Journal of Scientific and Human Dimensions
مجلة الأبعاد العلمية والإنسانية
Volume 1, Issue 2, 2025, Pages: 96-106
Journal homepage: https://jshd.com.ly/index.php/jshd/en

Investigation and Modelling of a Dual Solar Photovoltaic System for Consistent Energy Supply at Al-Brega Clinic, Libya

Mohamed Abdulhadi Faraj Hamad [1 *], Mansour Khalifa Hamad Mohammed [2]
[1] Department of Electric and Electronic Engineering, Bright Star University, Brega, Libya
[2] Department of Engineering Management, Faculty of Management, Bright Star University, Brega, Libya

دراسة ونمذجة نظام شمسي كهروضوئي مزدوج لتوفير طاقة متسقة في عيادة البريقة، ليبيا

محمد عبدالهادي فرج حمد [1*]، منصور خليفة حمد محمد [2]
[1] قسم الهندسة الكهربائية والالكترونية، كلية الهندسة، جامعة النجم الساطع، البريقة، ليبيا
[2] قسم الإدارة الهندسية، كلية الإدارة، جامعة النجم الساطع، البريقة، ليبيا

[*]Corresponding author: Elragae20102846@gmail.com

Received: October 10, 2025	Accepted: October 25, 2025	Published: December 04, 2025

Abstract:
This study delineates the design and simulation of a hybrid photovoltaic (PV) system to mitigate the ongoing electricity shortages at the AL-Brega Clinic in Libya. The system employs monocrystalline silicon cells, chosen for their superior performance in the local climate. A thorough literature analysis on photovoltaic technologies and solar cell varieties is presented, detailing their advantages and disadvantages. The system's performance was modeled using PVsyst software to ascertain the hourly energy output, guaranteeing it satisfies the clinic's projected annual energy requirement of 673.232 MWh, considering departmental consumption profiles. Initial design and computations were conducted utilizing Microsoft Excel. The modeling findings suggest an anticipated annual energy output of 3046 MWh from the planned photovoltaic system. A cost analysis indicates levelized costs of energy (LCOE) of LYD 0.0695/kWh and LYD 0.1511/kWh for the two evaluated scenarios. The estimated payback period, determined by the financial offset of crude oil used to produce an equivalent quantity of power, is roughly 16 years. This study illustrates the technical and economic viability of deploying a solar photovoltaic system to bolster energy security and mitigate environmental effect for essential healthcare infrastructure in Libya.

Keywords: Hybrid Solar PV System, Off-grid Power, Healthcare Facility, PVsyst Simulation, Libya, Renewable Energy, Cost.

الملخص
توضح هذه الدراسة تصميم ومحاكاة نظام كهروضوئي هجين (PV) لتخفيف حدة نقص الكهرباء المستمر في عيادة البريقة في ليبيا. يستخدم النظام خلايا سيليكون أحادية البلورة، اختيرت لأدائها المتفوق في المناخ المحلي. يقدم هذا البحث تحليلًا شاملًا للأدبيات المتعلقة بتقنيات الطاقة الكهروضوئية وأنواع الخلايا الشمسية، مع توضيح مزاياها وعيوبها. تمت نمذجة أداء النظام باستخدام برنامج PVsyst لتحديد إنتاج الطاقة في الساعة، مما يضمن تلبية احتياجات العيادة السنوية المتوقعة من الطاقة والبالغة 673.232 ميجاوات/ساعة، مع مراعاة أنماط استهلاك الأقسام. أُجري التصميم والحسابات الأولية باستخدام برنامج مايكروسوفت إكسل. تشير نتائج النمذجة إلى إنتاج طاقة سنوي متوقع قدره 3046 ميجاوات/ساعة من النظام الكهروضوئي المخطط له. يشير تحليل التكلفة إلى أن تكلفة الطاقة المُستوية (LCOE) تبلغ 0.0695 دينار ليبي/كيلوواط ساعة و0.1511 دينار ليبي/كيلوواط ساعة للسيناريوهين المُقيّمين. وتُقدر فترة الاسترداد، المُحددة بالتعويض

المالي للنفط الخام المُستخدم لإنتاج كمية مُكافئة من الطاقة، بحوالي 16 عامًا. وتُوضح هذه الدراسة الجدوى الفنية والاقتصادية لنشر نظام الطاقة الشمسية الكهروضوئية لتعزيز أمن الطاقة وتخفيف الأثر البيئي على البنية التحتية الأساسية للرعاية الصحية في ليبيا.

الكلمات المفتاحية: نظام الطاقة الشمسية الكهروضوئية الهجين، الطاقة المستقلة عن الشبكة، مرفق الرعاية الصحية، محاكاة أنظمة الطاقة الكهروضوئية، ليبيا، الطاقة المتجددة، التكلفة.

Introduction

In the past, the use of Solar Photovoltaic (PV) systems is being seen in a wide variety of applications in developing nations or energy constrained areas [1]. These systems can support goods like rural communication systems and fridges to store medicines in rural hospitals located in areas with no conventional electricity supply systems or where the systems are not efficient. In the recent past, PV systems became popular for gathering electricity in off-grid electrical generation in rural and semi-urban areas where population density is low and electricity supply networks are not available [2]. The solar energy systems also very usable and low on upkeep; don't consume any kind of fuel; hence, nonpolluting and sustainable making them an asset to the environment. Many countries were likewise able to set considerable objectives to encourage the utilization of this energy source's growth. For example, solar energy literature indicates a high source of possibility in terms of the economic advancement of the economy [3].

For several years now, the Libyan city of AL-Brega has struggled with a power cut which has hampered essential services [4]. And further weakened already vulnerable jobs. As seen from the image, the AL-Brega Medical Complex is one of the facilities that was severely affected due to these outages [5]. The number of pregnancies in the area of AL-Brega is on the rise, especially in the summer. As a result, the Clinic's capabilities are stretched and are more vulnerable to the severe effects of the power cuts. The research project looks into the impact of using solar energy to improve the quality of life within the confines of the village concerning the installation of a solar system at AL-Brega Clinic (ABC). Also, resolving Clinic electricity problems should cut down on pollution.

Essential services have been hampered in the Libyan city of AL-Brega due to a persistent electricity shortage in recent years. and further weakened already vulnerable livelihoods. The AL-Brega Medical Complex, as shown in the accompanying image, is one of the facilities severely impacted by these power shortages [6]. With increasing pregnancies in the AL-Brega area, particularly during the summer, the Clinic's resources are overstretched and more susceptible to the severe effects of power cuts. This study explores how the installation of a solar system at the AL-Brega Clinic (ABC) can enhance the standard of living in the village, alleviate the Clinic's electricity problems, and reduce pollution through the use of environmentally friendly solar energy.

This study is contributed to providing a study to investigate installation of PV system in AL-Brega Clinic (ABC). While the remaining sections are as follows: Section 2 presented the case study along with the collected data. The following methodology of the study are positioned in Section 3. The utilized mathematical equations are presented in Section 4. The acquired results are presented in Section 5 followed by the last section of summary conclusion and up to date cited references from high ranked journals.

Case study

A power crisis has afflicted Libya on a continual basis mainly because of problems of electricity generation and supply [7]. The General Electric Company of Libya (GECoL), which manages the electrical power production in Libya, is a state-owned enterprise with financial and administrative independence. However, over the years, GECoL has fallen short in meeting rising electricity demand, especially in summer months when massive cooling load from air conditioners exert further pressure on the system. The power plants have decreased efficiency in electricity generation and the transmission facilities have aged [8]. The problems are more pronounced in rural areas of Libya like ALBrega where grid technical failures are commonplace and unreliable transmission lines dominate [9]. Furthermore, all of Libya's power generation relies on fossil fuels, which increases environmental pollution and greenhouse gas emissions. Fossil fuels utilization is becoming problematic due to international action on climate change and carbon emissions [8].

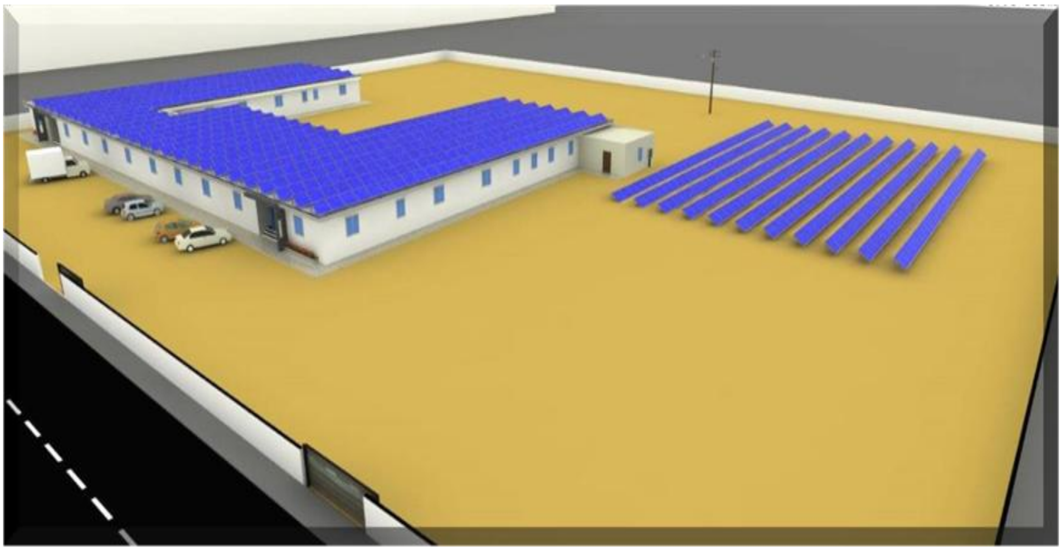


Figure 1: Building at AL Brega Clinic with the Anticipated PV System.

Table 1: Libyan power plants.

Power plants name	Units	The unit's installed capacity in megawatts	Station installed capacity in megawatts	Operation Date
Al Zaouia	5	165	1440	2000
	2	165		2005
	3	150		2007
Misurata	2	285	570	2010
Western Mountain	4	156	936	2005
	1	156		2010
	1	156		2012
South of Tripoli	5	100	500	1994
West of Tripoli	4	65	500	1976
	2	120		1982
North Benghazi	3	150	915	1995
	1	165		2002
	2	150		2007
Al Zuwetina	4	285	1140	1980
Darna	2	60	120	1982
Tobruk	2	60	120	1982
Khams Steam	4	130	520	1980
Khams Gaseous	4	160	640	1990
Abu Khammash	3	25	75	1980
Al Kufra	2	25	50	2008
North Benghazi	2	280	810	2009
	1	250		2012
Al sarir	3	250	750	2010

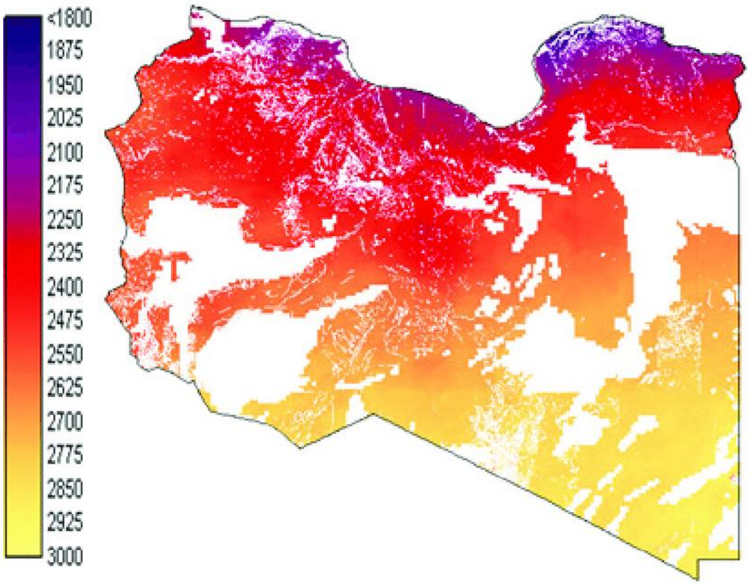


Figure 2: Libya's rate of solar radiation

Stand-alone solar systems operate independently of the public electricity grid [10]. This system needs batteries to store the electrical energy produced in more than the demand and will be utilized at night or during other periods when demand outpaces supply [11]. A crucial component characteristic that sets a Stand-alone system apart from a grid-tied one is energy storage. If the sun vanishes behind thick clouds for a long period or at night, sometimes a backup generator is used.

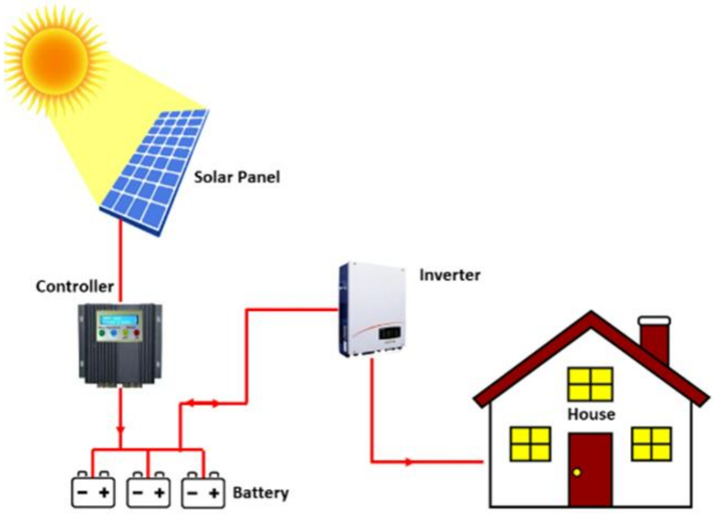


Figure 3: Off-grid system

The merits' and drawbacks of solar systems can be considered in the study as in the subsection below.

1.1 Advantages of PV solar system.

1. Renewable, limitless, and sustainable, solar energy is a natural energy source that can be used to power vehicles, heat water, and light up houses, among other things [12].

2. After initial installation, solar PV systems typically just need occasional cleaning, making them comparatively minimal maintenance.

3. If necessary, the extra electricity that the building is not utilizing for extended periods like during vacations can be sold to the service providers.

4. One-time investment in the purchase starts yielding returns immediately and eventually is highly cost-effective.

5. When utilized as a principal energy source, solar energy is a clean, pollution-free energy source that guarantees a decrease in greenhouse gas emissions. Furthermore, when operating, photovoltaic panels don't damage the environment in any other way. (For instance, wind turbine flashing and noise).

1.2 The drawbacks of photovoltaic systems.

1. The primary shortcoming of solar power is the installation price. While it has become increasingly cost-competitive, as described above, the panels themselves are still relatively expensive, making it unaffordable for many individual and organization users who do not have long-term budget allocation resources.

2. The batteries are charged by solar power so that at nighttime, the devices powered by solar energy can be used; these batteries are large, heavy, and require much storage space. They also need a replacement from time to time.

3. Solar panels are huge and take up considerable space; some roofs might be small to fit in the number of solar panels one would need.

4. Weather, for example, Rainy and overcast weather can have an impact on how much sunshine reaches the solar panels and how much energy is stored. The only way to overcome this difficulty is to save enough of it during the day to be used at night.

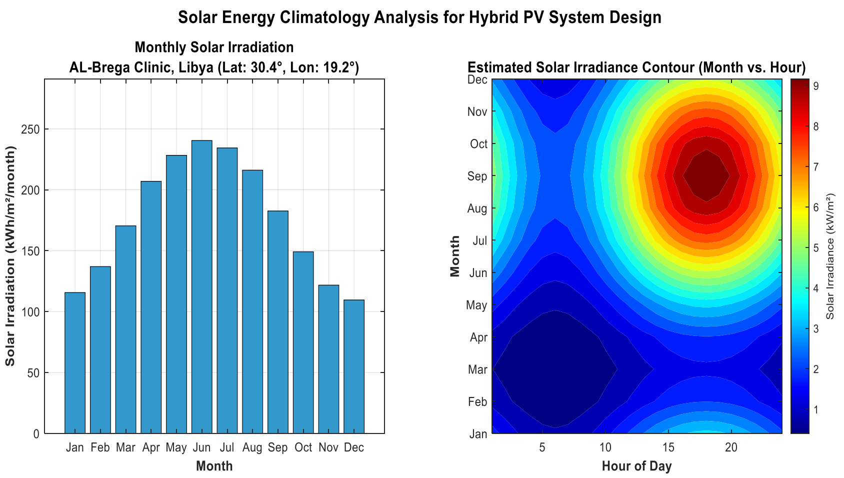
Methodology

This section outlines the process for using the Excel/PVsyst software system to assess the PV system [13]. The solar PV system is simulated, and models are created in this study. run to energize ABC. The sample showing different solar power plants, electrical transformers, space needed and all to make a decision and all for the project's process's success. The Libyan Ministry of Health provided it, which supervises ABC, by collecting wall as well as accessible land region outside the Clinic, and electricity data were collected from the General Electricity Company of Libya.

But before, for such particulars it's important to analyze the varied components feasible for this, System principles, clinic consumption, modeling approach, Weather, temperature, PV System type, site annual solar irradiation determination, area determination of solar panel, inverter determination, operation and extra info utilization including battery description.

This study employs a simulation-based methodology to design and evaluate the hybrid PV system for the AL-Brega Clinic. The process involves:

1. **Data Collection:** Gathering clinic energy consumption data from GECoL and site specifics (roof/land area) from the Libyan Ministry of Health [14]. Table 3 shows the average daily temperature and solar radiation at the Clinic location as further plotted in Figure 4. One of the reasons this program receives attention is because of the extremely accurate outcomes.



2.

3. **Figure 4:** Solar energy climatology analysis for hybrid PV system design.

Table 2: Daily electricity requirements for the Al Brega clinic

Equipment	Power requirement (kw)	Duration (h)	Consumption (kWh/day)
Orthopedic room	5	7	35
Shelter	4	24	96
Laboratory analysis	5	24	120
blood bank	3	24	72
Dental Clinic	18	10	180
X-ray room	80	9	720
Internal medicine clinic	4	8	32
Emergency department	7	24	168
Operating room	20	7	140
Recovery room	8	8	64
Air conditioning	18	10	180
Lighting	4	4	16
Meeting hall	2	2	4
Other devices	4	4	16
Total	182		1843

Table 3: Monthly averages for temperature and solar radiation

Month	Global Irradiation kWh/m^2./day	Temperature (°C)
January	3.16	11.8
February	4.09	12.9
March	5.15	17.3
April	5.87	20.9
May	6.52	24.9
June	7.20	26.9
July	7.41	28.5
August	6.71	28.6
September	5.63	26.8
October	4.37	23.5
November	3.50	18.1
December	2.69	13.4

4. **System Sizing & Preliminary Design:** Using Microsoft Excel for initial calculations of energy demand, PV array sizing, inverter selection, and battery storage requirements based on load profiles for PV system model that shown in Figure 5.

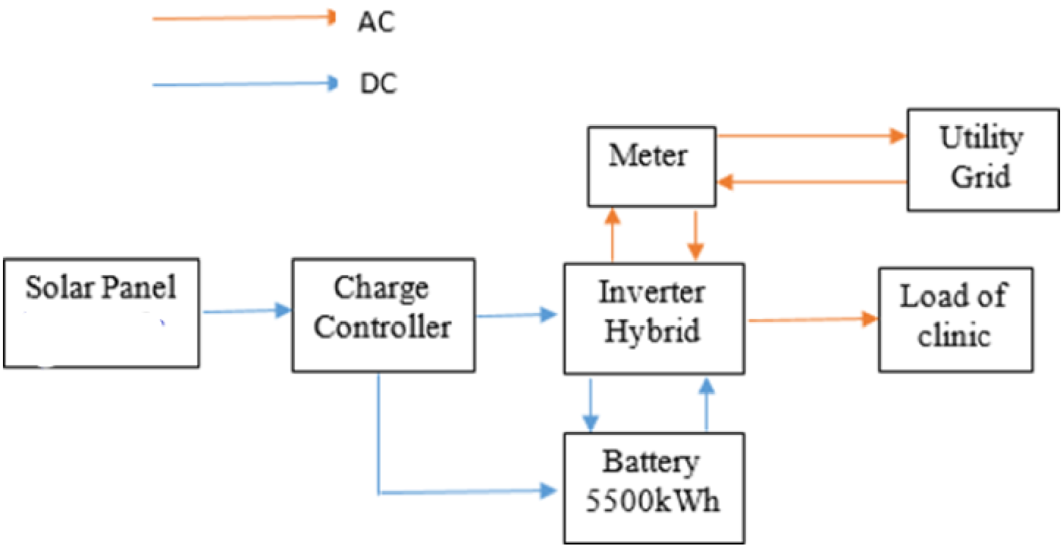


Figure 5: PV System Model.

Mathematical model equations

1. PV

where P_{STC} is power under standard test conditions, G is solar irradiance, k is temperature coefficient, and T_{Cell} is cell temperature [15].

$$P_{PV} = P_{STC} * \left({}^{G}/_{G_{STC}} \right) * \left(1 - K(T_{Cell} - T_{STC})\right) \quad (1)$$

2. BT

The battery is considered to store energy for night time and used when needed. The energy balance that BT made can be calculated in Eq. (2) with the help of Eq. (3) [16].

$$Hourly\ Energy\ From\ PV(kWh)\ -\ Load\ required\ (kWh)\ \rightarrow\ (one)\ Energy\ Balance \quad (2)$$

for charging, considering efficiency (η) and self-discharge (σ).

.

Autonomy (hours) = (Total Battery Capacity * DoD) / Average Daily Load. (3)

To transform the DC electricity generated by the solar panels into AC power with the appropriate frequency and voltage which is needed to meet the requirements of the local grid network a grid-tie solar inverter was selected, taking into consideration that this is the foundation of modern grid technology [17]. In addition, the selection of inverter was carried out to find a fit for PV array output, to ensure safe and efficient operation. Basic conditions have been considered to achieve the synchronization process: The Siemens PV2000 was the sole inverter utilized in this investigation. Its attributes are listed in Table 4. Additionally, the Specification of System Components are tabulated in Table 5.

Table 4: Features of the inverter.

Input Dc		*Output Ac*	
Maximum MPP voltage	1500V	Grid voltage	450V
Minimum MPP voltage	802V	Nominal AC power	2000kW
Absolute max. PV voltage	1500V	Maximum AC power	2000kW
Maximum PV power	4000kW	Maximum AC current	2100
Maximum PV current	3200 A	Frequency	50-60Hz
		Type	Triphase
		Efficiency	98.77%

Table 5: Specification of System Components [18].

Component	Parameter	Value
PV Module	Type	Monocrystalline Silicon
	Peak Power (Pmax)	550 W
	Efficiency	21.5%
Inverter	Capacity	100 kW
	Efficiency	98%
Battery	Type	Lithium-Ion
	Total Capacity	500 kWh
	Depth of Discharge (DoD)	80%

Results and Discussion

Th PVsyst software performs the process of obtaining solar radiation. This was chosen in order to acquire extensive geographical data related to daily, monthly, and hourly solar radiation incidents on the Clinic location.

1.3 Solar Resource and System Layout:

The optimal tilt angle for the PV array at the AL-Brega site was determined to be 30°, aligned with findings from similar climates. Figure 6 illustrates the annual solar irradiation at the site, showing high potential, especially during summer months.

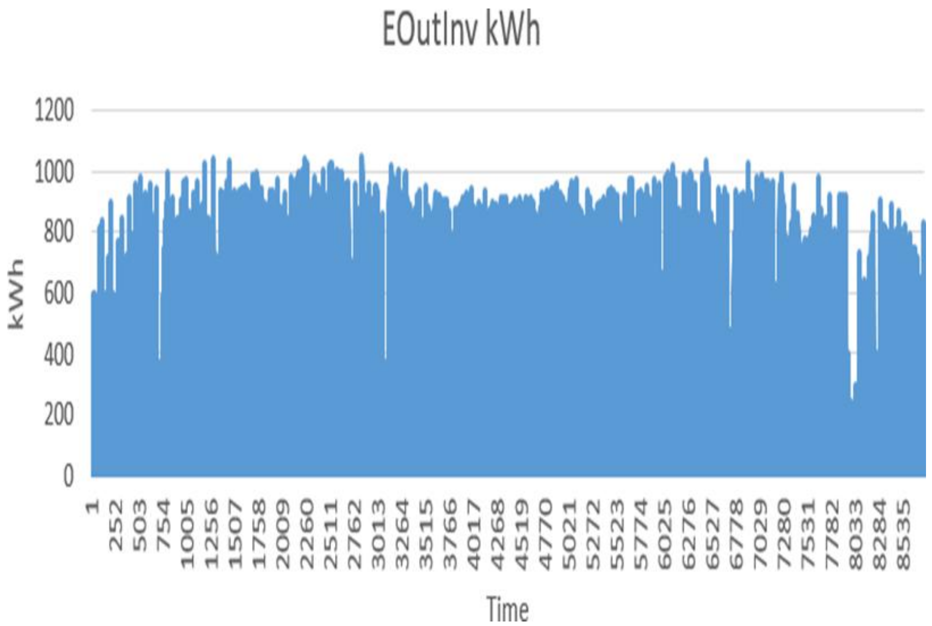


Figure 6: Hourly 0utput power of the PV system

1.4 Energy Production and Consumption:

The simulated PV system yields an annual energy production of **3046 MWh**, significantly exceeding the clinic's annual consumption of 673.232 MWh. The surplus energy (~2373 MWh/year) could potentially supply approximately 160 nearby households, highlighting the system's capacity to support community energy needs.

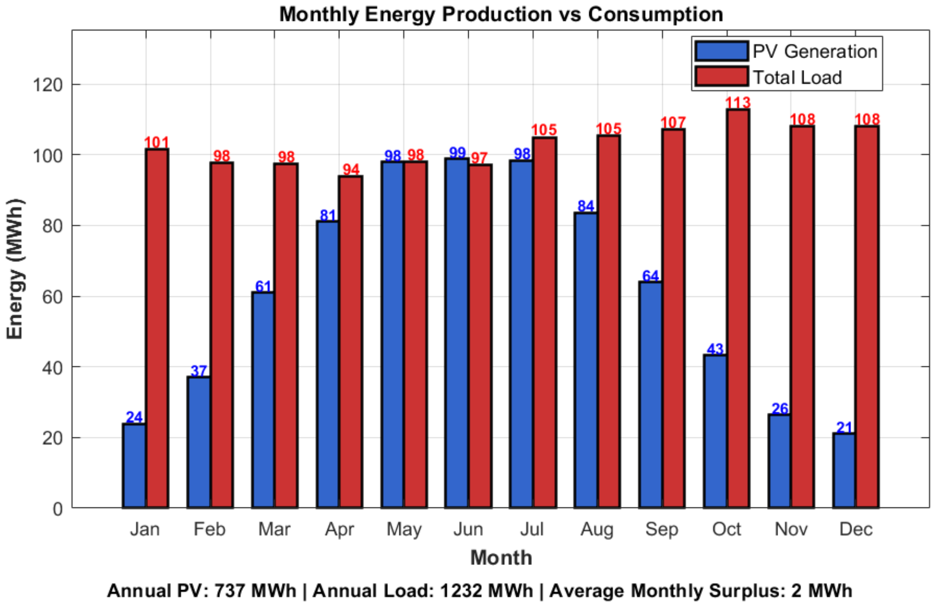


Figure 7: Monthly energy production vs consumption.

1.5 Economic and Environmental Analysis:

The Levelized Cost of Energy (LCOE) was calculated for two financing scenarios, resulting in LYD 0.0695/kWh and LYD 0.1511/kWh. The payback period, based on offsetting crude oil consumption (estimated at 2.021 barrels per MWh displaced), is approximately 16 years. The project would mitigate an estimated 66,542 tonnes of CO_2 annually.

Conclusion

This study demonstrates that a hybrid solar PV system is a technically and economically viable solution to ensure reliable power for the AL-Brega Clinic in Libya. The proposed system exceeds the clinic's demand, producing a significant surplus that could power approximately 160 homes. This would enhance local energy resilience and reduce CO_2 emissions by an estimated 66,542 tonnes annually. The financial analysis indicates a payback period of about 16 years.

The research is set against the backdrop of Libya's critical energy challenges, where 95% of electricity relies on fossil fuels, leading to frequent blackouts that endanger vital services like healthcare. The study argues that decentralizing renewable energy, particularly in rural areas, is essential to diversify the economy, reduce grid strain, and improve the country's environmental standing.

For future work, the integration of solar tracking systems could boost energy yield by 20-25%. Expanding this model to design a solar microgrid capable of powering an entire small town is a promising direction for further research, highlighting Libya's significant potential for large-scale solar installations.

References

[1] J. Li, P. Liu, and Z. Li, "Optimal design and techno-economic analysis of a solar-wind-biomass off-grid hybrid power system for remote rural electrification: A case study of west China," Energy, vol. 208, p. 118387, Oct. 2020, doi: 10.1016/j.energy.2020.118387.

[2] A. Elbaz and M. T. Güneşer, "Optimal Sizing of a Renewable Energy Hybrid System in Libya Using Integrated Crow and Particle Swarm Algorithms," Adv. Sci. Technol. Eng. Syst. J., vol. 6, no. 1, pp. 264–268, Jan. 2020, doi: 10.25046/aj060130.

[3] A. Alsharif, C. W. Tan, R. Ayop, K. Y. Lau, and C. L. Toh, "Sizing of Photovoltaic Wind Battery system integrated with Vehicle-to-Grid using Cuckoo Search Algorithm," in 2021 IEEE Conference on Energy Conversion (CENCON), IEEE, Oct. 2021, pp. 22–27. doi: 10.1109/CENCON51869.2021.9627291.

[4] N. A. Fadhil, M. Elmnifi, O. D. . Abdulrazig, and L. J. Habeeb, "Design and modeling of hybrid photovoltaic micro-hydro power for Al-Bakur road lighting: A case study," in Materials Today: Proceedings, Elsevier Ltd, Nov. 2021, pp. 2851–2857. doi: 10.1016/j.matpr.2021.10.072.

[5] M. M. Elsokah and A. R. Zerek, "Design and development Intelligent Medical Care Bed Using Voice Recognition," in 2022 IEEE 2nd International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering, MI-STA 2022 - Proceeding, 2022, pp. 299–304. doi: 10.1109/MI-STA54861.2022.9837521.

[6] A. Alsharif and Aisha Douma; Abdussalam Ali Ahmed; Abdulgader Alsharif; Mohamed Belrzaeg, "Application of Artificial Neural Networks Technology for Handwritten Arabic Letters Recognition," Int. J. Emerg. Trends Eng. Res., vol. 10, no. 2, pp. 123–127, Feb. 2022, doi: 10.30534/ijeter/2022/161022022.

[7] Y. Kassem, H. Çamur, and R. A. F. Aateg, "Exploring Solar and Wind Energy as a Power Generation Source for Solving the Electricity Crisis in Libya," Energies, vol. 13, no. 14, p. 3708, Jul. 2020, doi: 10.3390/en13143708.

[8] M. A. Sharif, M. Hossin, and S. A. Al-Hashmi, "Simulation and optimization of a Concentrating Solar Power Plant with Thermal Energy Storage in Sebha city by using system advisor model (SAM)," J. Pure Appl. Sci., vol. 20, no. 4, pp. 125–131, 2021, doi: 10.51984/jopas.v20i4.1718.

[9] A. A. M. Almabrouk, O. M. Hebala, and S. M. El Safty, "Improvement of Voltage Profile in Libyan Transmission Network Using Particle Swarm Optimization Technique," in 2022 IEEE 2nd International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering, MI-STA 2022 - Proceeding, 2022, pp. 780–785. doi: 10.1109/MI-STA54861.2022.9837496.

[10] M. E. T. Souza Junior and L. C. G. Freitas, "Power Electronics for Modern Sustainable Power Systems: Distributed Generation, Microgrids and Smart Grids—A Review," Sustainability, vol. 14, no. 6, p. 3597, Mar. 2022, doi: 10.3390/su14063597.

[11] 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.

[12] 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.

[13] R. Maruthi Prasad and A. Krishnamoorthy, "Design validation and analysis of the drive range enhancement and battery bank deration in electric vehicle integrated with split power solar source," Energy, vol. 172, pp. 106–116, Apr. 2019, doi: 10.1016/j.energy.2019.01.116.

[14] Walid Alsuessi, "General Electric Company of Libya (GECOL)," Eur. Int. J. Sci. Technol., vol. 4, no. 1, pp. 61–69, 2015, [Online]. Available: www.eijst.org.uk

[15] I. Imbayah, M. Hasan, H. El-Khozondare, M. Khaleel, A. Alsharif, and A. Ahmed, "Review paper on Green Hydrogen Production, Storage, and Utilization Techniques in Libya," Sol. Energy Sustain. Dev. J., vol. 13, no. 1, pp. 1–21, Feb. 2024, doi: 10.51646/jsesd.v13i1.165.

[16] K. El Harouri et al., "Grid-Connected Plug-in Electric Vehicles Charging Stations Energy Management and Control," Int. J. Energy Convers., vol. 7, no. 2, p. 49, Mar. 2019, doi: 10.15866/irecon.v7i2.17001.

[17] 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., vol. 295, p. 126070, 2021, doi: 10.1016/j.jclepro.2021.126070.

[18] Y. F. Nassar, H. J. El-Khozondar, S. Y. Alsadi, N. M. Abuhamoud, and G. M. Miskeen, "Atlas of PV Solar Systems Across Libyan Territory," Proc. - 2022 Int. Conf. Eng. MIS, ICEMIS 2022, pp. 1–6, 2022, doi: 10.1109/ICEMIS56295.2022.9914355.