Feasibility Assessment of a Solar PV Plant in South Jaghbub, Libya: A Comparative Analysis of Floating and Ground-Mounted Systems

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Abstract: ***Located in South Jaghbub, Libya-a region blessed with abundant solar resources-this study evaluates the feasibility of solar photovoltaic (PV) power generation through two configurations: floating and ground - mounted systems. Using the System Advisor Model (SAM), the ground - mounted design emerged as the superior option, projecting an impressive annual output of 209, 804, 384 kWh in its first year. This analysis not only underscores South Jaghbub's potential as a prime site for solar energy but also supports Libya's push to diversify its renewable energy mix, offering practical insights for engineers and policymakers alike.***

Keywords: PV, SAM model, Libya, floating solar, ground - mounted solar

1. Introduction

Libya possesses vast renewable energy resources, primarily solar and wind energy, which have the potential to transform the country into a regional hub for clean energy. However, political and economic challenges have hindered the full exploitation of these resources. By addressing these challenges and investing in robust infrastructure, Libya can achieve significant progress in sustainable energy development.

South Jaghbub receives an annual global solar radiation of 2, 200 kWh/m² and approximately 3, 100 hours of sunshine per year, making it ideal for solar energy projects. Several studies have proposed sustainable renewable energy applications suitable for this region [2]– [6].

The declining cost of solar panels has positioned photovoltaic (PV) systems as a leading solution for solar energy generation. According to the International Renewable Energy Agency (IRENA), the cost of PV systems has decreased by 82%, making them one of the most cost - effective renewable energy technologies [2]. Moreover, government policies and investments in PV research and development can further enhance system efficiency and reduce costs. Libya, with its exceptional solar resources, offers immense potential for PV deployment. A study by the University of Tripoli highlights Libya's annual solar radiation levels of 2, 500 kWh/m², underscoring its suitability for solar power generation [3].

Environmental factors such as weather conditions, surface temperature, and dust accumulation significantly impact the efficiency of solar energy systems. Dust storms, strong winds, and high temperatures, common in Libya, can reduce solar panel productivity by 20–30%, as demonstrated by studies conducted in regions with similar conditions, such as Jordan [4]. These challenges emphasize the need for tailored strategies to mitigate environmental impacts and optimize solar energy system performance in harsh climates.

The System Advisor Model (SAM) [5] is a widely used software tool in the renewable energy sector for simulating and analyzing various energy systems, including photovoltaic (PV), wind, and concentrating solar power (CSP) systems. A validation study comparing SAM's predictions for CSP plants with experimental data confirmed its accuracy and reliability in modeling real - world performance [6].

This study explores design layouts and system simulations for proposed PV power plants in South Jaghbub, considering site - specific weather conditions and solar irradiance data. The analysis was conducted using SAM to evaluate the performance and feasibility of the proposed PV systems.

This work is significant as it provides an actionable blueprint for leveraging Libya's solar wealth, potentially reducing reliance on fossil fuels in a region ripe for sustainable growth.

2. Solar and Weather Data

Jaghbub is located south of Tobruk, with geographic coordinates of 28.517889° latitude and 023.950195° longitude. As shown in Figure 1, South Jaghbub's location is ideal for solar PV plants due to its long, dry summer season, which provides optimal conditions for solar energy generation. Weather and solar irradiance data for the site were obtained from the Global Solar Atlas [1], which incorporates Solargis [7] data. This data served as the foundation for predicting PV power output.

Figure 1: The proposed location for the solar power plant [1]

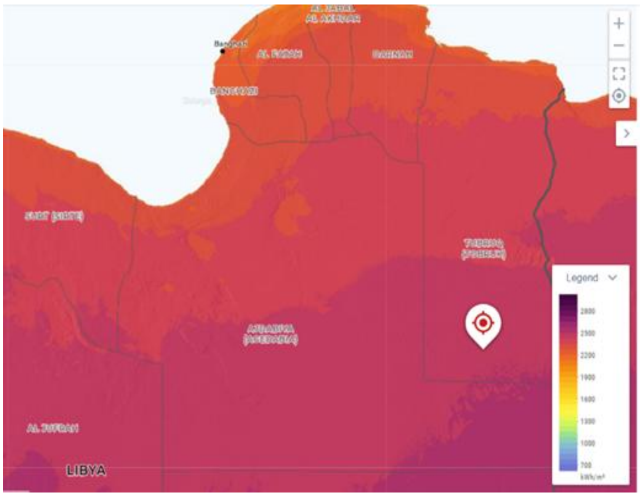

Figure 2: The region's high solar irradiance levels [1]

Figure 2 displays the annual specific PV power output map (PVOUT specific), representing the yearly average AC electricity (kWh) generated by a PV system per 1 kWp of installed capacity.

For the selected site, the PVOUT specific is 1, 953 kWh/kWp, indicating excellent potential for a commercial - scale PV power plant.

The Global Solar Atlas [1] provides location - specific parameters such as direct normal irradiance (DNI), global horizontal irradiance (GHI), diffuse horizontal irradiance (DIF), and others listed in Table 1. These parameters are crucial for simulating and evaluating system performance using SAM.

Table 1: Annual solar and weather data for South Jaghbub [1]

Parameter	Site
Latitude, Longitude	28.517889°, 023.950195
Time zone	UTC+02, Africa/Tripoli [EET]
Specific PV Power Output PVOUT)	1953 kWh/kWp
Direct normal irradiation DNI	2241.1 kWh/m2
Global horizontal irradiation GHI	2215.5 kWh/m2
Diffuse horizontal irradiation DIF	732.3 kWh/m2
Global Tilted Irradiance (GTI OPTA)	2490.5 kWh/m2
Optimum Tilt Angle (OPTA)	32°
Air Temperature) TEMP)	21.1 °C
Terrain Elevation) ELE)	144 m

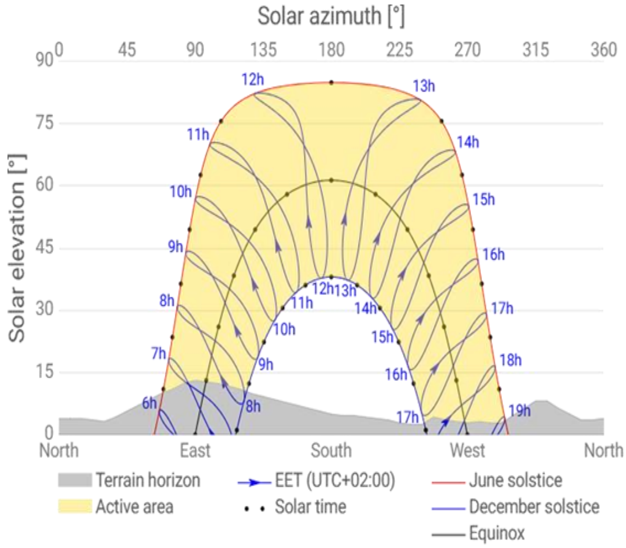

Figure 3: Sun path chart for South Jaghbub [1].

Additionally, Figure 3 depicts the sun path chart for South Jaghbub, which is used to determine solar azimuth and altitude.

In summary, the solar energy data provided by the Global Solar Atlas [1] are estimates suitable for exploratory work. These data are particularly useful for initial assessments, as they provide default values for many critical design factors in photovoltaic (PV) system planning. This research primarily utilized these data to compare two PV system layouts, as described in Section 3.1, and to conduct a more detailed evaluation of the PV system.

To perform a more comprehensive analysis, the study employed the System Advisor Model (SAM) software to simulate a PV plant with a detailed configuration, as outlined in Section 3.2. Weather and solar radiation data were imported from Solargis [7], a reliable platform known for providing accurate solar resources and meteorological data. These data are essential for conducting realistic and precise performance analyses of solar energy systems, as emphasized in previous studies such as [8] and [9]. For instance, Darwish (2021) emphasized the importance of using advanced simulation tools like SAM for designing efficient PV systems, particularly in regions with high solar potential. Similarly, Šúri et al. (2011) demonstrated the effectiveness of integrating accurate solar data from platforms like Solargis for optimizing PV system performance.

3. Results

This study focuses on the analysis of two layouts of large - scale solar photovoltaic (PV) systems: floating systems and ground - mounted systems. A detailed description of these layouts is provided in Section 3.1, using data extracted from GlobalSolarAtlas [1]. A more detailed analysis including system simulation and visualization of results using SAM software is performed in Section 3.2.

3.1 PV plant layouts

This study analyzed two large - scale PV plant layouts: floating and ground - mounted systems. Both systems have an installed capacity of 1, 000 kWp, as shown in Table 2. The floating system uses a default azimuth angle of 180° and a tilt angle of 10°, while the ground - mounted system uses a default azimuth angle of 180° and a tilt angle of 32°.

Table 2: PV plant layouts [1]

Parameter	Floating large scale	Ground - mounted large scale
PV panel azimuth	180°	180°
PV Panel Tilt	10°	32°
Design capacity	1000 kWP	1000 kWP
Annual Energy Production	1.728 GWh per year	1.943 GWh per year
Global irradiation on a sloped surface	2354.1 kWh/m2 per year	2477.8 kWh/m2 per year

The hourly average PV power output for the floating configuration, shown in Figures 4 and 5, peaks at 730.4 kWh in July. For the ground - mounted system, the hourly peak occurs in March, reaching 808.8 kWh, as shown in Figures 7 and 8. The monthly average total PV power output for both layouts is presented in Figures 6 and 9. The floating system achieves a maximum monthly output of 180 MWh in July, while the ground - mounted system reaches 185 MWh in March.

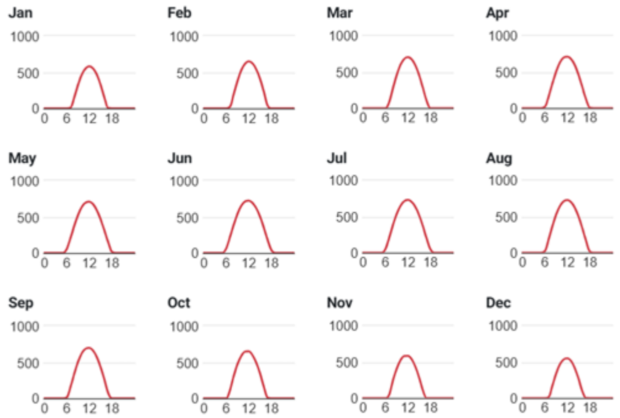

Figure 4: Hourly average PV energy production from a floating plant (kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6						0.057						
6 - 7			0.310	20.226	57.907	65.493	54.100	22.853	14.614	0.790		
7 - 8	10.573	23.689	85.914	162.761	209.794	222.656	209.573	186.226	161.324	114.967	49.935	13.630
8 - 9	155.517	199.950	277.680	341.999	380.069	393.556	385.590	369.062	344.279	311.925	247.611	172.348
9 - 10	329.560	378.848	458.010	506.705	525.537	540.806	537.787	528.812	507.558	473.487	407.911	340.092
10 - 11	470.967	525.808	597.516	629.970	635.371	650.546	648.923	645.103	622.658	585.560	523.652	466.108
11 - 12	551.121	615.707	680.351	699.497	695.117	709.696	713.148	711.573	684.520	643.365	581.840	534.918
12 - 13	579.402	647.730	704.917	712.565	706.889	722.182	730.398	728.135	695.769	648.266	584.914	550.525
13 - 14	548.857	619.903	675.400	679.432	671.666	688.263	702.838	697.876	656.389	593.644	537.245	511.469
14 - 15	463.637	537.817	590.473	594.264	588.516	615.963	630.842	620.433	565.979	488.968	431.137	411.245
15 - 16	322.259	403.626	451.944	457.471	463.571	498.839	515.608	497.625	427.913	341.802	281.483	266.949
16 - 17	147.843	231.673	279.484	290.450	310.010	347.498	364.067	337.635	258.891	158.957	104.595	91.941
17 - 18	6.734	41.110	98.384	118.937	149.519	183.135	195.408	162.837	73.770	9.725	0.432	1.121
18 - 19			0.429	6.637	16.173	42.290	45.646	16.354				
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	3,586	4,226	4,901	5,221	5,410	5,681	5,734	5,525	5,014	4,371	3,751	3,360

Figure 5: Total PV energy production from a floating plant (kWh)

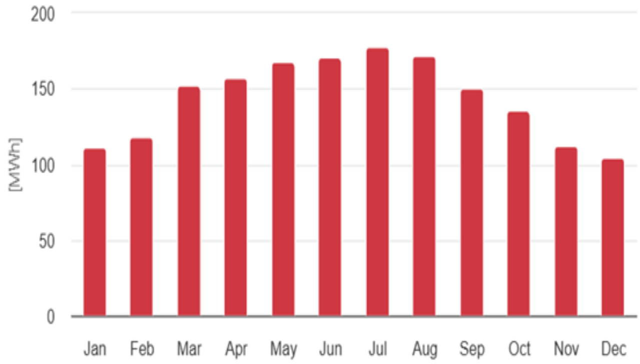

Figure 6: Monthly average PV energy production from a floating plant (kWh)

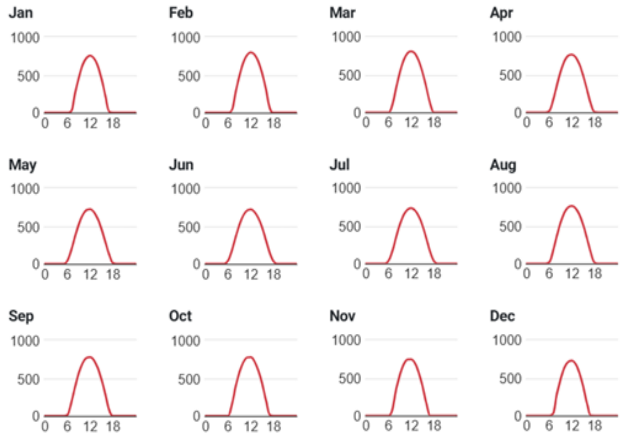

Figure 7: Hourly average PV energy production from a ground - mounted plant (kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6						0.036						
6 - 7			0.387	18.951	45.927	47.438	40.006	18.662	15.369	1.130		
7 - 8	20.553	36.120	102.870	160.841	183.085	178.045	167.131	168.653	176.605	153.446	83.561	26.701
8 - 9	257.868	276.158	328.225	357.059	363.948	358.142	353.445	367.620	384.827	394.249	354.800	288.991
9 - 10	463.986	490.142	536.221	540.437	523.909	519.659	521.928	545.683	569.707	581.123	546.323	484.702
10 - 11	631.689	661.255	693.496	676.558	643.650	639.680	644.534	673.578	697.207	707.976	679.678	633.691
11 - 12	720.933	761.858	783.434	750.775	708.097	704.410	714.670	745.146	764.236	770.409	743.089	711.356
12 - 13	751.286	795.617	808.874	764.207	720.393	718.057	733.299	762.436	775.570	774.487	744.862	727.152
13 - 14	715.832	763.242	776.008	727.828	682.157	681.284	703.234	729.629	732.373	712.870	691.344	681.935
14 - 15	615.784	669.798	681.934	635.635	592.108	601.975	624.627	645.636	632.212	593.324	567.023	562.209
15 - 16	443.917	514.037	525.459	484.490	455.876	473.866	498.281	510.698	477.268	423.072	388.138	384.997
16 - 17	223.525	308.132	327.538	299.385	288.926	309.600	332.127	333.516	285.531	204.566	163.114	160.969
17 - 18	14.337	59.157	116.718	115.432	124.057	141.715	155.366	145.687	79.139	13.364	0.683	2.197
18 - 19			0.504	6.430	12.369	32.040	33.175	12.870	0.027			
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	4,860	5,336	5,682	5,538	5,345	5,406	5,522	5,660	5,590	5,330	4,963	4,665

Figure 8: Total PV energy production from a ground - mounted plant (kWh)

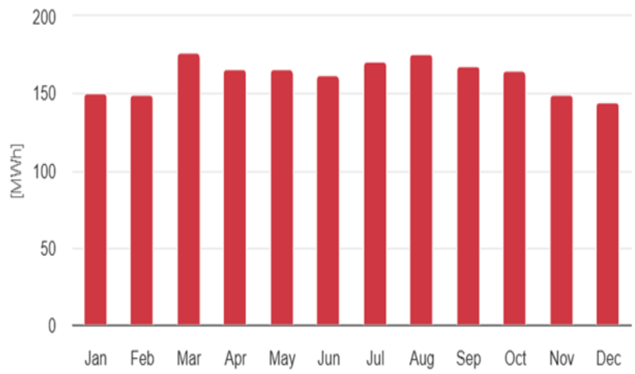

Figure 9: Monthly average PV energy production from a ground - mounted plant (kWh)

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While both layouts exhibit seasonal variations, the ground - mounted system demonstrates more consistent energy output throughout the year, resulting in higher annual energy production. Table 2 shows an annual output of 1.728 GWh for the floating system and 1.943 GWh for the ground - mounted system, indicating that the ground - mounted layout is more favorable for the proposed site.

Research by Huld and Müller (2021) in Energy Conversion and Management [11] demonstrated that integrating solar resource data (e. g., Solargis) with performance modeling tools (e. g., SAM) significantly improves the reliability of solar energy project assessments. This synergy enhances cost estimation by optimizing system design (via SAM's financial modules) while leveraging accurate solar irradiance and meteorological data (Solargis). The study also highlights how terrain suitability analysis reduces installation risks, corroborated by broader literature (Polo et al., 2021) [12] .

3.2 PV plant SAM simulation

The System Advisor Model (SAM) was used to simulate the proposed PV power plant. The plant's size and layout details are presented in Table 3. A tilt angle of 32° (with an azimuth of 180°) was assumed for the simulation.

Table 3: PV plant sizing

Rated DC power	99, 999.610 kWDC
Total AC power output	91, 301.940 kWAC
Inverter DC input capacity	94, 490.230 kWDC
Quantity of solar panels	142, 775
Number of strings	5, 711
Total module Area	439, 747.00 m^2

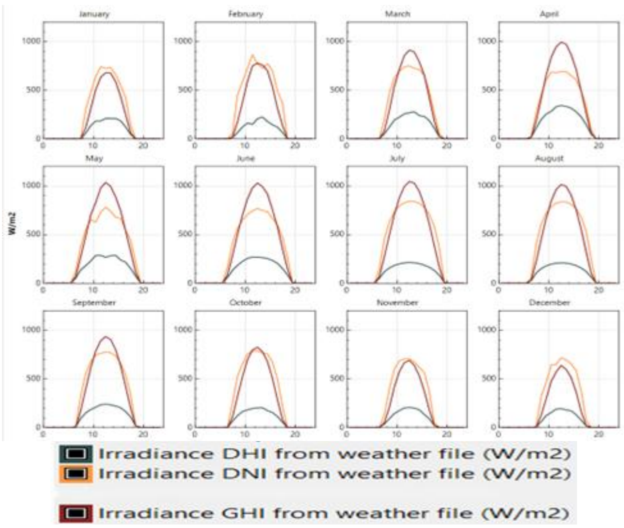

Figure 10: Irradiance DHI, DNI, and GHI hourly data

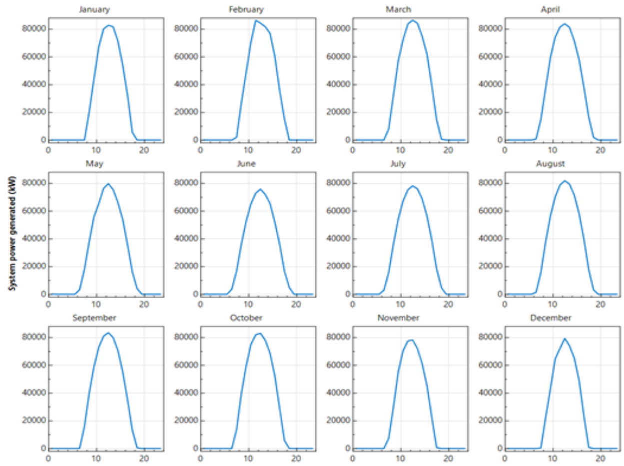

Figure 11: Hourly power generation of a PV plant.

The hourly irradiance data (DHI, DNI, and GHI) for the proposed South Jaghbub site are presented in Figure 10. The highest irradiance levels are observed during February, March, July, and August, with a maximum GHI of 800 W/m². Figure 11 shows the PV plant's hourly power generation. The peak power output reaches 9, 000 kW during February and March.

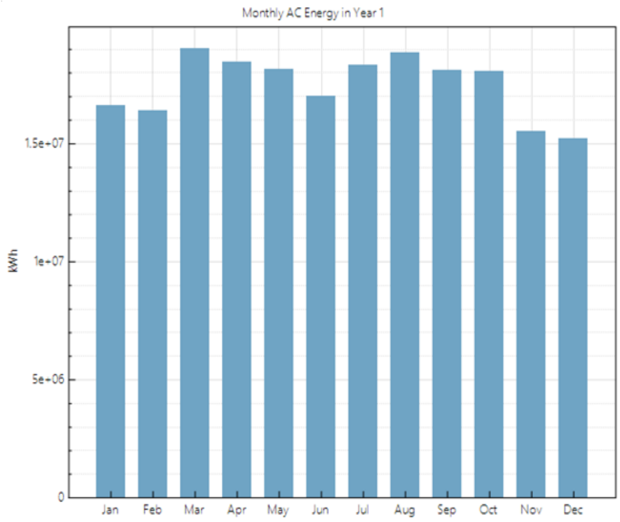

Figure 12: Monthly Electricity Generation of the PV system

The monthly electricity generation from the PV system is presented in Figure 12. The peak energy output occurs in March, consistent with the month's optimal weather conditions. Table 4 summarizes the SAM simulation results, including the DC capacity factor, which reached 24.0% in the first year.

Table 4: SAM Simulation Results

Metric	Value
Annual Energy (year 1)	209, 804, 384 kWh
Capacity Factor (year 1)	24.0 %
Energy Yield (year 1)	2, 098 kWh/kW
Performance Ratio (year 1)	0.81

4. Conclusion

This study confirms that South Jaghbub, Libya, holds exceptional promise for solar PV development, with the ground - mounted system outperforming its floating counterpart in annual energy yield (209, 804, 384 kWh in year one). As PV technology becomes ever more affordable, such projects offer Libya a viable path to diversify its energy mix, harnessing abundant solar resources to meet sustainability goals. These findings provide a practical foundation for engineers and policymakers aiming to advance renewable energy in the region.

References

[1] Global Solar Atlas: https: //globalsolaratlas. info/map?c=28.517889, 23.950195, 11&s=28.517889, 23.950195&m=site&pv=hydro, 180, 10, 1000
[2] IRENA (2020): "Renewable Power Generation Costs in 2020" - International Renewable Energy Agency.
[3] Al - Habaibeh, A. et al. (2019): "Solar Energy Potential in Libya: A Review" - University of Tripoli.
[4] Al - Kouz, W., Al - Dahidi, S., Hammad, B., & Al-Abed, M. (2019): "Modeling and Analysis Framework for Investigating the Impact of Dust and Temperature on PV Systems' Performance and Optimum Cleaning Frequency" - Applied Sciences, 9 (7), p.1397.
[5] National Renewable Energy Laboratory, System Advisor Model (SAM): https: //sam. nrel. gov/
[6] Al- Soud, M. S., & Hrayshat, E. S. (2020): "Performance Analysis of Parabolic Trough Solar Thermal Power Plants Using SAM: A Case Study in the Middle East" - Renewable Energy, 145, 1234–1245.
[7] Solargis: https: //solargis. com
[8] Darwish, M. A. A. (2021): "Design of a Photovoltaic System Using SAM and ETAP Software" - 2021 International Conference on Green Energy, Computing, and Sustainable Technology (GECOST).
[9] Šúri, M., Cebecauer, T., & Skoczek, A. (2011): "SolarGIS: Solar Data and Online Applications for PV Planning and Performance Assessment" - 26th European Photovoltaics Solar Energy Conference.
[10] Sukhatme, S. P., & Nayak, J. K. (2011): "Solar Energy Engineering" - Tata McGraw - Hill Education.
[11] Huld, T., & Müller, R. (2021). Integration of solar resource data and performance modeling for improved reliability of solar energy assessments. Energy Conversion and Management, 237, 114123.
[12] Polo et al. (2021) in *Renewable Energy* (Vol.172, pp.985–995)