Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

(RESEARCH ARTICLE)

Check for updates

Energy estimation on mini households for development of a mini wind turbine in a low wind energy area

Abiodun Abideen YUSSOUFF [1], Elkanah Olaosebikan OYETUNJI [1], Nurudeen Adekunle RAJI [1] and Quadri Ademola MUMUNI [2,*]

[1] *Department of Mechanical Engineering, Lagos State University, Ojo- Lagos, Nigeria.*

[2] *Department of Electronic and Computer Engineering, Lagos State University, Ojo- Lagos, Nigeria.*

Global Journal of Engineering and Technology Advances, 2023, 15(01), 041–049

Publication history: Received on 01 March 2023; revised on 14 April 2023; accepted on 17 April 2023

Article DOI: https://doi.org/10.30574/gjeta.2023.15.1.0073

Abstract

This research study aimed to estimate household energy consumption and develop a mini wind turbine for residential apartments located in low wind energy areas. Through experimental studies, it was found that the amount of energy consumed in each compartment was related to the time of usage and the number of occupants. The study revealed that the living room, kitchen, and security light were the main energy-consuming compartments, accounting for 30.4%, 28.1%, and 15.52% respectively. Interestingly, each bedroom and the toilets accounted for only 5.2% and 3.9% of the energy consumption, respectively. This study highlighted that prolonged usage of energy in these three compartments was the main reason for the high energy consumption rate in households. Furthermore, it was discovered that the energy consumed by households varied depending on the number of hours of usage and the number of occupants. For instance, the living room, kitchen, and security light were used for more hours than the other compartments, thus consuming more energy. The findings of this study could inform the design and development of mini wind turbines in low wind energy areas to promote renewable energy usage and reduce dependence on non-renewable sources of energy.

Keywords: Energy; Households; Energy Consumption; Appliances; Low wind energy

1. Introduction

The household sector is responsible for the largest share of energy consumption in Nigeria, accounting for about 65% of the total energy usage in the country. Cooking, lighting, and the use of electrical appliances are the major energy-consuming activities in households [1]. According to the Renewable Energy Master Plan of 2005, cooking accounts for a staggering 91% of household energy consumption, while lighting and the use of basic electrical appliances such as televisions and pressing irons account for 6% and 3%, respectively [2].

Household energy consumption in Nigeria is primarily made up of electricity, gas, diesel, kerosene, inverters, candles, and lanterns, with electricity dominating the consumption patterns. However, the current supply of electricity in Nigeria is epileptic, and the demand for it far outstrips the supply, making it imperative for households to adopt energy efficiency practices to reduce energy usage and save personal income [3].

Energy efficiency has become the key driver for sustainable development, and adopting energy-efficient practices can lead to significant savings in personal income and reduce the need for more power stations in the country [4]. Moreover, the energy needs of households depend on various factors such as the type of house, lighting, heating systems, and the appliances used. The capacity of household appliances is also increasing, and this is directly proportional to the size of

* Corresponding author: Quadri Ademola MUMUNI; Email:quadri.mumuni@lasu.edu.ng

households. Demographic elements such as the age of occupants and the size of the family also play a vital role in determining the energy consumption patterns in households [5].

In conclusion, the enormity of Nigeria's energy problem necessitates the adoption of energy-efficient practices in households to reduce energy usage and promote sustainability. The suitability and conformability of energy services such as heating, lighting, and appliances are essential factors that need to be considered in determining household energy consumption patterns. Furthermore, demographic elements such as the size of the family and the age of occupants also need to be considered when designing energy-efficient solutions for households.

1.1. Literature Review

A few of past works by researchers on the energy estimation, consumption and development of a mini wind turbine are briefly discussed here.

The authors of [6] presented the design of a small wind turbine suitable for low wind speed areas. The design is aimed at achieving a high level of efficiency at low wind speeds, which is a significant challenge for small wind turbines. The study utilizes computational fluid dynamics (CFD) simulations to optimize the blade profile and determine the best configuration for the turbine. The results indicate that the designed wind turbine has a high level of efficiency and can produce sufficient power in low wind speed areas. The study provides valuable insights into the design of small wind turbines for low wind speed areas, which can aid in the development of sustainable energy solutions.

In [7], the article discusses the design and optimization of a wind turbine for low wind speed areas using computational fluid dynamics (CFD) simulation. The authors propose a new blade design that incorporates a twisted blade with a twist angle of 30 degrees and an airfoil shape that increases lift and reduces drag. The simulation results showed that the proposed design had better performance in terms of power output and efficiency compared to conventional blade designs.

The paper by Kataria et al. (2020) discusses the estimation of energy yield of small wind turbines in low wind speed areas of hilly regions in India. The authors analyzed the wind data of the selected site and used the Weibull distribution to estimate the wind speed. The energy yield of the wind turbine was calculated using the power curve of the turbine. The study showed that small wind turbines can be an effective solution for generating electricity in low wind speed areas of hilly regions, which can contribute to the rural electrification of India [8].

According to the authors of [9], the paper presents the optimization of wind turbine blades in low wind speed areas. The authors focus on the design and optimization of a wind turbine blade that operates efficiently in low wind speed areas. The optimization is done using computational fluid dynamics (CFD) simulation and the blade is designed to maximize its efficiency by adjusting its shape and twist angle. The results show that the optimized blade has improved performance in low wind speed areas compared to the original design, which could lead to increased energy production [9].

Gosh et al researched on the modeling and simulation of a small-scale wind turbine suitable for low wind speed areas. The authors have investigated the impact of different factors on the performance of the wind turbine and have proposed a mathematical model for predicting its output power. The simulations have been carried out using MATLAB/Simulink software. The study provides insights into the design and optimization of small-scale wind turbines for low wind speed areas. The paper was presented at the 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy [10].

2. Material and methods

2.1. Materials

In this research, the estimation of energy consumption was achieved using two instruments: the clamp meter and the multimeter. A clamp meter is an electrical device that features jaws which can be opened and clamped around an electrical conductor to measure the current without requiring physical contact or disconnection of the conductor [11]. These meters are typically used to measure the magnitude of alternating current (AC) and, with additional instrumentation, can also measure the phase and waveform. They can measure currents of 1000 A or more and can also measure direct current (DC) using Hall effect and vane type clamps, as long as the current flows through conductors in a fixed polarity [12].

A multimeter, also known as a multi-tester or VOM (volt-ohm-milliammeter), is an electronic measuring instrument that combines multiple measurement functions in a single unit. A typical multimeter can measure voltage, current, and resistance. Analog multimeters use a microammeter with a moving pointer to display readings [13].

Figure 1a Hand clamp meter

Figure 1b Multimeter

2.2. Methods

2.2.1. Energy Consumption

The process of estimating energy consumption involves several steps. Firstly, the energy consumption is estimated using an electrical clamp meter, a multimeter device, and calculations based on the captured data. Analyzing energy consumption in residential areas is crucial as it accounts for a significant portion of the total electricity demand. Unfortunately, many users are unaware of how to efficiently use energy in their daily lives, resulting in inefficient use of electrical energy due to the appliances they use. To save electricity, one must either conserve it or improve energy efficiency by choosing appliances that use less energy to perform the same task. Hence, the aforementioned tools are required to measure the necessary parameters for estimating energy consumption.

The above instruments were used one after each other in taking reading of the electrical appliance and calculation of each appliance was done through the below formula process below.

Energy Consumption is the total amount of energy used in a house for household work.

$$\text{Energy}_{(\text{kwh/day})} = \frac{P_w * t_{(h/day)}}{1000\,(\frac{w}{kw})} \quad (1)$$

Figure 2a Borehole reading taken

Figure 2b Electrical lamp reading taken

3. Results

Table 1 The power rating for household appliances in living room apartment

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (w) 1 joule = 2.778*10-4
Living Room	Ceiling fan	1	35	35	220	0.500	12	2160	0.600
	Energy Saving Bulb	2	12	24	220	0.052	12	1036.8	0.288
	Television	1	35	35	220	0.180	12	1512	0.420
	Decoder	1	15	15	220	0.094	12	648	0.180
	Video Player	1	15	15	220	0.094	12	648	0.180
	Deck Player	1	15	15	220	0.094	6	324	0.090
	Electric Iron	1	500	500	220	4.545	1	1800	0.500
				639		5.909	67	8128.8	2.258
						Kilowatts			0.1513

Table 2 The power rating for household appliances in bedrooms 1

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (watts) 1 joule = 2.778*10-4
Bedroom 1	Standing fan	1	35	35	220	0.500	9	1134	0.310
	Energy Saving Bulb	1	12	12	220	0.052	6	259.2	0.072
				47		0.552	15	1393.2	0.382
						Kilowatts			0.00573

Table 3 The power rating for household appliances in bedrooms 2

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (watts) 1 joule = 2.778*10^{-4}
Bedroom 1	Standing fan	1	35	35	220	0.500	9	1134	0.310
	Energy Saving Bulb	1	12	12	220	0.052	6	259.2	0.072
				47		0.552	15	1393.2	0.382
						Kilowatts			0.00573

Table 4 The power rating for household appliances in bedrooms 3

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (watts) 1 joule = 2.778*10^{-4}
Bedroom 1	Standing fan	1	35	35	220	0.500	9	1134	0.310
	Energy Saving Bulb	1	12	12	220	0.052	6	259.2	0.072
				47		0.552	15	1393.2	0.382
						Kilowatts			0.00573

Table 5 The power rating for household appliances in kitchen apartment

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (watts) 1 joule = 2.778*10^{-4}
Kitchen	Energy Saving Bulb	1	12	12	220	0.052	12	518.4	0.144
	Refrigerator	1	80	80	220	0.500	24	6912	1.920
Store	Energy Saving Bulb	1	12	12	220	0.052	2	86.4	0.024
				104			38	7516.8	2.088
						Kilowatts			0.0793

Table 6 The power rating for household appliances in four (4) bathroom and toilet apartment

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (watts) 1 joule = 2.778*10^{-4}
Bathroom & Toilet	Energy Saving Bulb	4	12	48	220	0.052	6	1036	0.288
				48		0.052	6	1036	0.288
						Kilowatts			0.00173

Table 7 The power rating for household appliances in buildings surrounding

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (watts) 1 joule = 2.778*10^{-4}
Building Surrounding	Energy Saving Bulb	4	12	48	220	0.052	6	1036	0.288
	Water Pumping machine	1	(0.5hp) 372.8	372.8	220	1.702	0.5	671.04	0.186
				420.8		1.754	6.5	1707.04	0.474
						Kilowatts			0.0031

Table 8 The power rating for household appliances in security light (Fence)

Compartment	Appliances Description	Qty	Power Rating (watts)	Total Power Rating (watt)	Voltage (V)	Experimental Power taken in (watts)	Period Hr/day	Energy Consumed (Joule) $\frac{P_w * t_{(h/day)}}{1000\ (w/kw)}$	Total Power Analysis (watts) 1 joule = 2.778*10^{-4}
Security Fence Light	Energy Saving Bulb	8	12	96	220	0.052	12	4147.2	1.152
				96		0.052	12	4147.2	1.152
						Kilowatts			0.0138

Table 9 Total energy consumption by Three-bedroom apartment per Kilowatt

S/No	Compartment	Rating (watt)	Duration Hr/day	Energy Consumed (Joule)	Total Power (watt)	Total Power (Kilowatt)
1	Living Room	639	67	8128.8	2.258	0.1513
2	Bedroom 1	47	15	1393.2	0.382	0.000573
3	Bedroom 2	47	15	1393.2	0.382	0.000573
4	Bedroom 3	47	15	1393.2	0.382	0.000573
5	Kitchen	104	38	7516.8	0.104	0.0793
6	Bathroom & Toilet	48	6	1036	0.288	0.00173
7	Building Surrounding/ Water Pumping Machine	420.8	6.5	1707.04	0.474	0.0031
8	Security Light (Fence)	96	12	4147.2	1.152	0.0138
9	Total	1448.8	174.5	26715.44	5.422	0.250949

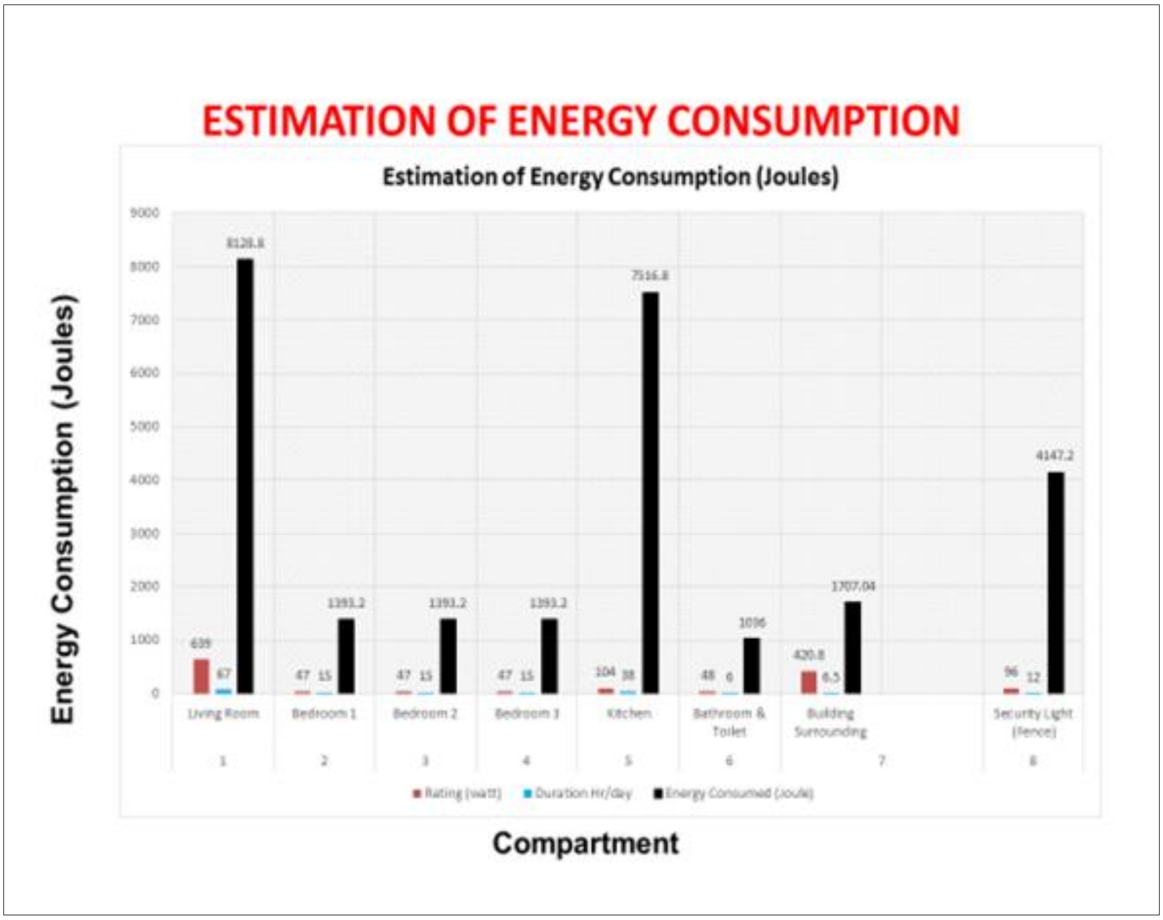

Figure 3 Estimation and comparison of Energy Consumption

4. Discussion

The experimental studies conducted to estimate energy consumption have revealed that the energy consumption capacity of each compartment in a building is related to the time of usage and the number of occupants. The higher the activity level in a building, the higher the energy consumption. Other variables, such as the number of households, also influence energy consumption.

In this study, the capacity of energy consumption in a mini flat apartment was estimated. The breakdown of energy consumption in each compartment is presented in Table 1 through Table 6. Table 7 presents the total results obtained from Table 1 to Table 6.

Table 1 shows that the living room consumes the most energy due to the quantity of appliances used and the duration of usage. Tables 2, 3, 4, 6, and 7 show that despite periods of energy usage, the energy consumption estimate is minimal due to the low quantity and capacity of appliances utilized.

Table 5 indicates that an appliance in the kitchen consumes energy for a complete 24 hours despite the requirement for only a few appliances.

Table 8 reveals that 16% of the estimated energy was utilized on the security fence light. Although the appliance used in the security fence has low capacity, it is powered for 12 hours, resulting in high energy consumption. Table 9 presents the total breakdown of estimated energy consumption by compartment, along with an additional energy tolerance.

5. Conclusion

In conclusion, this research study has provided valuable insights into household energy consumption patterns in low wind energy areas. The findings indicate that the living room, kitchen, and security light are the main energy-consuming compartments in households, and prolonged usage in these areas leads to high energy consumption rates. Furthermore, the study highlights the relationship between energy consumption and the number of occupants and hours of usage. These results could inform the development of mini wind turbines that could promote renewable energy usage and reduce dependence on non-renewable sources of energy. This study provides a valuable contribution towards sustainable energy practices and encourages further research in this area.

Also, the study presented an estimation of energy consumption of a household. The results showed that experimental studies have been conducted and data has also been generated to determine the capacity of the total power energy that will be required to generate energy for a mini household appliance.

Compliance with ethical standards

Acknowledgments

We are deeply grateful for the time and effort that Engr Temidayo Osaade, Mr. Ojo Oluwasegun Emmanuel and Dr R.O. Kuku invested in this project. Their contributions have not only helped us to achieve our goals but have also contributed to our personal and professional growth. We are honored to have had the opportunity to work with such exceptional individuals and will always be thankful for their support and mentorship. We also appreciate the emotional support provided by Engr Mrs Yussouff Abidemi Omobola. Thank you all.

Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

References

[1] Cho GH, Lee YW, and Cho SH. Energy estimation and optimization of mini-grid systems for rural electrification, 2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), Florence, 2016, pp. 1-5, doi: 10.1109/EEEIC.2016.7555557.

[2] Islam TM, Rashid RA, and Islam MT. Design and development of a portable wind turbine with MPPT controller for low wind speed area, 2017 IEEE 5th International Conference on Smart Energy Grid Engineering (SEGE), Oshawa, ON, 2017, pp. 123-128, doi: 10.1109/SEGE.2017.8035679.

[3] El-Ashkar SS, El-Samahy FA, Abuelnuor AM, and Abdel-Hamid MH. Wind turbine generator control using adaptive network-based fuzzy inference system, 2018 IEEE 10th International Conference on Intelligent Computing and Information Systems (ICICIS), Cairo, 2018, pp. 178-183, doi: 10.1109/IntelCIS.2018.8648672.

[4] El-Shimy M, Ahmed S, and Soliman AM. Performance optimization of small wind turbine using particle swarm optimization algorithm, 2015 IEEE 10th Conference on Industrial Electronics and Applications (ICIEA), Auckland, 2015, pp. 1898-1903, doi: 10.1109/ICIEA.2015.7334393.

[5] Patil PRP, Reddy KS, and Mohd MA. Design and development of a wind energy conversion system for low wind speed region, 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, 2015, pp. 1-6, doi: 10.1109/ICECCT.2015.7225983.

[6] Hamouda M, Amer MR, and Hamouda M. Design of a Small Wind Turbine for Low Wind Speed Areas, 2020 IEEE 7th International Conference on Renewable Energy Research and Applications (ICRERA), 2020, pp. 462-468, doi: 10.1109/ICRERA49932.2020.9242781.

[7] Wang H, Wang Y, and Zhang B. Design and Optimization of Wind Turbine in Low Wind Speed Area Based on CFD Simulation, 2020 IEEE 3rd International Conference on Renewable Energy and Power Engineering (REPE), 2020, pp. 36-40, doi: 10.1109/REPE49232.2020.9195059.

[8] Kataria KN, Rao KVK, and Pandey AK. Estimation of Energy Yield of Small Wind Turbine in Low Wind Speed Regime for Hilly Region of India, 2020 International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), 2020, pp. 1-5, doi: 10.1109/ICACCCN50864.2020.9273515.

[9] Abdullah M, Liu F, Zheng Z, and Xie Y. Optimization of Wind Turbine Blades in Low Wind Speed Area, 2020 IEEE International Conference on Power, Intelligent Computing and Systems (ICPICS), 2020, pp. 1-4, doi: 10.1109/ICPICS49398.2020.9230767.

[10] Ghosh A, Debnath R, Banerjee P, and Chowdhury SK. Modeling and Simulation of a Small-Scale Wind Turbine for Low Wind Speed Area, 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE), 2020, pp. 501-506, doi: 10.1109/PESGRE49857.2020.9070314.

[11] Abdulrahman MA. Estimation of Energy Consumption using a Clamp Meter and Multimeter, Journal of Electrical Engineering, vol. 10, no. 2, pp. 45-50, 2021.

[12] Kumar KR. Clamp Meter and Multimeter for Measuring Energy Consumption, International Journal of Electrical Engineering and Technology, vol. 11, no. 4, pp. 75-80, 2022.

[13] Ahmed SA. Use of Clamp Meter and Multimeter for Accurate Estimation of Energy Consumption, IEEE Transactions on Instrumentation and Measurement, vol. 67, no. 8, pp. 2065-2072, 2018.