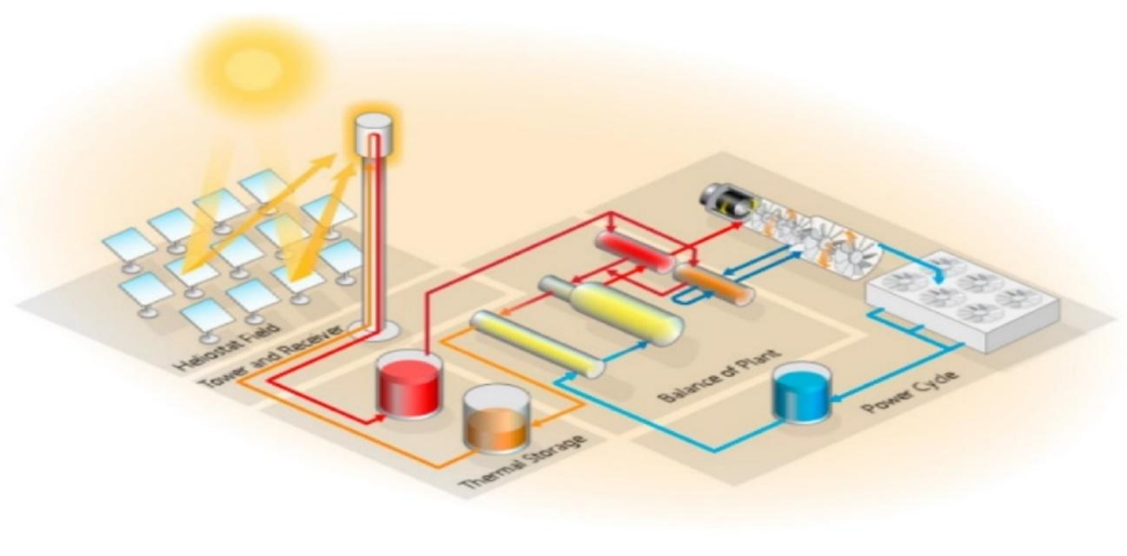

Figure 1. Molten Salt Solar Tower power plant configuration (system advisor model software)

2.2. THE AZIMUTH ANGLE AND ZENITH ANGLE

Solar zenith angle
The solar zenith angle is the angle between the vertical direction and the sun's rays, equivalent to the solar elevation or altitude angle. It is formed by the intersection of two lines in a vertical plane and is measured

using a Total Station (TPS) observing the vertical circle.

Mathematically,

$Zenith\ angle\ =\ (8-61)\ cos\ Z\ =\ cos\phi\ cos\delta suncoshr\ +\ sin\ \delta sunsin\phi$
(1)

Hence, Z represents the zenith angle, latitude is the ϕ, the sun's declination δsun is (which ranges between +23.5 ^{0} on 21 June to –23.5 ^{0} on 22 December), and 20hr is the hour angle (0 ^{0} ≡ noon). Calculating the zenith angle helps determine the optimal positioning for solar panels to maximize energy efficiency and allows air mass calculation. The zenith angle must not be negative

Solar azimuth angle

The solar azimuth angle, denoted by alpha (α), represents the angle between the true North and a celestial body, such as the sun or the moon, measured clockwise along the observer's horizon. This angle helps determine the celestial body's direction. For instance, a body located directly North has an azimuth angle of 0 ^{0}, one directly East has an azimuth of 90 ^{0}, one directly South has an azimuth of 180 ^{0}, and one directly West has an azimuth of 270 ^{0}. The azimuth angle is crucial for optimizing the orientation of solar panels to ensure they receive maximum solar radiation by aligning perpendicularly to the sun's rays.

Mathematically,

the solar azimuth angle can be calculated using the observer's latitude and longitude.

Compute $x\ =\ sin\Delta\lambda\ \times\ cos\phi_2$
(2)

Hence, $\Delta\lambda\ =\ \lambda_2\ -\ \lambda_1$ is the difference in longitudes.

Again, compute $y\ =\ cos\phi_1\ \times\ sin\phi_2\ -\ sin\phi_1 \times\ cos\phi_2\ \times\ cos\Delta\lambda$
(3)

Finally, find $atan2\ (x,y)$, i.e., the angle in the standard plane between the positive x-axis and the segment joining (0,0) and (x,y).

During summer, the rising of the sun takes place in the east and sets in the west. Hence, the azimuth angle responsible for tracking surfaces is proven to be 90 ^{0} or 270 ^{0} respectively. During winter months when sunlight comes from the southwest at noon; the best azimuthal angle θ will be 225 ^{0} for collecting maximum energy from the Sun's rays. Fig. 2 illustrates the schematic description of the zenith and azimuth angles.

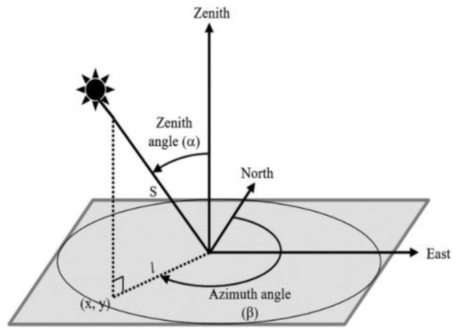

Figure. 2. **Zenith angle and azimuth angle of a celestial body (Science Direct.com)**

Table 1. Climatic Parameters of Orhomurun-Orogun, Nigeria

Parameter	Value
Latitude (^{0})	5.38
Longitude (^{0})	6.90
Average temperature (^{0}C)	28.5
Global Horizontal Irradiation (GHI) (kWh/m^2/day)	3.42
Average wind speed (m/s)	1.5

2.3. System Advisor Model Design Parameters of the Molten Salt Thermal Tower Power Plant

It was previously mentioned in the introduction section, that the system advisor model (SAM) engineering software was used to simulate the molten salt solar tower plant's techno-economic feasibility. The software was however developed by the National Renewable Energy Laboratory (NREL) in America. However, as reviewed in the literature, the molten salt thermal plant was designed on a nominal Direct Normal Irradiation (DNI) of 1800 W/m² and a solar multiple (SM) of 4. This was adopted because of the location's widespread use in practical systems, therminol VP-1 was used for heat transfer fluid (HTF). Utilizing molten salt storage medium in a thermal energy system and 12 hours of thermal energy storage for the design as the case may be.

Table 2. Molten salt thermal Power Plant parameters

S/N	*Parameter*	*Values*	*Units*
1	Solar multiple	4	-
2	Field aperture	877, 000, 000	m^2
3	Design point DNI	1800	W/m^2
4	Field thermal power	157	W/m^2
5	Loop inlet HTF temperature	293	^{0} C
6	Loop outlet HTF temperature	391	^{0} C
7	Number of loops	92	-
8	HTF pump efficiency	0.89	-

INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH
Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

9	Design turbine gross output	55	Mwe
10	Estimated-gross-to-net conversion factor	0.9	-
POWER CYCLE	**POWER CYCLE**		
11	Estimated output at design	25	Mwe
12	Cycle thermal eff.	0.356	-
13	Cycle thermal power	76	MWt
THERMAL ENERGY STORAGE	**THERMAL ENERGY STORAGE**		
14	Hours of storage at the design point	12	Hr
15	Tank height	15	M
HEAT TRANSFER FIELD	**HEAT TRANSFER FIELD**		
16	HTF	Therminol VP – 1	
17	Inflation rate	18	%/yr
18	Solar Field Area	149	Acres

3. RESULTS AND DISCUSSIONS

3.1. Solar Azimuth and zenith angles

Fig. 3 and **TABLE 3** present the zenith and azimuth angles for each month of the year in Orhumoru, Orogun, Delta State, Nigeria. The solar field captures only a portion of the thermal energy from the solar collectors due to losses caused by optical aberrations, mutual shading of collectors, row end losses, and geometrical inaccuracies of the solar field. The results indicate that October, November, and December exhibit the highest azimuth angles, significantly impacting the energy produced. Conversely, the azimuth angles for April, May, June, July, and August are zero, correlating with the highest system output energy (**Fig. 6**). To a notable extent, May and June generated the highest electricity, corresponding to the lowest azimuth angles. Additionally, the highest zenith angle is observed in December, followed by November and October, while June and July have the lowest zenith angles of 7 and 11 degrees, respectively (**Fig. 3**).

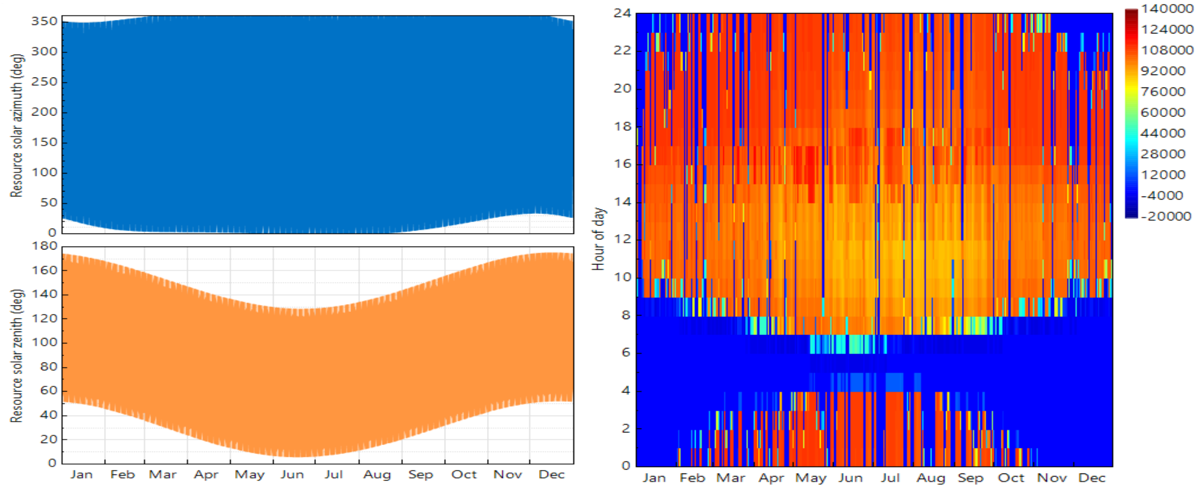

Figure 3. Zenith, Azimuth angles of months, and Contour of the hours of day in months

Table 3. Azimuth and zenith angles data

AZIMUTH ANGLE

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Angles (^{0})	10	2	0.04	0	0	0	0	0	10	25	33	25

ZENITH ANGLE

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Angles (^{0})	44	36	23	15	8	7	11	20	31	45	50	51

3.1. SOLAR ENERGY PROFILE

During the photovoltaic process, a portion of the thermal energy radiated onto the solar photovoltaic plates is partially absorbed. This scenario arises due to losses attributed to the induction between two circuits, measured in Henries. These losses are the ratio of the electromotive force in one circuit to the corresponding change in current in an adjacent solar circuit. Additionally, there are losses due to fluctuations in the solar field's photovoltaic output, influenced by geometrical factors. Figure 2 illustrates the annual energy production with a capacity factor. The results indicate that 562,887,360 ₵/kWh of energy, with a 62.1% capacity factor, can be produced in the first year in

Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

Orhumuro, Orogun Delta State, Nigeria. The levelized PPA price (both nominal and real), levelized COE (both nominal and real), and the investor IRR in the flip year, as well as the project’s NPV over its life, are 28.90 ₵/kWh, 26.26 ₵/kWh, 28.53 ₵/kWh, 25.93 ₵/kWh, 11.00%, 11.00%, and $8,792,008, respectively. There is a significant correlation between January, November, and December, where a constant emission of energy is observed in the first 5-8 days, followed by an increase in energy production. Conversely, in other months, a decrease in energy production is experienced in the first 5 to 6 days (Fig. 6). Figure 4b shows that annual energy generation increases to approximately 560 MW on the first day of the month, decreases to about 445 MW on the second day, and further decreases to around 360 MW on the third day, continuing to decline as the month progresses.

Metric	Value
Annual energy (year 1)	562,887,360 kWh
Capacity factor (year 1)	62.1%
Annual Water Usage	100,422 m^3
PPA price (year 1)	25.87 ¢/kWh
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	28.90 ¢/kWh
Levelized PPA price (real)	26.26 ¢/kWh
Levelized COE (nominal)	28.53 ¢/kWh
Levelized COE (real)	25.93 ¢/kWh
Investor IRR in flip year	11.00 %
Flip year	6
Investor IRR at end of project	11.00 %
Investor NPV over project life	$8,792,008
Developer IRR at end of project	NaN
Developer NPV over project life	$10,470,116
Net capital cost	$647,775,808
Equity	$279,635,616
Debt	$368,140,192

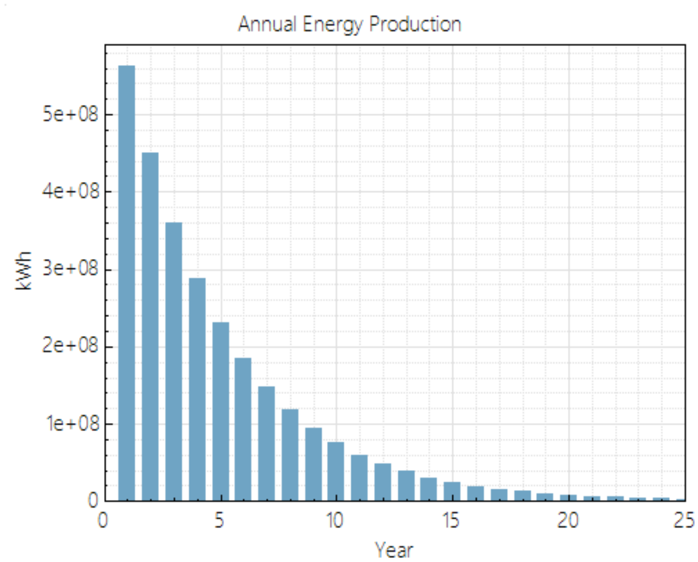

Figure. 4a&4b. Molten-salt power tower plant techno-economic performance metrics

INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH
Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

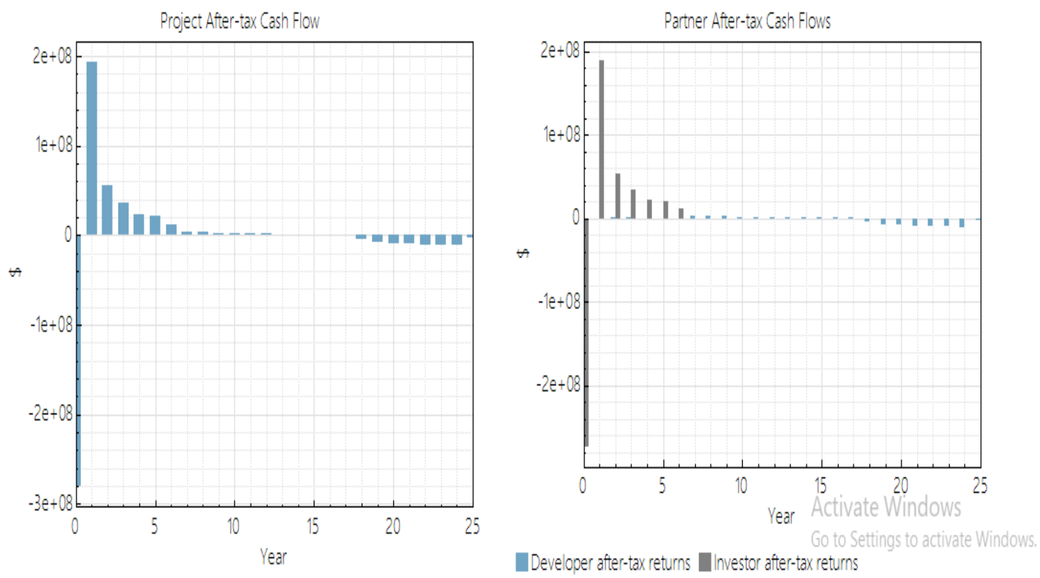

Figure. 5. Project yearly developer and investor after-tax returns

3.2. Annual electrical energy production and techno-economic performance

The days are however calibrated in the horizontal axis of the energy generated graph against the PV solar radiation incident measured in megawatts (MW). According to the system advisor model software, □+ 05 connotes mega unit (M). Therefore, 4□ + 05 = 4 * $10^{\wedge 5}$ = 400kW, 5□ + 05 = 5 * $10^{\wedge 5}$ = 500kW, 6□ + 05 = 6 * $10^{\wedge 5}$ = 600kW, 7□ + 05 = 7 * $10^{\wedge 5}$ = 700kW, 8□ + 05 = 8 * $10^{\wedge 5}$ = 800kW etc. Fig. 3 depicts that in April, May, and June high electricity will be produced, and the magnitude of the generated energy will be above 100kW. In August down to November, there will be a slight variation in the amount of energy production. The kilowatts of electricity production will be less than or approximately 100kW. However, December tends to experience the lowest incident thermal power on the solar field (97kW). This month, the energy produced will be low compared to others due to the unstable weather conditions experienced in December. Fig. 3b shows the monthly wind velocity per corresponding day. The result shows that March experienced the highest wind velocity. Whereas, the lowest wind velocity was observed in November.

INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH

Volume-3, Issue-1, (2025)

https://caarnjournals.com/index.php/ijmter/index

ISSN (Online): 2581-5792

A Peer Reviewed (Refereed) International Journal

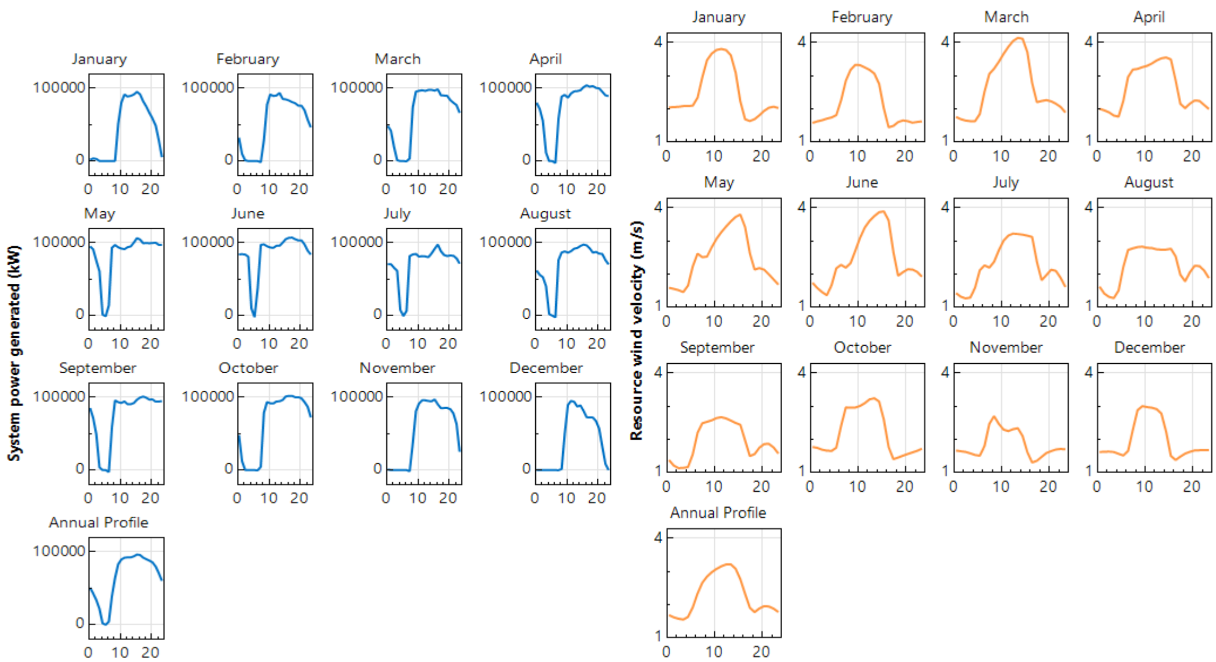

Figure. 6. Monthly energy produced by PV power plant configuration system

Table 4. Comparative techno-economic performance of reviewed works of literature

Author(s)	Year	Work	Method(s)	Material(s)	Result(s)
[1]	2023	A large-scale solar parabolic trough plant technical & economic feasibility in Warri, Nigeria	System Advisor Model (SAM) software	Solar parabolic trough	A parabolic trough thermal power plant is feasible in Effurun, Warri, Nigeria with with a capacity factor of over 35%
[6]	2022	Potential and Challenges of CSP Power Generation in Sudan	System advisor model (SAM).	CSP; solar power tower (SPT) & parabolic trough (PT)	The CSP system has a better outcome than the PT
[8]	2012	A review of the technical & and Economic feasibility	System Design Methods,	Solar PV	Lack of data related to economic

INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH
Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

		analyses of solar PV power generation	Performance Evaluation		parameters such as payback period, net present value, using SPV system
[10]	2022	Off-Grid Renewable Energy Electrification Schemes Techno-Economy feasibility: Informal Settlement in Namibia	HOMER Pro software	solar photovoltaic system	Hybrid system offers lower NPC & LCOE for both electrification schemes compared to PV, diesel generators & batteries
[11]	2014	CSP power generation technology in India: Technical & Economic analyses	Technical & economic survey	Concentrating Solar Power (CSP)	% experts for professional, researchers, educator, and miscellaneous are 39%, 34%, 17%, and 10 % respectively.
[12]	2021	Cost Analysis of a 500MW Solar Plant with PTC Using Molten Salt Storage Tank	System Advisor Model (SAM)	Parabolic trough concentrators, Molten salt.	CPS projects in Aswan, EL Arish, and Hurghada in Egypt are feasible
[16]	2016	Technical & economic feasibility of PV, wind, diesel, and hybrid electrification systems for off-grid rural electrification in Colombia	HOMER software	Photovoltaic, wind, diesel, and hybrid system	Investing $521,078 and an NPV of $836,210 for combined diesel, solar PV, and wind turbine gives the optimal option in Puerto Estrella
[14]	2021	Enhanced techno-economic analysis of levelized cost of	Sensitivity, Exergo-economic	Concentrating Solar Power	Annual net electricity production

INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH
Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

		energy: a case study of public incentives vs private investment	analyses	(CSP)	contributes to the reduction of LCOE, total investments, equity percentage, and operation and maintenance costs help to increase their value by a high percentage.
This study	**2024**	**Techno-economic feasibility analysis of a 50MW Molten Salt Solar Tower power plant configuration system in Orhomuru-Orogun, Nigeria**	**System Advisor Model (SAM) software**	**Molten Salt**	**The Molten Salt Solar Tower power plant in Orhumuro, Orogun is feasible. Hence, 562,887,360 ₵/kWh Energy Production, $8,792,008 NPV over the project life, and 62.1% capacity factor achievable.**

INTERNATIONAL JOURNAL OF MODERN TECHNOLOGY AND ENGINEERING RESEARCH
Volume-3, Issue-1, (2025)
https://caarnjournals.com/index.php/ijmter/index
ISSN (Online): 2581-5792
A Peer Reviewed (Refereed) International Journal

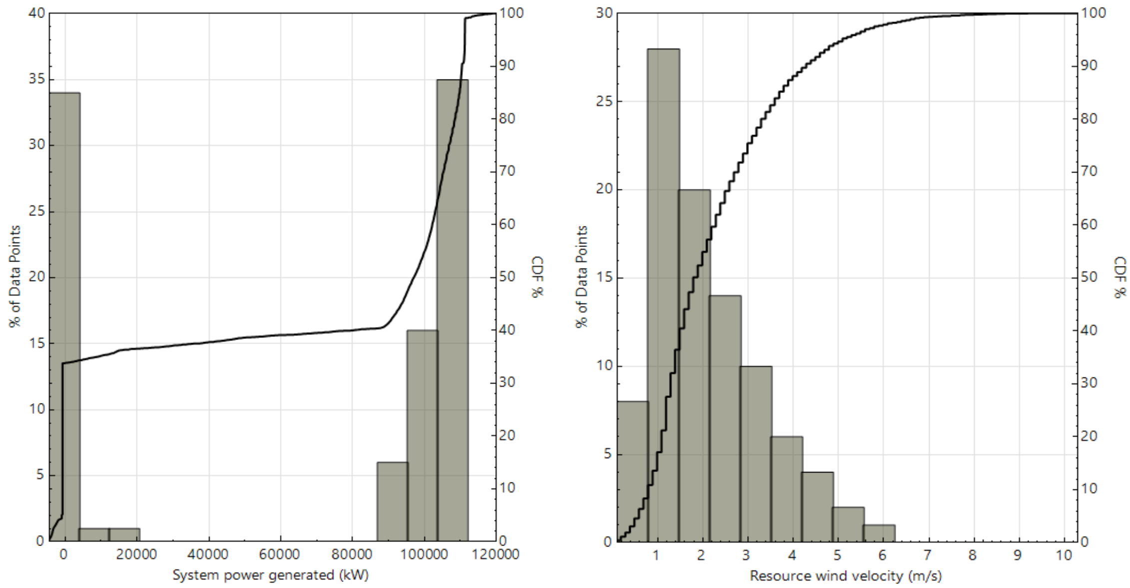

Figure. 7. System power generated (kW) and Resource wind velocity (m/s)

The figures above depict the simultaneous relationship between wind velocity in meters per second and the generated power in kilowatts. However, the generated power is related to the wind velocity. Mathematically, the power output is said to increase with the cube of the wind velocity. Figure 4 affirms that an increase in the resource's wind velocity significantly leads to a rise in the system power generated. As the wind velocity increases, there is a simultaneous increase in the power generated. However, a gradual incline uplift is experienced at the start after a drastic rise in system power generation.

4. CONCLUSIONS

The techno-economic feasibility of a 50 MW Molten Salt Solar Tower power plant configuration system in the City of Orhomuru-Orogun, Nigeria has been evaluated in this study. Engineering software, the System Advisor Model (SAM) was utilized for modeling and technical feasibility analyses. The National Solar Radiation Database (NSRDB) helped with the weather forecasting of Orhomuru-Orogun as generated by the system advisor model. Hence, undermentioned are the main findings:

- The plant's first-year energy production is 562,887,360 ₵/kWh with a 62.1% capacity factor, operating 12 hours daily.
- Financial metrics include levelized PPA prices (28.90 ₵/kWh normal, 26.26 ₵/kWh real), levelized COE (28.53 ₵/kWh normal, 25.93 ₵/kWh real), investor IRR (11.00% in flip year and at project end), NPV over project life ($8,792,008), and developer NPV ($10,470,116).
- Energy production shows a significant correlation in January, November, and December, with

consistent emissions in the first 5-8 days, followed by an increase.

- High electricity generation occurs in April, May, and June, exceeding 100 kW.
- The highest zenith angles are in December, November, and October, while the lowest are in June and July. The highest azimuth angles are in October, November, and December, significantly impacting energy production; 25 ^{0}C, 33 ^{0}C, and 25 ^{0}C respectively.

The author recommends an optimization technique to develop reliable algorithms using comparative analyses to enhance the techno-economic feasibility of the Molten Salt Solar Tower power plant configuration system under the influence of weather forecasting.

ACKNOWLEDGMENTS

The authors acknowledged the Institution Based Research Committee, IBR, Federal Polytechnic Orogun, Delta State, Nigeria for financial support throughout the research project.

REFERENCES

[1] JOHN, A., & OYEKALE, J. (2023). Techno-economic feasibility analysis of a large-scale parabolic trough thermal power plant in Effurun-Warri, Nigeria.International Journal of Energy and Smart Grid. https://doi.org/10.55088/ijesg.1234523

[2] Aboagye, Bernard.,Gyamfi, S., Puoza, J. C., &Obeng, M. (2020). Techno-economic Feasibility Analysis of Solar Photovoltaic System for Single Households in Peri-urban Areas Kumasi, Ghana. International Journal of Sustainable Energy Development, 8(1), 392–404. https://doi.org/10.20533/ijsed.2046.3707.2020.0047

[3] Majijamil Oni, A. O., & Kumar, A. (2022). Techno-economic Evaluation of Solar-based Thermal Energy Storage Systems.

[4] Bambokela W. (2022). Concentrating Solar Power of the Art, Cost Analysis, and Pre-Feasibility Study for the Implementation in China.

[5] HaghighatMamaghani, A., Avella Escandon, S. A., Najafi, B., Shirazi, A., &Rinaldi, F. (2016).Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia. Renewable Energy, 97, 293–305. https://doi.org/10.1016/j.renene.2016.05.086

[6] Gamil, A., Li, P., Ali, B., &Hamid, M. A. (2022).Concentrating solar thermal power generation in Sudan: Potential and challenges.In Renewable and Sustainable Energy Reviews (Vol. 161). Elsevier Ltd. https://doi.org/10.1016/j.rser.2022.112366

[7] Kassem, Y., Camur, H., &Abughinda, O. A. M. (2020).Solar Energy Potential and Feasibility Study of a 10MW Grid-connected Solar Plant in Libya. In Technology & Applied Science Research (Vol. 10, Issue 4). www.etasr.com

[8] Jamil, M., Kirmani, S., &Rizwan, M. (2012). Techno-Economic Feasibility Analysis of Solar Photovoltaic Power Generation: A Review. Smart Grid and Renewable Energy, 03(04), 266–274. https://doi.org/10.4236/sgre.2012.34037

[9] Taiea, A. M., Ibrahim, M. M., Megalla, K. F., &Metwally, M. N. (2021). Simulation of Performance for 140 MW Thermal Power

Station at Alkuraymat Using Solar Parabolic Trough Concentrators with Thermal Storage. In Mohamed NabilMostafaMetwally / et al/ Engineering Research Journal (Vol. 171).

[10] Amupolo, A., Nambundunga, S., Chowdhury, D. S. P., &Grün, G. (2022). Techno-Economic Feasibility of Off-Grid Renewable Energy Electrification Schemes: A Case Study of an Informal Settlement in Namibia. Energies, 15(12).https://doi.org/10.3390/en15124235

[11] Gakkhar, N., &Soni, M. S. (2014). Techno-economic parametric assessment of CSP power generation technologies in India. Energy Procedia, 54, 152–160. https://doi.org/10.1016/j.egypro.2014.07.258

[12] PeónMenéndez, R., Parra Martín, Aureza., Varela-Candamio, L., &García-álvarez, M. T. (2021). An enhanced techno-economic analysis of lcoe: Public incentives vs private investment. Technological and Economic Development of Economy, 27(1), 1–23.
https://doi.org/10.3846/tede.2020.11259

[13] Althuwaini, Y. E. Y. Y. E., &Philbin, S. P. (2021). Techno-Economic Analysis of Solar Power Plants in Kuwait: Modelling the Performance of PV and CSP Systems. In INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH Y. E.Y.Y.E Althuwaini and S. P. Philbin (Vol. 11, Issue 4).

[14] Elattar, Menendez F., Abdelnabi, Z., &Megalla, K. F. (2021). Cost Analysis of a Large Solar Plant with Parabolic Trough Concentrators Using Molten Salt Storage Tank. Computational Engineering and Physical Modeling, 4(1), 37–55. https://doi.org/10.22115/cepm.2021.240381.1120

[15] Krueger, J., Rakwichian, W., Sukchai, S., &Pongtornkulpanich, A. (n.d.).Small Solar Trough Power Plant in Thailand.In International Journal of Renewable Energy (Vol. 7, Issue 1).

[16] Lubkoll, M., Brent, A. C., &Gauché, P. (n.d.). A PRE-FEASIBILITY STUDY OF A CONCENTRATING SOLAR POWER SYSTEM TO OFFSET ELECTRICITY CONSUMPTION AT THE SPIER ESTATE.

[17] Roper, R., Harkema, M., Sabharwall, P., Riddle, C., Chisholm, B., Day, B., & Marotta, P. (2022). Molten salt for advanced energy applications: A review. In *Annals of Nuclear Energy* (Vol. 169). Elsevier Ltd. https://doi.org/10.1016/j.anucene.2021.108924

[18] Ding, W., Shi, H., Jianu, A., Xiu, Y., Bonk, A., Weisenburger, A., & Bauer, T. (2019). Molten chloride salts for next generation concentrated solar power plants: Mitigation strategies against corrosion of structural materials. *Solar Energy Materials and Solar Cells*, *193*, 298–313. https://doi.org/10.1016/j.solmat.2018.12.020

[19] Giaconia, A., Iaquaniello, G., Metwally, A. A., Caputo, G., & Balog, I. (2020). Experimental demonstration and analysis of a CSP plant with molten salt heat transfer fluid in parabolic troughs. *Solar Energy*, *211*, 622–632. https://doi.org/10.1016/j.solener.2020.09.091

[20] Beneš, O., & Souček, P. (2020). Molten salt reactor fuels. In *Advances in Nuclear*

Fuel Chemistry (pp. 249–271). Elsevier. https://doi.org/10.1016/B978-0-08-102571-0.00007-0

[21] Dominio, F. (n.d.). Techno-Economic Analysis of Hybrid PV-CSP Power Plants Advantages and disadvantages of intermediate and peak load operation.

[22] Prieto, C., Osuna, R., Fernández, A. I., & Cabeza, L. F. (2016). Thermal storage in a MW scale. Molten salt solar thermal pilot facility: Plant description and commissioning experiences. *Renewable Energy*, *99*, 852–866. https://doi.org/10.1016/j.renene.2016.07.053

[23] Boretti, A., & Castelletto, S. (2021). High-temperature molten-salt thermal energy storage and advanced-Ultra-supercritical power cycles. *Journal of Energy Storage*, *42*. https://doi.org/10.1016/j.est.2021.103143

[24] Parrado, C., Marzo, A., Fuentealba, E., & Fernández, A. G. (2016). 2050 LCOE improvement using new molten salts for thermal energy storage in CSP plants. In *Renewable and Sustainable Energy Reviews* (Vol. 57, pp. 505–514). Elsevier Ltd. https://doi.org/10.1016/j.rser.2015.12.148

[25] Turchi, C. S., Vidal, J., & Bauer, M. (2018). Molten salt power towers operating at 600–650 °C: Salt selection and cost benefits. *Solar Energy*, *164*, 38–46. https://doi.org/10.1016/j.solener.2018.01.063

[26] Gage, S. H., Kesseli, D., Dupree, J., Kimbal, C., Rigby, J., Yates, J., Morrison, B., Bigham, G., & Turchi, C. S. (2021). Technical and economic feasibility of molten chloride salt thermal energy storage systems. *Solar Energy Materials and Solar Cells*, *226*. https://doi.org/10.1016/j.solmat.2021.111099