African Journal of Advanced Pure and Applied Sciences (AJAPAS)

Volume 1, Issue 1, January 2022, Page No: 31-40
Website: https://aaasjournals.com/index.php/ajapas/index

Hybrid Systems Renewable Energy Based Street Lighting Planning: A Case Study

Abdulgader Alsharif [1 *], Raffa Younis Jomah [2], Abdussalam Alshareef [3], Mohamed Almihat [4], Ahmed Salah [5], Ahmed Al Smin [6].

[1] Department of Communication Engineering, College of Civil Aviation Technology and Meteorology, Espiaa, Libya
[2] Affiliation, Department of Electrical engineering, Faculty of Technical Sciences, Sebha, Sebha, Libya
[3]Department of Civil Engineering College of Civil engineering, Sebha University, Sebha, Libya
[4]Department of Electrical and Electronic Engineering, Azahra Higher Institute of Sciences and Technology, Azahra, Libya
[5] Division of Electric Power Engineering, School of Electrical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia
[6] Higher Institute of Science and Technology Suk Algumaa, Tripoli, Libya

[*]*Corresponding author: abduulgaderalsharif@gmail.com*

Article history
Received : December 12, 2021
Accepted : December 22, 2021
Published : January 01, 2022

Keywords:
Photovoltaic
Wind Turbine
Street lighting
Renewable energy sources
High-Pressure Sodium Lamps

Abstract: Libya is a country located in the middle of North Africa and is highly blessed with abundant sources of renewable energy. In spite, of these blessings, the streetlight across the country uses High-Pressure Sodium Lamps (HPSL) and is powered from conventional fossil-based sources. Consequently, due to the fast-growing population in the country, satisfying the load demand from the conventional energy source (fossil fuel) remains a challenge. However, improving the living standard of humans through utilizing Renewable Energy Sources (RESs) provides economic and environmental benefits. This study proposed a RES-based street lighting system to reduce the burden on the national grid and to overcome the struggle of satisfying the load demand due to increased population. The RES sources such as solar energy and wind can generate green energy due to the high potential in the country. A solar photovoltaic (PV) and wind turbine (WT) will be used as an interface for street lighting.

Cite this article as: 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, Issue 1, pp. 12-21, 2021.

Introduction

The Different nations across the globe have started exploiting various RESs in their quest to achieve affordable and clean energy as part of the Sustainable Development Goals (SDG7). This is geared toward improving the human standard of living through technology. The Renewable Energy Authority of Libya (REAOL) conducted a study aimed at finding the renewable energy potentials in the country. The finding of the investigation confirmed the enormous potential of renewable energy. Despite, this enormous natural endowment, the power generation in the country is based on conventional energy which contributes to carbon dioxide (CO2) emissions. In recent years Libya started facing high load demands due to increasing population. This resulted in load shading and power interruption. Assimilation of Renewable Energy Resources in the power generation scheme could cover part of this load demand reduce CO2 emissions [1] and increase the system efficiency and reliability.

The sole provider of electricity in Libya is the General Electricity Company of Libya (GECOL) supplying around 20 % of the generated electricity to street lighting [2]. The street lighting system uses a high-pressure sodium lamp. Replacing the old system with a new RESs based system will result in reducing the peak load demand and improving the overall performance of the power system [3]. Perhaps, the RE in Libya solar and wind in particular if the implementation can accomplish sustainable power and protect the environment. In order to address long hours of blackout due to power interruption, street lighting using a Lighting Emitting Diodes (LEDs) system powered by Photovoltaic (PV) and wind turbine (WT) can be utilized [4].

A study on sustainable street lighting systems to replace the conventional street lighting system aimed at reducing the energy usage of the streetlights is very essential. Previous research in this area highlights the potential of using RES in street lighting making it an interesting area of research due to its merits in preventing CO2 emission and saving fuel [5][6]. In an effort to exploit the RESs to reduce the over-dependency on fossil fuel which is envisaged to deplete in the next decades [7], the Libyan authorities (REAOL) target 500 MW power generation from PV by 2025 and 2500 MW clean energy production from wind by 2030 [8]. A review on developing and designing smart highway street lighting systems based on clean energy is presented in [9]. In addition, challenges and opportunities of solar-based LED street lights are discussed in [10]. A proposed street lighting based on a hybrid system to provide green energy is reported in [11]. A case study for 100 units of lighting streets in the eastern side of Libya (Al-Bakur) has been reported in [3]. The study considered photovoltaic and micro-hydro as energy sources. A study considering the potential, challenges, and future perspectives for the application of PV in Libya has been reported in [12]. The author highlights a different area where RESs are being used in Libya. In [13] HOMER software is used to analyze and model the collected data. The study area under consideration is more than 3 km, using an LED lamp with 30 kW PV and 0.9 kW Hydro respectively. The combined cost of energy is $0.032 kWh.

The study is carried out in three phases. Phase one studies the existing street lighting system, Phase two is to develop a sustainable, Finally, phase three is to replace the conventional system. The main contribution of this article is to benchmark the use of LED-based street lighting systems supplied by RESs and conventional fossil fuel-based streetlighting using HPSL using a nature-inspired algorithm. The rest of the article is organized as follows: Section 2 discusses the renewable sources in the case study. Section 3 is the mathematical modeling calculation of using HPSL. The results are presented in Section 4. The conclusion of the study is placed in Section 5. Eventually, the acknowledgments followed by the references are positioned in the last section.

Renewable energy sources in Libya

Libya is a country located in the African continent with its capital in Tripoli and blessed with four climate seasons. The population is 7 million, a 2000 km coastal region, and an area of 1750000 Km2. The country has the potential generating electricity with PV due to the high solar irradiance as illustrated in Figure.1. Table 1 presents various sources of generating energy in Libya.

Table 1 Fuel types with their generated energy in Libya

Fuel type	Energy generated (kWh)
Light fuel oil	418
Heavy fuel oil	500
Natural gas	3.1722

The solar radiation in the northern part is 7.5 kWh/m2/d while that of the southern part is 8.1 kWh/m2/d with approximately 3000 sunshine per year [14]. Recently, different cities in the country installed solar streetlights due to the continuous interruption in public electricity. Sabha, Al-Marj, and Ubari have already installed the LED-based solar lighting financially supported by the United Nations Development Program (UNDP).

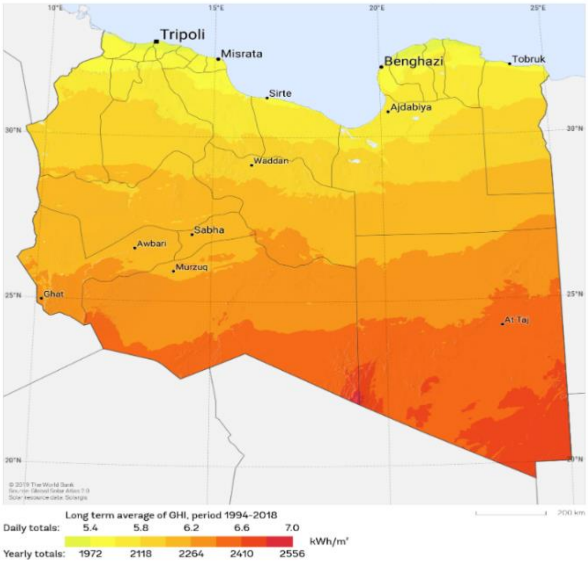

Figure 1 Horizontal solar irradiance of Libyan.

LED-based light is environmentally friendly and does not have emits CO2. While across the globe, countries like Egypt, China (Bejing Olympic Wrestling Venue), Oman (Sultan Qaboos University) [15], Malaysia, South Africa, Zimbabwe [6], Nigeria [16], Turkey [17], and Chile (Calama city) [18] have shifted attention towards implementing LED-based street lighting system supported by around 13 international foundations. The ambient temperature, solar irradiance, and wind speed contour plots of the study area (Tripoli) are shown in Figure 2, Figure 3, and Figure 4 respectively.

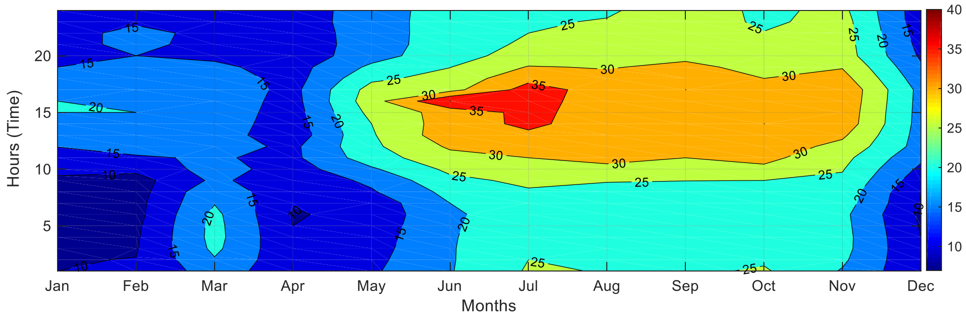

Figure 2 Ambient temperature contour plot

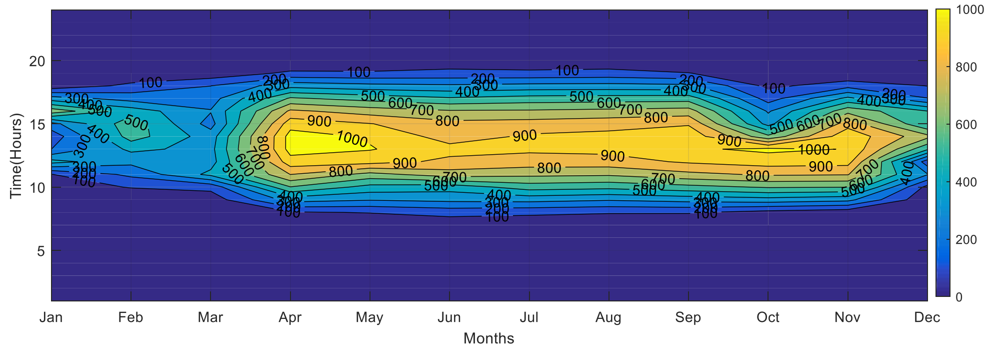

Figure 3 Solar irradiance contour plot

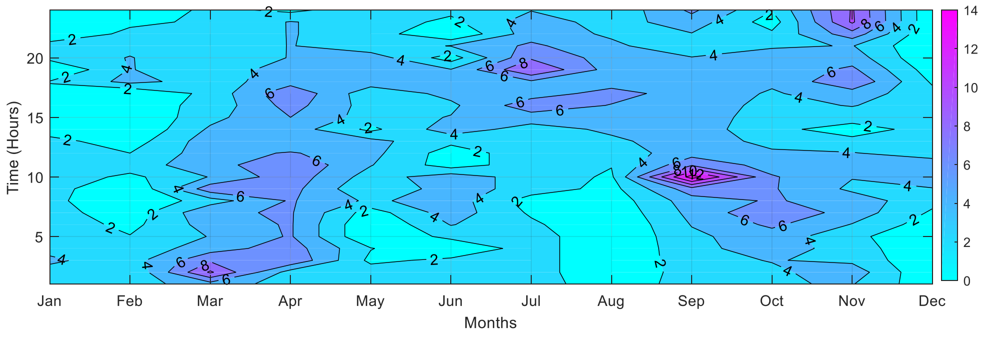

Figure 4 Wind speed contour plot

The average monthly weather data for the study area (Tripoli) is sourced from (the PVWATT calculator) and presented in Table 2.

Table 2 Monthly average solar irradiation ad wind speed

Month	Mean solar irradiation (kWh/m^2)	Mean wind speed (m/s)	Mean ambient temperature (ºC)
January	56.2329	2.7327	11.8975
February	68.1288	4.2086	13.0132
March	88.1781	3.8223	14.4899
April	95.9973	4.6386	18.0921
May	103.2370	4.5368	23.3205
Jun	100.0959	4.1466	27.1045
July	79.7027	4.1466	28.0202
August	73.8479	3.2912	27.7619
September	88.9808	3.5215	27.1820
October	70.9274	3.3137	22.9750
November	61.5411	2.6493	17.6241
December	55.3178	3.2373	12.7179

Various specifications of conventional lamps High-pressure sodium lamps (Fig. 5) and the LED lamps (Fig. 6) for street lighting with their specifications are presented in Table III and Table IV, respectively. While the comparison between these lamps is tabulated in Table V.

Figure 5 High-pressure sodium lamps (250-400 Watts).

Table 3 LED Specification.

Item/Article	Specification
Solar panel	320W/36V, Mono-Crystalliane, >18% Effecency
LED lamp	80W/24V, 2-unit LED modules, SAN’ AN 5050, 168LM/W, 5700k, IP68
LED lamp	40W/24V, 1-unit LED modules, SAN’ AN 5050, 168LM/W, 5700k, IP68
MPPT controller	20A, automatic dust to dawn auto-dimming, PV input power, 280W@12V, 560W@24V

Table 4 High-pressure sodium lamps specification

Wattage	Volts (V)	Curerent (A)	Power (W)		Current Crest Factor
Lucalax^{TM} – Internal Ignator 50		85	0.76	50	1.45
70		90	0.98	70	1.45
Lucalax^{TM}-TD Double Ended 1000		250	4.70	1000	1.45
Lucalax^{TM}-E-Z Lux^{TM} 110		115	1.22	110	1.42

Table 5 Comparison in cost between HPS and LED.

Measurement parameters	LED	HPS
Daily hour operation	12	
Days of operation/ month	30	
Total hours of operation/month	360	
Power consumption of one lamp	112	250
Total number of installed lamps	10	
Total kWh/Month	403.2	900
Cost of operation (125 LP per kWh)	$32.25	$75
VAT (10%)	$3.225	$7.5
Total/ month	$35.475	$82.5
Total/ year	$425.7	$990
Yearly saving	$564.3	

(a) (b)

Figure 6 LED for street lighting (a) and (b).

Table 6 Solar Street lighting specification.

Product name	Parameters	Rating	Units
LED Light model:	Power input	120	W
CSL-B120 (CREE XTE LED)	Voltage	24	V DC
PV Panel: JS 160	V_{OC}	22.25	V
	I_{SC}	9.82	A
	P_{MAX}	160	W
	V_{MAX}	17.5	V
	I_{MAX}	9.14	A
	Efficiency	13.7	%
Battery: NPG12-200	Rated capacity	200	Ah
	Nominal voltage	12	V
Phocos industrial	Nominal voltage	12/24	V
Charge controller: CIS XX 2L	Maximum charge/load current	20	A
Street light pole	Height of the pole	8	Meters

The type of wind turbine considered in this study is AMPAIR

Table 7 400W Wind Solar Hybrid Street Light specifications [11]

Configuration	3 Blades, Horizontal axis, upwind
Rotor Diameter	Φ1.25m
Rated Power	400W at 11m/s
Maximum Output Power	600W at 15m/s
Battery Bank Voltage	12 V_{dc}
System Output Voltage	12 V_{ac}
Cut-in Wind V_{speed}	2.5 m/s
Working Wind Speed	3-25 m/s
Survival Wind Speed	50 m/s
Generator Efficiency	>0.80
Wind Energy Utilizing Ratio	0.40 Cp
Alternator	Permanent magnet alternator, SCF technology
Alternator Weight (kg)	5.5 kg
Gearbox	None, Direct drive, front generator design
Blade Material	Fiberglass reinforced composite
Over Speed Regulation	Passive furling tail design
Shutting Down Method	Manual & Automatic electromagnetism Braking

Where the comparison cost of the two mentioned lamps is presented in Figure 7, while the different utilized loads in the study area.

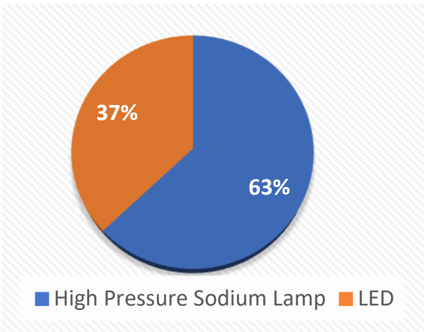

Figure 7 Cost range between the LED and HPSL.

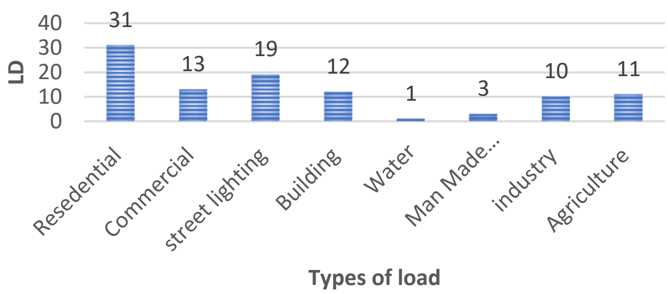

Figure 8 Different types of loads.

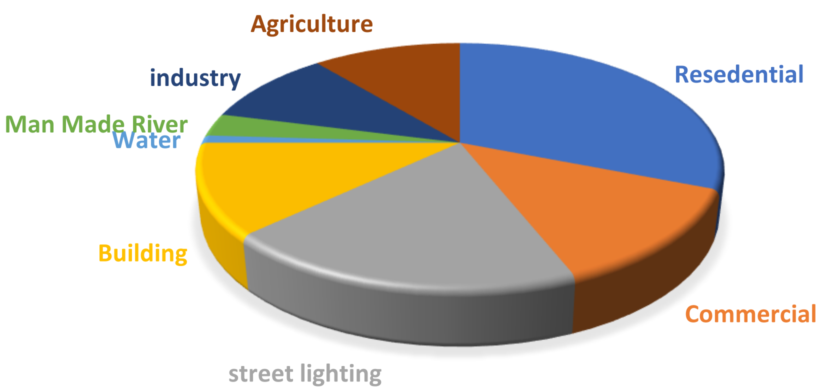

Figure 9 Types and shares of customers of Libyan electricity generation

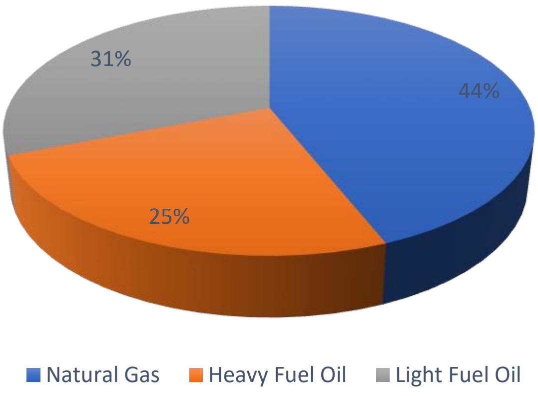

Figure 10 Types and percentage of the fuel used in electricity generation

Figure 11 Hybrid solar/wind street lighting system [11].

Table 8 Load details [4].

Parameters	Value	Units
AD	3	Days
Operating hours	18:00 to 06:00	Pm-Am
Battery voltage	24	V
LED	100	W

The benefit of using LED street lighting is listed in Fig. 12. On the other hand, the drawbacks depend on the natural sources and intermittency and fluctuation. While the aforementioned issue can be addressed by energy storage system units [4].

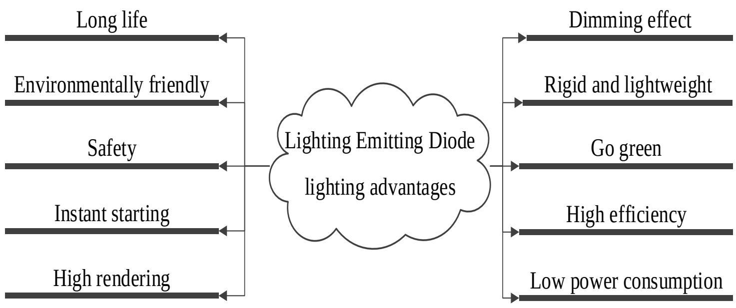

Figure 12 LED lighting advantages [15][3].

Mathematical calculation

The methods used for calculating the investment cost of each LED or HPS lamp are mathematically presented using the techno-economic analysis method [19].

$$E = I_{peak} \times R_{average} \times \eta \times \alpha \times V \quad (1)$$

$$E = P_{LED} \times d_m \times h \quad (2)$$

$$N = \frac{2}{15} \cos^{-1}(-\tan^{-1} \emptyset \tan \partial) \quad (3)$$

$$\partial = 23.5 \sin\left(360 \times \frac{284 + n}{365}\right) \quad (4)$$

Results and discussion

The RESs are a very important solution to power and environmental issues. By using the foregoing RESs, the SDG7 is achieved. Furthermore, there are some limitations behind utilizing the RESs that can be addressed by using the energy storage systems. In street lighting systems using LED supplied by the RE nature sources can mitigate the CO2 emission and reduce the dependency on the grid in the cases of voltage fluctuation or interruption.

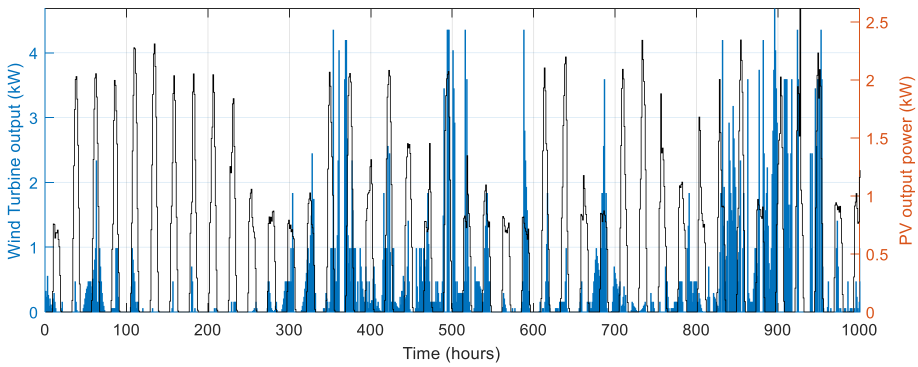

Figure 13. Generated output from RESs (WT and PV).

Conclusion

This paper proposed a stand-alone system for street lighting using two widely used RESs (PV and WT) sources. Additionally, a comparison between the conventional lamp known as high-pressure sodium (HPS) supplied by the grid and the LED supplied by the RESs has been discussed. Alternative sources are highly required to improve

the lifestyle by avoiding the challenges of electricity interruption and being environmentally friendly and energy saving.
Moreover, using a high-pressure sodium lamp system and LED lamps system in street lighting systems saves up to 75% of energy and lowers CO2 emission by 75%.

Moreover, using different algorithms or optimization techniques in order to obtain the optimal number of configurations. In terms of cost, the rating cost of electricity is 0.15 to 0.20 $/kWh while lighting the street by the LED can cost (1250200 LD= 893$), whereas the conventional lamp using HPSL costs around 2117255 LD =1512325). The aforesaid prices depend on the central bank of Libya rates where the 1$=1.4 LD (at the last quarter of 2022).

References

[1] A. Khalil, Z. Rajab, and A. Asheibi, "The economic feasibility of photovoltaic systems for electricity production in Libya," *7th Int. Renew. Energy Congr.*, pp. 1–6, 2016.

[2] "General Electricity Company of Libya (GECOL)," 2021. https://www.gecol.ly/gecol_en/ (accessed Mar. 24, 2021).

[3] A. Khalil, Z. Rajab, M. Amhammed, and A. Asheibi, "The benefits of the transition from fossil fuel to solar energy in Libya: A street lighting system case study," *Appl. Sol. Energy*, vol. 53, no. 2, pp. 138–151, Apr. 2017, doi: 10.3103/S0003701X17020086.

[4] Z. Rajab, A. Khalil, M. Amhamed, and A. Asheibi, "Economic feasibility of solar powered street lighting system in Libya," in *2017 8th International Renewable Energy Congress (IREC)*, Mar. 2017, no. January, pp. 1–6, doi: 10.1109/IREC.2017.7926027.

[5] D. Mazzeo, N. Matera, P. De Luca, C. Baglivo, P. M. Congedo, and G. Oliveti, "A literature review and statistical analysis of photovoltaic-wind hybrid renewable system research by considering the most relevant 550 articles: an upgradable matrix literature database," *J. Clean. Prod.*, p. 126070, Jan. 2021, doi: 10.1016/j.jclepro.2021.126070.

[6] W. R. Nyemba, S. Chinguwa, I. Mushanguri, and C. Mbohwa, "Optimization of the design and manufacture of a solar-wind hybrid street light," *Procedia Manuf.*, vol. 35, pp. 285–290, 2019, doi: 10.1016/j.promfg.2019.05.041.

[7] O. A. Mohamed and S. H. Masood, "A brief overview of solar and wind energy in Libya: Current trends and the future development," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 377, no. 1, p. 012136, Jun. 2018, doi: 10.1088/1757-899X/377/1/012136.

[8] O. A. Mohamed and S. H. Masood, "A brief overview of solar and wind energy in Libya: Current trends and the future development," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 377, no. 1, 2018, doi: 10.1088/1757-899X/377/1/012136.

[9] M. Y. Mukta, M. A. Rahman, A. T. Asyhari, and M. Z. Alam Bhuiyan, "IoT for energy efficient green highway lighting systems: Challenges and issues," *J. Netw. Comput. Appl.*, vol. 158, no. August 2019, p. 102575, 2020, doi: 10.1016/j.jnca.2020.102575.

[10] S. Bello-Yusuf and A. Bello, "Energy Sustainability Paradox: Exploring the Challenges and Opportunities of Solar LED Street Lights in Sokoto, Nigeria," *Niger. J. Environ. Sci. Technol.*, vol. 4, no. 2, pp. 260–271, 2020, doi: 10.36263/nijest.2020.02.0204.

[11] S. Georges and F. H. Slaoui, "Case Study of Hybrid Wind-Solar Power Systems for Street Lighting," in *2011 21st International Conference on Systems Engineering*, Aug. 2011, pp. 82–85, doi: 10.1109/ICSEng.2011.22.

[12] 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.

[13] N. Abbas Fadhil, M. Elmnifi, O. D. . Abdulrazig, and L. Jaafer Habeeb, "Design and modeling of hybrid photovoltaic micro-hydro power for Al-Bakur road lighting: A case study," *Mater. Today Proc.*, no. xxxx, Nov. 2021, doi: 10.1016/j.matpr.2021.10.072.

[14] A. Khalil, A. Asheibi, A. Asheibe, Ashraf Khalil, and A. Asheibi, "The Chances and Challenges for Renewable Energy in Libya," *Proc. Renew. Energy Conf.*, no. November 2015, pp. 1–6, 2015.

[15] M. I. Masoud, "Street lighting using solar powered LED light technology: Sultan Qaboos University Case Study," in *2015 IEEE 8th GCC Conference & Exhibition*, Feb. 2015, pp. 1–6, doi: 10.1109/IEEEGCC.2015.7060015.

[16] N. M. Kumar, A. K. Singh, and K. V. K. Reddy, "Fossil Fuel to Solar Power: A Sustainable Technical Design for Street Lighting in Fugar City, Nigeria," *Procedia Comput. Sci.*, vol. 93, no. September, pp. 956–966, 2016, doi: 10.1016/j.procs.2016.07.284.

[17] 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.

[18] M. Ali, M. Orabi, E. Abdelkarim, J. A. A. Qahouq, and A. El Aroudi, "Design and development of energy-free solar street LED light system," in *2011 IEEE PES Conference on Innovative Smart Grid Technologies - Middle East*, Dec. 2011, pp. 1–7, doi: 10.1109/ISGT-MidEast.2011.6220812.

[19] I. S. Mardikaningsih, W. Sutopo, M. Hisjam, and R. Zakaria, "Techno-economic feasibility analysis of a public street light with solar cell power," *Lect. Notes Eng. Comput. Sci.*, vol. 2, pp. 769–773, 2016.

[20] I.S. Naser, Mohamed Alsharif, Adel Hamad Rafa, and Abdussalam Ali Ahmed, Impact of Wind Farm Location on Voltage Stability,Sebha university Journal of Pure & Applied Sciences Vol.20 No. 4 2021, Doi: 10.51984/JOPAS.V20I4.1820.

[21] Abdussalam Ali Ahmed, Renewable Energy Home Design in Bani Walid City/Libya, Saudi J Eng Technol, Sep 2019; 4(9): 339-344

[22] Alhusein N, Ahmed A. Climate Change Impacts on Future Solar Photovoltaic System Performance and Power Output in Libya. Alq J Med App Sci. 2022;5(1):185-192. https://doi.org/10.5281/zenodo.6396004