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Applicability of Solar Energy in Libyan Southern Cities: Challenges and Difficulties

Abdulgader Alsharif[1]*, Ibrahim Imbayah[2],Ali Abdulraheem[3]
Ali Mohammed Abdoulha Massoud[4],Omar.N. Elazoomie[5]

[1]*Dept of Electrical & Electronics Eng. College of Technical Science, Sabha-Libya
[2]Dept. of Energy Engineering, College of Renewable Energy, Tajoura, Libya,
[3]Dept of Mechanical Eng. Higher Institute of Engineering Technologies, Sebha, Libya
[4]Dept of Mechanical Eng. College of Technical Science, Sabha-Libya
[5]Dept of Electrical & Electronics Eng.Higher institute of Science and Technology -Azizia, Libya.
*Corresponding author email: alsharif@ctss.edu.ly

Abstract

Renewable Energy Sources (RES) become important in recent years in research that enlightens the lives of people by meeting their daily electricity demand. This work focuses on shedding light on the utilization of renewable energy sources such as PV in some of the Libyan southern cities (Sebha, Murzuk, Ghat, Ubari, and Wadi Alshatti) to spread peace and avoid internal migrants. Libya with the help of the availability of resources of solar irradiance and wind speed, the load can be met along with reducing the deficit. The obtained green energy from RESs could play a substantial role in meeting Sustainable Development Goal 7 (SDG7) and Climate Action Goal 13 (CAG13) solutions. Hopefully, this study is expected to be a guideline to researchers in the field to assist them in their future studies. In this study, we compared five cities located in southern Libya in terms of global solar radiation, temperatures, and relative humidity, and also compared the productivity of PV modules for a full year by simulating 1 kW of PV modules in each city and the results were good for installing solar panel plants in the aforementioned cities.

Keywords: Renewable Energy Sources, Libyan southern cities, Sustainable Development Goal Seven, 1 kW of PV, solar panel.

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إمكانية تطبيق الطاقة الشمسية في مدن الجنوب الليبي: التحديات والصعوبات

عبد القادر الشريف[1]*، إبراهيم امبية[2]، علي عبد الرحيم[3]، علي محمد عبدالله مسعود [4]، عمر نورالدين العزومي[5]
[1]قسم الهندسة الكهربائية والإلكترونيات. كلية العلوم التقنية، سبها _ ليبيا.[2]
قسم هندسة الطاقة، كلية الطاقة المتجددة، تاجوراء _ ليبيا ،
[3]قسم الهندسة الميكانيكية، المعهد العالي للتقنيات الهندسية – سبها، ليبيا
[4] قسم الهندسة الميكانيكية،. كلية العلوم التقنية، سبها _ ليبيا
[5]قسم الهندسة الكهربائية والإلكترونيات.المعهد العالي للعلوم والتقنية_ العزيزية، ليبيا.
alsharif@ctss.edu.ly

الملخص

اكتسبت مصادر الطاقة المتجددة في السنوات الأخيرة أهمية في السنوات الأخيرة في الأبحاث التي تنير حياة الناس من خلال تلبية احتياجاتهم اليومية من الكهرباء. يركز هذا العمل على تسليط الضوء على الاستفادة من مصادر الطاقة المتجددة مثل الطاقة الكهروضوئية في بعض مدن الجنوب الليبي (سبها ومرزوق وغات و أوباري و وادي الشاطئ) لنشر السلام وتجنب الهجرة الداخلية. ليبيا بمساعدة توافر موارد الإشعاع الشمسي وسرعة الرياح، يمكن تلبية الأحمال مع تقليل العجز. يمكن أن تلعب الطاقة الخضراء التي يتم الحصول عليها من مصادر الطاقة المتجددة دورًا كبيرًا في تحقيق الهدف 7 من أهداف التنمية المستدامة (SDG7) والهدف 13 من أهداف العمل المناخي (CAG13). ونأمل أن تكون هذه الدراسة دليلاً للباحثين في هذا المجال لمساعدتهم في دراساتهم المستقبلية. قارنا في هذه الدراسة بين خمس مدن تقع في جنوب ليبيا من حيث الإشعاع الشمسي العالمي ودرجات الحرارة والرطوبة النسبية، وقارنا أيضًا إنتاجية الوحدات الكهروضوئية لمدة عام كامل من خلال محاكاة 1 كيلوواط من الوحدات الكهروضوئية في كل مدينة وكانت النتائج جيدة لتركيب محطات الألواح الشمسية في المدن المذكورة أعلاه.

الكلمات المفتاحية: مصادر الطاقة المتجددة، مدن الجنوب الليبي، الهدف السابع من أهداف التنمية المستدامة، 1 كيلو واط من الألواح الكهروضوئية، الألواح الشمسية.

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Introduction

Due to the climate changes in African content, each country is differing in weather conditions [1]. Libya is one of the African countries blessed with high solar radiation and wind speed to produce energy and meet Sustainable Development Goal Seven (SDG7) and Climate Action Goal 13 (CAG13) [1]. The country is placed on an area of 1.76 million square kilometers with 4 seasons and is inhabited by almost 6 million [2]. Each side of the country is placed with a various number of services; however, the southern region faces some challenges such as achieving sustainable development goals that lead people to travel to the capital cities (Tripoli-Benghazi-Misrata) for better living [3].Solar radiation in the southern cities is high in comparison with other cities in the country differs due to the different locations with different environments [4], [5], [6]. On the contrary, Wind speed is high in various seasons [7].

General Energy Company of Libya (GECOL) is the only company that is feeding the electricity in the country [8]. Hybrid systems of integrating PV with the grid are considered in [9]. [10]. Some local studies investigating the use of streetlights as conducted in [11], [12].Solar generation analysis for local communication in the country [13], and an investigation of utilizing RESs [14], [15]. Considering various forms of energy to meet European demand through its border countries such as Libya [16], [17], and [18]. Other case studies presenting the estimation of sunshine duration in Tripoli are conducted in [19].

Based on the high-tech provided technology of artificial intelligent, the microgrid challenges can be overcome as reported in[20]. Based on the recent studies regarding microgrid systems along with energy management strategies, most of the rising challenges are selecting the proposer EMS and the integrated components [21].

This paper contributes to the knowledge and comparison of solar radiation and temperature data in the southern cities of Libya measured by NASA, and knowing the productivity of 1 kW for a year from photovoltaic modules for some cities in the south of Libya using the SAM program.

Solar energy projects in southern Libya

Investments in the field of solar energy have witnessed a clear and wide scope during the past years globally [22]. As for what was implemented in Libya by the United Nations Development

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Program (UNDP 2018) [23] through the installation of solar energy systems in 15 hospitals, the share of the southern region was 3 hospitals, namely:

- Sebha Hospital.
- Ubari General Hospital
- Ubari General Hospital – Dialysis

The following Figures 1 and 2 show the systems that have been installed at Sebha Hospital and Ubari Hospital. Figure 3 presents the streetlights using solar panels in Ubari city.

Figure 1. Solar energy system installed at Ubari Hospital.

Figure 2. Solar power system installed at Sebha Hospital.

Figure 3**.** Street lighting using solar panels in Ubari [24].

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Data and methodology

Study Regions

Libya is generally characterized by solar radiation, though the amount varies by region. The southern region is considered more favourable for solar energy investment [25], [26]. We chose to study five cities located in southern Libya, as shown in Figure 4 and geographical details in Table 1. They were compared in terms of global solar radiation, temperatures, and annual energy production from photovoltaic modules.

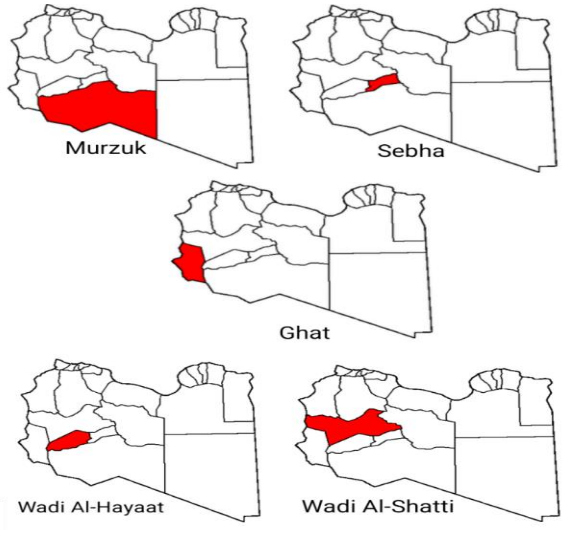

Figure 4. Maps of Libyan Southern Cities.

Table 1.Geographical details of some cities in Libya [5].

Location	Latitude [deg]	Longitude [deg]	Altitude [m]
Murzuk	25.90˚N	13.89˚E	453
Sebha	27.00˚N	14.40˚E	420
Ghat	24.96˚N	10.17˚E	668
Wadi Al-hayaat	26.42˚N	12.62˚E	646
Wadi Al-shatti	27.80˚N	12.73˚E	492

Sun path curve:

When designing solar energy systems, the sun path curve is crucial. Determining the shadows of objects close to the solar plains is made possible by the sun's path curve, which aids in understanding the sun's angles at different times of the day and year. As seen in Figure 5 the solar azimuth angle for June. Moreover, in Table 2, solar

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irradiance data on the horizontal and inclined at 30 degrees south, showing the highest and lowest average temperature. The sun path created online to ascertain the proper spacing between the rows of solar flats to minimize its influence on task [27].

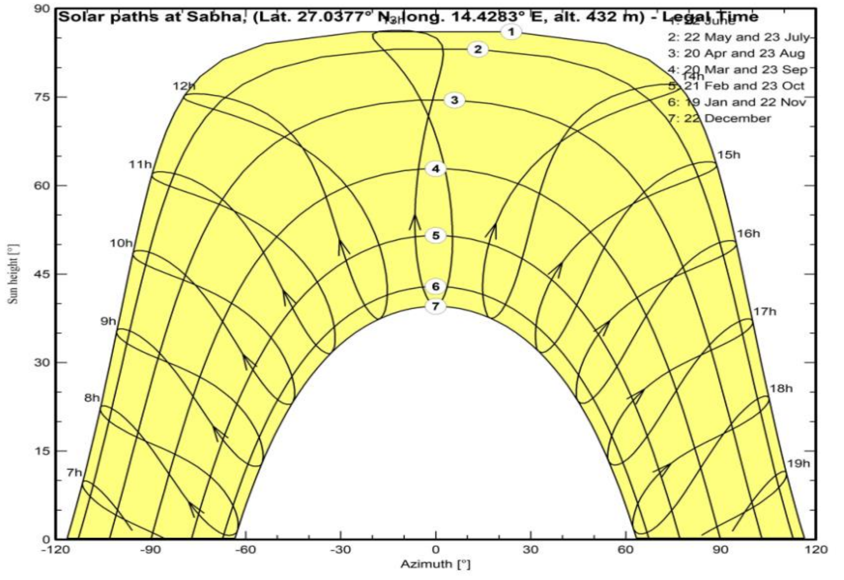

Figure 5. The sun's path for the southern region [1]

Table 2. Solar irradiance data on the horizontal and inclined at 30 degrees south, showing the highest and lowest average temperature.

Month	Global Horizontal Irradiation (kWh/m²/mth)	Horizontal Diffuse Irradiation (kWh/m²/mth)	Temperature (°C)	Wind Velocity (m/s)	Linke Turbidity (-)	Relative Humidity (%)
January	121.2	37.2	12.7	4.29	3.698	49.7
February	131.4	47.5	14.9	4.69	4.328	40.5
March	174.0	69.0	20.6	5.13	5.138	30.5
April	189.8	82.9	25.3	6.20	7.000	25.5
May	207.4	96.6	29.5	6.50	7.000	20.5
June	211.6	91.4	30.9	6.00	7.000	20.5
July	230.4	76.9	32.8	5.60	5.598	21.5
August	212.6	77.3	32.5	5.40	5.643	26.8
September	179.8	67.6	26.1	4.81	5.410	30.8
October	154.5	59.0	19.4	4.30	5.686	40.2
November	126.8	37.0	14.0	3.90	4.480	49.1
December	109.3	33.0	11.0	3.90	3.797	49.1

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Month	Global Horizontal Irradiation (kWh/m²/mth)	Horizontal Diffuse Irradiation (kWh/m²/mth)	Temperature (°C)	Wind Velocity (m/s)	Linke Turbidity (-)	Relative Humidity (%)
Year	2048.9	777.1	24.2	5.2	5.586	33.1

Therefore, the annual data as table 2 are:

- Solar Energy: - Total annual global horizontal irradiation is 2048.9 kWh/m², peaking in July (230.4 kWh/m²) and lowest in December (109.3 kWh/m²).

- Total horizontal diffuse irradiation is 777.1 kWh/m², highest in May (96.6 kWh/m²). - Temperature: - Average annual temperature is 24.2°C, peaking in July (32.8°C) and lowest in December (11.0°C).

- Wind Velocity: - Annual average is 5.2 m/s, with the highest in May (6.50 m/s) and the lowest in November and December (3.90 m/s).

- Atmospheric Clarity (Link Turbidity): - Yearly average is 5.586, with the clearest conditions in December (3.797) and most hazy in May-July (7.000).

- Relative Humidity: - Annual average is 33.1%, highest in January (49.7%) and lowest in May and June (20.5%).

This data reflects seasonal variations in solar energy, temperature, wind speed, and atmospheric conditions, showing the summer months as hotter and clearer but less humid.

Data Climatology collected data

The data used in this study are daily averages for each month of global solar radiation, ambient temperature, and relative humidity collected from NASA as shown in Figures 6, 7, and 8 [27]. Specifically, the dataset includes the following variables:

1. **Global Solar Radiation:** The total solar radiation received by a horizontal surface per unit area. This information is essential for modeling and simulating solar energy conversion processes and aids in assessing the potential energy output of photovoltaic systems.

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2. **Ambient Temperature:** The average daily temperature of the surrounding air, which affects how well solar panels and related control systems operate.

The research ensures a comprehensive analysis by capturing long-term trends and mitigating the influence of short-term volatility or abnormalities through daily and monthly data averaging.

By offering insights into performance measures including energy yield, stability, and fault tolerance, these characteristics are crucial for the design, simulation, and optimization of solar energy systems under various climatic circumstances.

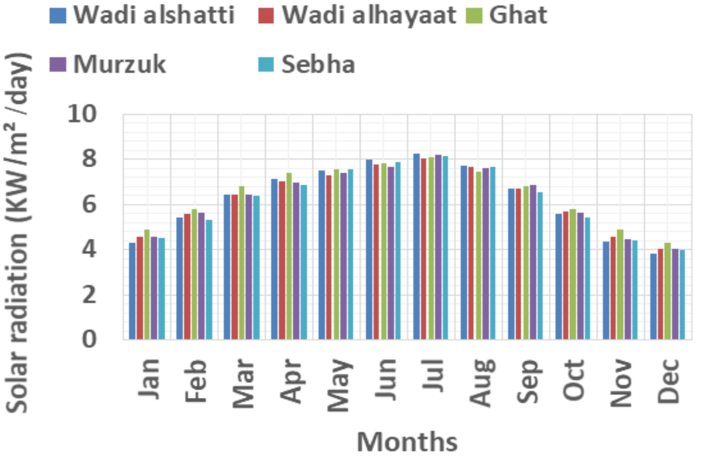

Figure 6.Comparison of daily averages for each month between global solar radiation and some cities in southern Libya.

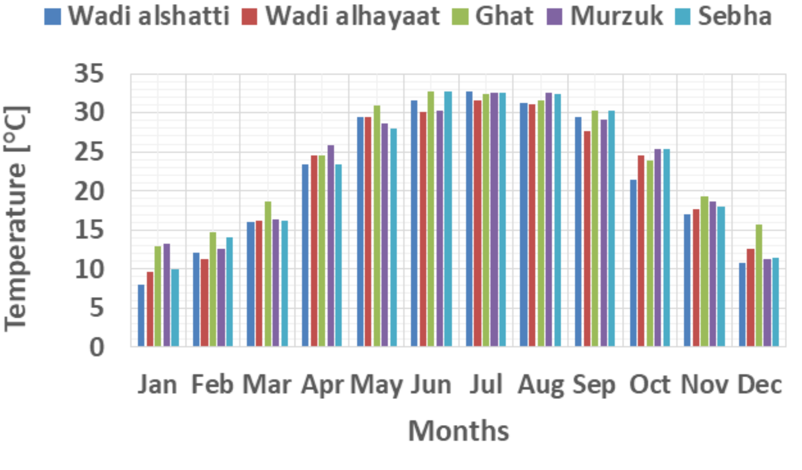

Figure 7.Comparison of daily averages for each month between temperatures for some cities in southern Libya.

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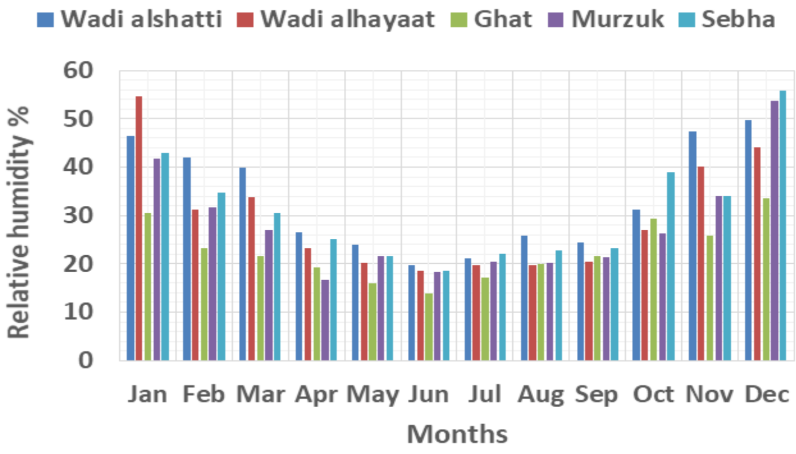

Figure 8.Comparison of daily averages for each month between relative humidity for some cities in southern Libya.

Methodology

The methodology used in this study was to simulate 1 kW of PV modules using SAM software based on each city's data as demonstrated in Figure 9. We considered that all PV modules are oriented in the south direction and the tilt angle is equal to the latitude of each city where (**β**=**φ**).

β: solar panel tilt angle.

φ: the latitude of the location.

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Figure 9. The program used in the simulation.

Result and discussions

To find out the annual productivity of solar energy in some of the cities selected for the study in southern Libya, we simulated 1 kW of PV modules in each city using the SAM program, and the results were good and close in all cities, and the highest productivity in Ghat city reached 2034 KWh / KWp. And the lowest in Murzuq city, where it reached 1990 KWh / KWp in Figure 10 shows the energy yield from PV modules per month for all cities.

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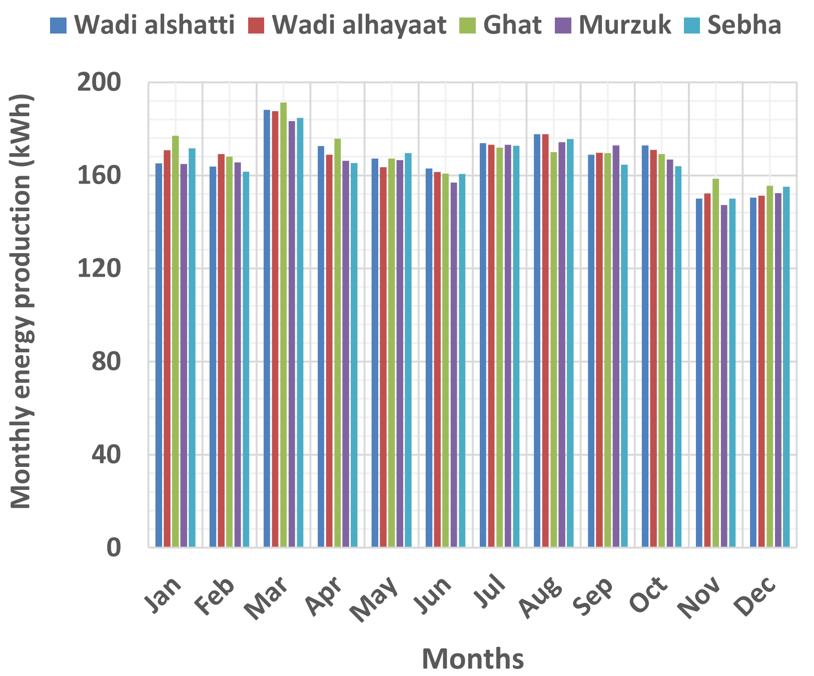

Figure 10. Monthly energy production per kilowatt of PV modules for all cities.

Conclusion

By comparing the studied cities in southern Libya, they all have a good rate of global solar radiation, as shown in Figure 2. The results of the simulation of 1 kW output for a year from PV modules for all the study cities showed good and close results, with the highest in Ghat and the lowest in Murzuq. Through data and simulations, cities in southern Libya have the potential to implement solar energy. However, there are multiple obstacles in the use of alternative energy, but there are possible solutions to overcome these obstacles. Through technology development, economic stabilization, and an appropriate legislative framework, the use of alternative energy can be promoted in cities in southern Libya. This requires a public-private partnership, raising awareness and education about the environmental and economic benefits of investing in alternative energy. By working together, sustainable growth and improved quality of life can be achieved in the cities of southern Libya.

http://www.doi.org/10.62341/aimo1756

References

[1] M. Marzouk, K. Attia, and S. Azab, "Assessment of Coastal Vulnerability to Climate Change Impacts using GIS and Remote Sensing: A Case Study of Al-Alamein New City," *J Clean Prod*, vol. 290, p. 125723, 2021, doi: 10.1016/j.jclepro.2020.125723.

[2] A. Almagtof, I. M. Saleh Ibrahim, A. Almagtof, I. M. Saleh Ibrahim, and A. Almagtof, "Renewable energy in Libya - the present and the vision," no. November, 2010.

[3] A. O. M. Maka, S. Salem, and M. Mehmood, "Solar photovoltaic (PV) applications in Libya: Challenges, potential, opportunities and future perspectives," *Clean Eng Technol*, vol. 5, p. 100267, 2021, doi: 10.1016/j.clet.2021.100267.

[4] N. AbouSeada and T. M. Hatem, "Climate action: Prospects of green hydrogen in Africa," *Energy Reports*, vol. 8, pp. 3873–3890, 2022, doi: 10.1016/j.egyr.2022.02.225.

[5] A. O. M. Maka, S. Salem, and M. Mehmood, "Solar photovoltaic (PV) applications in Libya: Challenges, potential, opportunities and future perspectives," *Clean Eng Technol*, vol. 5, p. 100267, 2021, doi: 10.1016/j.clet.2021.100267.

[6] F. K. Bannani, T. A. Sharif, and A. O. R. Ben-Khalifa, "Estimation of monthly average solar radiation in Libya," *Theor Appl Climatol*, vol. 83, no. 1, pp. 211–215, 2006, doi: 10.1007/s00704-005-0157-9.

[7] I. M. S. I. Al-Jadi, M. A. EKhlat, and N. M. Krema, "Photovoltaic in Libya applications, and evaluation," *Proceedings of the InternationalConference on Renewable Energy for Developing Countries*, pp. 1–11, 2005.

[8] Walid Alsuessi, "General Electric Company of Libya (GECOL)," *European International Journal of Science and Technology*, vol. 4, no. 1, pp. 61–69, 2015.

[9] A. Guwaeder and R. Ramakumar, "A Study of Grid-connected Photovoltaics in the Libyan Power System," *Energy and Power*, vol. 7, no. 2, pp. 41–49, 2017, doi: 10.5923/j.ep.20170702.02.

[10] A. Alkilany, A. Ahmed, H. Said, and A. Abu Bakar, "Application of the k-means clustering algorithm to predict load shedding of the Southern Electrical Grid of Libya," in *Fourth edition of the International Conference on the*

http://www.doi.org/10.62341/aimo1756

Innovative Computing Technology (INTECH 2014), IEEE, Aug. 2014, pp. 244–247. doi: 10.1109/INTECH.2014.6927763.
[11] A. Alsharif, R. Y. Jomah, A. Alshareef, M. Almihat, A. Salah, and A. Al Smin, "Hybrid Systems Renewable Energy Based Street Lighting Planning: A Case Study," *African Journal of Advanced Pure and Applied Sciences (AJAPAS)*, vol. 1, no. 1, pp. 31–40, 2022.
[12] A. C. Duman and Ö. Güler, "Techno-economic analysis of off-grid photovoltaic LED road lighting systems: A case study for northern, central and southern regions of Turkey," *Build Environ*, vol. 156, no. January, pp. 89–98, 2019, doi: 10.1016/j.buildenv.2019.04.005.
[13] M. Almaktar, A. M. Elbreki, and M. Shaaban, "Revitalizing operational reliability of the electrical energy system in Libya: Feasibility analysis of solar generation in local communities," *J Clean Prod*, vol. 279, p. 123647, 2021, doi: 10.1016/j.jclepro.2020.123647.
[14] A. M. A. Mohamed, A. Al-Habaibeh, and H. Abdo, "An investigation into the current utilisation and prospective of renewable energy resources and technologies in Libya," *Renew Energy*, vol. 50, pp. 732–740, Feb. 2013, doi: 10.1016/j.renene.2012.07.038.
[15] A. Guwaeder, H. Sarhan, and I. Aldaouab, "A study of the penetration of photovoltaic generation into the Libyan power system," in *2017 International Energy and Sustainability Conference (IESC)*, IEEE, Oct. 2017, pp. 1–5. doi: 10.1109/IESC.2017.8167477.
[16] A. O. M. Maka and J. M. Alabid, "Solar energy technology and its roles in sustainable development," *Clean Energy*, vol. 6, no. 3, pp. 476–483, Jun. 2022, doi: 10.1093/ce/zkac023.
[17] H. Shamatah, S. Azouz, A. Khalil, and Z. Rajab, "The potential of the rooftop grid-connected PV systems in Benghazi," in *2017 IEEE Jordan Conference on Applied Electrical Engineering and Computing Technologies (AEECT)*, IEEE, Oct. 2017, pp. 1–6. doi: 10.1109/AEECT.2017.8257778.
[18] A. M. A. Mohamed, A. Al-Habaibeh, H. Abdo, and S. Elabar, "Towards exporting renewable energy from MENA region to Europe: An investigation into domestic energy use and householders' energy behaviour in Libya," *Appl Energy*, vol. 146, pp. 247–262, 2015, doi: 10.1016/j.apenergy.2015.02.008.

http://www.doi.org/10.62341/aimo1756

[19] A. Ekhmaj, "Estimation of Sunshine Duration using Statistical Approach : Libya A Case Study Estimation of Sunshine Duration using Statistical Approach : Libya As A Case Study," no. April, 2017.
[20] M. Khaleel, A. A. Ahmed, and A. Alsharif, "Artificial Intelligence in Engineering," *Brilliance: Research of Artificial Intelligence*, vol. 3, no. 1, pp. 32–42, Mar. 2023, doi: 10.47709/brilliance.v3i1.2170.
[21] M. Shafiullah *et al.*, "Review of Recent Developments in Microgrid Energy Management Strategies," *Sustainability*, vol. 14, no. 22, p. 14794, Nov. 2022, doi: 10.3390/su142214794.
[22] Y. Nassar *et al.*, "Simulating the Energy, Economic and Environmental Performance of Concentrating Solar Power Technologies Using SAM," *Solar Energy and Sustainable Development Journal*, vol. 12, no. 2, pp. 4–23, Sep. 2023, doi: 10.51646/jsesd.v12i2.153.
[23] "UNDP. UNDP Installs Solar Panels in 15 Libyan Hospitals. plans more in 2018, p. 18. January 2018.," 2018.
[24] A. Alsharif, R. Y. Jomah, A. Alshareef, M. Almihat, A. Salah, and A. Al Smin, "Hybrid Systems Renewable Energy Based Street Lighting Planning: A Case Study," *African Journal of Advanced Pure and Applied Sciences (AJAPAS)*, vol. 1, no. 1, pp. 31–40, 2022.
[25] W. El-Osta and U. Elghawi, "Assessment of Energy Intensity Indicators in Libya: Case Study," *Sustainable Development Research (ISSN 2690-9898 e-ISSN 2690-9901)*, vol. 2, no. 1, p. p9, Mar. 2020, doi: 10.30560/sdr.v2n1p9.
[26] H. Moria and M. Elmnifi, "Feasibility Study into Possibility Potentials and Challenges of Renewable Energy in Libya," *International Journal of Advanced Science and Technology*, vol. 29, no. 3, pp. 46–60, 2020.
[27] SolarGis, "Solar resource maps of Libya," © 2019 Solargis. All rights reserved. [Online]. Available: https://solargis.com/maps-and-gis-data/download/libya