ECONOMIC FEASIBILTY OF SOLAR POWERED STREET LIGHTING SYSTEM IN SOMALIA

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To my beloved parents, thank you.

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ABSTRACT

Somalia is one of the rising countries that has suffered from an energy crisis due to high electricity losses, less qualified workers and a lack of productivity. The main objective of this research is to evaluate the technological possibilities and benefits of using solar energy to power streetlights in Via the combination of light emitting diode (LED) lights and photovoltaic cells. The cost of purchasing the equipment and operating a solar powered/LED device is consistent with the cost of running grid-connected street lights using electricity. The aim of the project was on the feasibility of using solar energy to power street lights. The functions of design and simulation was achieved through the assistance of HOMER software, the simulation model provides the monthly electricity provided by grid-connected street lights and solar street lights, as well as the best technically feasible solar energy system that is less net present cost (NPC), system energy cost and higher fraction of renewable energy, providing the lowest COE of $0.295/kWh and the total net present cost (NPC) of US$40,03030. This work focuses on the domestic aspect and offers a feasibility analysis to use solar energy and LED lights to serve this purpose and to alleviate this enormous consumption of energy. Solar-powered LED lights create light with the same luminance as 250-watt sodium bulbs Although the initial cost of installing the solar street light is higher than the conventional street lights, the overall long-term effect is quietly remarkable. A research involving 40 lamps over a distance of 2 km showed that in addition to saving national electricity, solar street lights save 59 percent after 20 years of using solar street lights.

ABSTRAK

Somalia adalah salah satu negara berkembang yang mengalami krisis elektrik kerana kehilangan elektrik yang tinggi, kakitangan yang kurang terlatih serta kekurangan kecekapan. Tujuan utama penyelidikan ini adalah untuk menentukan kemungkinan teknikal dan faedah menggunakan tenaga suria melalui gabungan sel fotovoltaik dan lampu Diod Pemancar Cahaya (LED) untuk menyalakan lampu jalan di Bosaso. Kos yang terlibat dalam pembelian peralatan dan menyelenggara sistem bertenaga suria / LED dihubungkan dengan kos penggunaan elektrik untuk menjalankan lampu jalan yang disambungkan ke grid. Projek ini mendalami kelayakan menggunakan tenaga suria untuk menyalakan lampu bagi jalanraya. Tugas reka bentuk dan simulasi dicapai melalui bantuan perisian HOMER, model simulasi memberikan tenaga elektrik bulanan yang dihasilkan oleh lampu jalan bersambung dan lampu jalan solar, serta digunakan untuk mengetahui sistem tenaga suria yang layak secara teknikal terbaik iaitu kos bersih sekarang (NPC), kos tenaga sistem dan pecahan tenaga boleh diperbaharui yang lebih tinggi, sistem ini memberikan COE terendah $ 0,295 / kWh dan jumlah kos bersih sekarang (NPC) bernilai US $ 40,030. Kajian ini tertumpu pada aspek nasional dan memberikan kajian kemungkinan menggunakan tenaga suria dan lampu LED untuk memenuhi tujuan ini dan memberi kelegaan dari penggunaan tenaga yang besar ini. Lampu LED yang digerakkan dengan tenaga suria menghasilkan cahaya dengan pencahayaan yang sama dengan lampu natrium 250 watt. Walaupun kos awal penerapan lampu jalan suria lebih tinggi daripada lampu jalan tradisional, tetapi hasil akhirnya dalam jangka masa panjang adalah mengesankan. Kajian yang melibatkan 40 lampu untuk jarak jauh 2km menyimpulkan bahawa setelah 20 tahun penggunaan lampu jalan suria juga menjimatkan 59% selain menjimatkan tenaga elektrik negara.

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LIST OF SYMBOLS AND ABBREVIATIONS

PV	-	Photovoltaic
LED	-	Light emitting diode
IEA	-	International energy agency
GHG	-	Greenhouse gases
GDP	-	Gross domestic product
HPS	-	High pressure sodium
DOD	-	Discharge of depth
VRLA	-	Valve controlled lead acid
MPPT	-	Maximum power point tracking
BMS	-	Battery management system
CBA	-	Cost benefit analysis
NPV	-	Net present value
SLS	-	Street lighting system
NPC	-	Net present cost
COE	-	Cost of energy
KW	-	Killo-watt
PWM	-	Pulse width modulation

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Somalia is situated in East Africa. Since the collapse of Somalia's central government in 1991, power supply has been the competitive private sector of Somalia alone. The total installed generation capacity is around 106 megawatts (MW). Although most power companies rely on diesel generators to produce electricity, interest and investment are growing in hybrid systems that draw on this solar and wind energy resources. Solar power could theoretically produce more than 2000 kWh / m2. Just an estimated 16 per cent of the population has electricity access. Somalia has higher tariffs compared to neighbouring countries [1].

Somalia 's average solar radiation has increased dramatically in the last few years from about 2900 to 3000 sunshine hours per year. This would prompt higher utilization of scant energy Photovoltaic (PV) technology is a practical solution to various problems with power applications in rural areas as well as in the centre and large cities. One of PV's most common applications is standalone PV lighting systems. Because the use of energy-efficient lighting is significant factor in sustainability and end [2].

In particular, for street lighting and home energy systems, renewable energy is one of the solutions that could play a significant role. Solar operated LED street lighting systems have gained a great deal of popularity over the last couple of years. Several studies have shown that the LED street lighting system powered by solar energy is economically feasible and saves electricity. Solar-powered street lights as the source of electricity. Somalia's urban road lighting is planned to be replaced by more efficient light sources and solar photovoltaic modules for energy generation [3].

According to the chosen high-power LED, the solar-powered LED for street lighting requires a proper device design with adequately installed solar photovoltaic and battery capacity to meet street lighting requirements. An integral aspect of most facilities is street lighting. However, with regard to street lighting construction schemes, high maintenance costs, improper illumination levels and inefficient power are commonly encountered. Several factors such as street type, street width, pole height, the distance between poles, and the type of lamp being used affect the lighting quality of a specific street Street lighting with solar energy as the energy source is an alternative energy-saving alternative. The running cost of street lighting is cheap and economical because the electricity comes from the sun. Solar street lighting uses solar cell panels that absorb sunlight and turn it into energy through a photovoltaic process[4]. The lighting can run automatically, with lights that go on at night and go out in the morning, with quick and inexpensive maintenance. The solar powerhouse's street lighting itself consists of many elements, including solar cell panels, LED lamps, lamp posts and battery boxes.

The solar street light source comes from the sun's light, which is then absorbed by the solar cell panel. By transforming the sunlight into a DC current, which is then stored within the battery, the solar cell panel phase begins. There is a device that functions as an energy flow sensor before being placed in the battery, and this tool controls a system that operates on a popular solar street lighting called a controller. When the lights must be on and when the lights must be off, the controller is given periods when there is also a device that controls when the battery should be charged. For an LED lamp with 50,000 h of life, the lifespan of the solar cell panel is 25 years, if the lights are on for 12 h every day The lamp will then run for 11 years and this lifetime can be contrasted to traditional street lighting based on solar, which is still used by the State Electricity Utility. Until now, Solar street lighting has proven advantages over traditional street lighting, but weather limitations and high investment costs restrict the deployment of solar-powered public road lighting. Therefore, the use of solar-based public lighting will be studied in detail in this report, in particular on the viability of investment [5].

1.2 Problem Statement

Lighting uses more electricity in the world than any nuclear or hydropower facility (over 2200 TWh per year)[3]. Using the largest share of commercial and public buildings, lighting accounts for approximately 17.5 percent of global energy use, followed by residential lighting, industrial sector lighting and outdoor / street lighting. This level of use can be substantially reduced to the same level of lighting achieved by the inefficient use of lighting technology, the lack of sufficient power, the increased use of daylight and the reduction of energy waste due to broad differences in the level of lighting. Recommended address Referred address (IEA).

Every year, 1.9 billion tons of CO2 are expected to be produced. This is equal to 70% of the world's vehicles leaving (The Climate Group, 2012). Street lighting is a social system, a significant indicator of the socio-economic development status of a nation. This provides pedestrians and drivers with improved road protection, which can minimize criminal activity in cities. In order to enhance business and the environment of urban and peri-urban life, street lighting also plays an important role. Some roads are not sufficiently illuminated due to the lack of proper regulatory and organizational mechanisms for street lighting in Somalia and, if any, the rest are killed due to inadequate electricity sources. A large number of roads were organized in towns and cities, which cannot be achieved with the benefits of street lighting.

Somalia is looking for ways of diversifying its energy and supply networks. It is desirable to investigate, as part of this distinction, whether types of energy-efficient technology and other energy sources (not linked to the national grid) can be used to provide effective street lighting. The study could consider the performance of the industry in the lighting field, such as light-emitting diodes, (LEDs and the use of available solar energy in Somalia. In Somalia, illumination during peaks requires a lot of energy [1] During peak hours, electricity would be saved if streetlights were withdrawn from the grid. As solar street lights can be powered by energy-efficient technology, the national grid can be eliminated and the necessary advantages can be given by street lights. Energy efficiency does not require a compromise in occupant comfort - not at all. Using higher efficiency makes it possible to increase comfort while reducing energy consumption It was found that street lighting projects are cost effective investment in securing tomorrow’s energy at today’s prices as well as going a long way to offsetting the effect of global warming [6]

1.3 Objectives

The objectives of this research are:

- To design a Stand-alone solar street lighting
- To comprehend the cost involved for the installation and operation of conventional street lighting in Somalia
- To evaluate the cost involved for the installation and operation of LED street lighting in Somalia.

1.4 Scope of Study

- This research was conducted using the technical parameters of the PV powered streetlights compared to that of the Conventional streetlights and the cost of operation and maintenance.
- The results will be analysed the comparison between the grid-powered sodium lamp street lighting system and the solar powered LED
- Design and optimization using homer software
- To determine these project economic feasibility of the solar powered street lighting using LED luminaries 60W for 2 km in Bosaso, Somalia

1.5 Report outline

This project report consists of five main parts:

a) Chapter 1: Introduction

This chapter explains-the project's introduction. It also outlines the project's context. This is also the creation of the solar street lighting system based on HOMER software® with detailed details. Also, issue statement, project priorities, scope of work, and overview of reporting.

b) Chapter 2: Literature Review

This chapter fundamentally assesses and addresses earlier studies and results for this field and how this initiative is concerned. This also defines any enhancement starting with previous efforts to combine the target of this project.

c) Chapter 3: Methodology

This chapter focuses on result analysis and discussion based on optimization and sensitivity analysis also follows some discusses about simulation results obtained for achieving the least cost feasible options. battery sizing referred to given capacity power.

d) Chapter 4: Results and Discussion

This chapter focuses on the interpretation of outcomes and discussion based on optimization and sensitivity analysis, as well as some discussions on the results of simulation obtained to achieve the least cost-effective choices.

e) Chapter 5: Conclusion and Recommendation

This chapter A particular conclusion is drawn on the basis of the findings of the research and project. Recommendations and potential work were proposed at the end and

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Energy is one of the fundamental elements needed to alleviate poverty and foster a nation's socio-economic growth. This is because power drives all sectors of the economy, such as food, health, water, the atmosphere, etc. The fact that the use of energy resources by anthropogenic activities releases greenhouse gases is equally worthy of note (GHGs). GHGs emitted after energy consumption have been classified as carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (IPCC, 2007). The solar energy resource for energy is the sun. After installation, it is free and produces no GHG emissions. When discovered, the energy resource must be theoretically converted to a useful energy for the good of humanity. On the opposite, solar energy is often influenced by some obstacles, ranging from the availability of resources to policies to encourage it and make it economically attractive. a political.

A comparative study was performed in Nigeria on the economics of street lighting powered by public electricity and solar energy. was carried out by[7]; The outcome revealed that the initial cost of installing solar energy for independent street lighting is N 6,402/hr, which is more costly than using public electricity at a cost of N 2,508.9/h. However, such ventures are becoming feasible over a span of 20 years. The feasibility stresses the need to complement and ultimately replace the current traditional street lighting operated by public utility electricity Several studies have recently been performed on the feasibility of adding photovoltaic to the lighting

industry. [8]The concept of solar powered LED roadway lighting using high-power LED luminaires (100 W) was investigated and the installation cost calculated for a two-lane 10 km highway. Compared to the mercury lamp, this solar-powered LED roadway lighting device will save 75 per cent of lighting resources. The payback time for the entire lighting system's excess expenditure is 3.3 years for high-power
Rizaho, China, is a solar-powered city with LEDs. The majority of traffic signals and street lights are powered by photovoltaic, in addition to 99% of households in the central district. The achievement was the result of an unprecedented combination of three main factors: Among the city's leadership, a supportive government policy, local solar companies that grabbed the chance, and strong political will. Furthermore, the first to get the panels mounted were government buildings and city leaders' homes: [6] Ten solar powered grid connected street lamps were planned and installed by Solar Gen Solutions in 2003 in South Wales, UK mainland. Excess power generated by the device is sold back to other customers for use. Monitoring was performed of the annual energy supplied to the grid and the energy consumed. The goal of the project was to compare consumption savings with the projected rise of 35 percent.

2.2 Energy Background in Somalia

Somalia is a state situated in the horn of the African area because of the country's political strife since the mid 1991s and the nation's absence of local government has remained to a great extent immature. It likewise murders the nation's assets and, specifically, its power framework. In metropolitan places, power age is generally accessible and is nearly given by diesel generators. Diesel-fuelled generators are ordinarily accessible in metropolitan habitats in Somalia, which brings about outrageous value unpredictability for its clients as oil costs depend on the variance of the world oil market. Following the continuous foundation of private autonomous energy makers in metropolitan communities just after the common war, diesel generators generally work under low-effectiveness part load conditions because of changing electrical interest combined with low nearby specialized prerequisites [1].

Somalia is experiencing three significant expansive based jolt difficulties: absence of network, incredibly significant expenses, and helpless unwavering quality. Simply a minuscule level of the nation's families and partnerships approach power. A

Credible factual data on the circumstance of energy in While the World Bank reports that 29.1 percent of Somalia's populace approaches power, the later appraisal from the 2014 African Energy Outlook assesses that not exactly a fourth of the populace has the advantage of power, Somalia is distant as not many studies have been directed in the country over the most recent couple of years. A critical provincial metropolitan separation is obscured by these figures. Power is practically non-existent in country zones. It significantly varies the nation over in metropolitan zones. Most recent figures for Mogadishu and Hargeisa are 60% and 68%, individually, of the populace, albeit more modest urban areas have only 23 percent associated with electrical utilities, including Markka. The evaluations of the extent of admittance to power are probably going to be overestimated in regions with higher quantities of inside dislodged individuals who are more hard to follow While these rates are really higher than tantamount urban communities in sub-Saharan Africa, particularly in Mogadishu Hargeisa and Bosaso The energy that organizations and family units have "admittance to" is hazardous. The essential issue is that, going from $0.80 to $1.50 each kilowatt hour, energy levies are among the most elevated on the world.

Comparatively, Kenya and Ethiopia's neighbouring countries enjoy average prices of $0.15 and $0.06, respectively. Not only do Somalis pay significantly higher electricity tariffs, but they also earn substantially less. The projected per capita GDP for Somalia is $128, a fraction of the per capita GDP of $454 for Ethiopia and $942 for Kenya.4 Somali people live in one of the world's poorest countries and pay one of the highest electricity tariffs of any country in Somalia, the difference in electricity tariffs is explained by the position and differential pricing of energy suppliers. Usually, people in areas far from urban centres pay the most in energy costs.5 Tariffs fluctuate among multiple suppliers within cities and suppliers do not generally use a standardized rate among their own customers. The lack of clarity and predictability causes challenges for both consumers and suppliers competing in the industry. The other electrical supply issue is its gross unreliability. Owing to the shortcomings of the current infrastructure, shortages and outages haunt the networks. Without rules or guidelines, solutions for electricity transmission and distribution have been improvised, even without professional technical training. These ad hoc systems lead to inefficiencies that lead to large losses of up to 40 percent during the production and distribution of energy to end-users. [1].

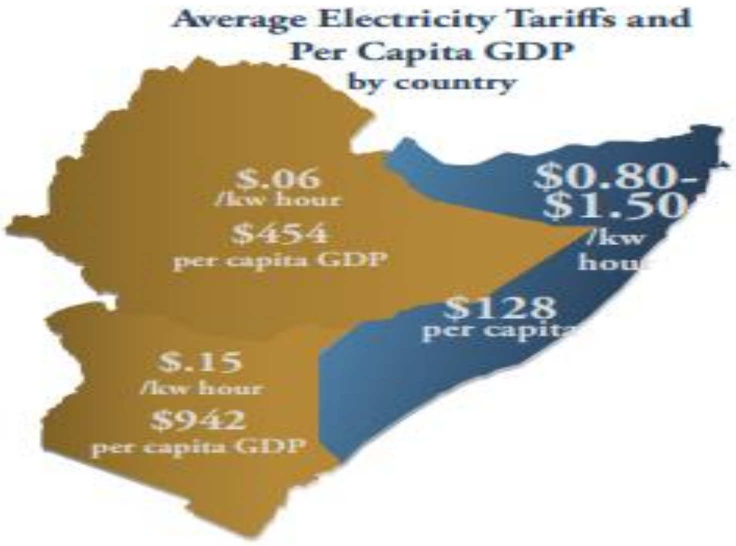

Figure 2.1: average electricity tariffs and per capita GPD

Pricing, unreliability, and restricted access issues illustrate why Somalia's electricity use is among the lowest in the world. The 2012 net electricity usage estimate was 288.3 million kilowatt hours, putting Somalia in the world's bottom quintile.7 A direr image is painted considering consumption per capita. The 28.7 kW per capita consumption of Somalia is only 1 percent of the world average (2,798 kWh), half that of Ethiopia (57 kWh) and just 19 percent of Kenya's use (153 kWh).

2.2.1 Solar energy

The average amount of sunshine is 5.7 kWh/m2/day. With more than 3,000 hours of intense and constant sunlight each year, Somalia is the ideal place to use solar energy. Solar energy resource had been used for Off-grid production and municipal water use in the country [9] Solar cooking has similarly appreciated certain absorption for the nation, also solar energy is perceived as the preferred energy basis for the convalescence of many municipal buildings in the country, especially health centers.

2.3 Street Lamp

Before we had radiant bulbs, gas lighting was being used in urban areas. The principal such streetlights were introduced in the Arab Empire, particularly in Cordoba, Spain. For the principal electric road lighting, Arc lights were utilized, at first the 'Electric flame' or 'Yablochoff candle' created by the Russian Pavel Yablochkov in 1875. This was a substituting current carbon bend light, which implied that at a similar rate, the anodes burned to the ground. Yablochkov candles were first used to enlighten the Grands Magazines du Louver, Paris, where 80 were conveyed. Before long, trial varieties of circular segment lights were utilized to light Holborn Viaduct and the Thames Embankment in London, the principal electric road lighting in Britain. By 1881, more than 4,000 were being used, however Frederic von Hefner-Alteneck of Siemens and Haskew had by then created an improved differential bend light [10].

Circular segment Lights had two fundamental disservices. To begin with, they discharge an extraordinary and cruel light that was awkward in standard roads of the city, in spite of the fact that they are support serious in modern destinations, for example, dockyards, as carbon cathodes effectively copy away. With the coming of modest, amazing and brilliant glowing lights toward the finish of the nineteenth century, they were out of utilization for road lighting, however they stayed in modern use for more. Before the appearance of extreme focus release lights, glowing lights utilized for road enlightenment were frequently worked as high-voltage arrangement circuits. Today, extreme focus release lights, likewise HPS high pressing factor sodium lights, are usually utilized in road lighting. For the least energy utilization, these lights have the best measure of photograph brightening. Notwithstanding, if picture light estimations are utilized, it very well may be perceived how wrong HPS lights are for late evening lighting. White light sources have been appeared to twofold the driver's fringe vision and improve the driver's brake response time by in any event 25 percent. At the point when S/P light estimations are utilized, HPS light yield should be diminished by a base estimation of 75 percent. These are currently standard plan measures for streets [11].

Figure 2.2: Old, new style and solar street lamp

2.3.1 Technical Parameters for Street lighting Technologies

For both industrial use and residential use, lighting is an important necessity. Innovations and continuous improvement in the field of lighting have given rise to immense opportunities in this field to save resources. Lighting systems are designed to reduce the cost of the life cycle while fulfilling the expected criteria for lighting (providing minimum lighting requirements to ensure proper functioning and user safety). To achieve an optimal architecture for energy efficiency, it is prudent to select the right combination of lamp and ballast that produces high lumens per watt and a fixture that meets design requirements and minimizes light transmission and light pollution. Lighting systems components are essentially classified under[12]:

- structural systems,
- electrical systems,
- optical systems

2.3.2 History of Solar Powered Streetlights

Earlier research on solar-powered streetlights have provided a high level of understanding of how solar energy is used around the world and how this project matches with the solar-powered street lighting application. The understanding of using solar energy to power a street light began in the 1990s as a way out of the year-round high cost of running street lights. The Parks and Recreation Department of Albuquerque, New Mexico One of the earliest research was performed by The study results revealed the feasibility of using solar energy to power street lights The design of the early systems included lamps with loads less than 50W, this was used. This study has laid the foundations for future designs. Studies conducted in Thailand used a simple photovoltaic device that operated seven hours a day and figured out how different types of lamps worked in remote villages. The categories that were instrumental in deciding the type of light to be used were light output in lumens, wattage, and colour rendition. The fluorescent lamp was chosen because of its lower cost and the adequacy of light output[13].

2.3.3 Solar Powered Streetlights in the Future

In the future, solar street lighting systems will be powered by changes in the effectiveness of equipment and the advancement of new technologies. The experiments were carried out using LED and HPS lamps (light emitting diodes). It illustrates the milestones achieved in the application of solar energy to light paths. Using LEDs is the newest type of street lighting that shows promise. Some study has been analysed in cities such as California and San Diego. In contrast to the other modes of street lighting, the application of LED lamps and the use of LEDs as a solution to the high cost of operating HPS lights. The prospect of introducing solar powered street lighting is improving with the advances in equipment and design. The move from grid-powered streetlights would be affected by the principle of cost and efficiency of powering solar streetlights. It becomes tempting when a concept or device can pay for itself within a shorter period of time.

2.4 Solar PV Design

A solar panel is made up of a semiconductor material which, through the use of a silicon composite pn junction, converts light into energy. The energy is mirrored, transmitted, or absorbed if light reaches some material. The following must be calculated when designing or dimensioning a solar PV system.

REFERENCES

[1] D. Poplack and K. Coolidge, "Powering Progress 2," p. 12, 2016, doi: 10.18289/OEF.2016.003.

[2] Z. Rajab, A. Khalil, M. Amhamed, and A. Asheibi, "Economic feasibility of solar powered street lighting system in Libya," *2017 8th Int. Renew. Energy Congr. IREC 2017*, no. Irec, pp. 1–6, 2017, doi: 10.1109/IREC.2017.7926027.

[3] W. E. C. 2016, "World Energy Resources 2016," *World Energy Counc. 2016*, pp. 6–46, 2016, [Online]. Available: https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources_SummaryReport_2016.10.03.pdf.

[4] P. Principi and R. Fioretti, "A comparative life cycle assessment of luminaires for general lighting for the office - Compact fluorescent (CFL) vs Light Emitting Diode (LED) - A case study," *J. Clean. Prod.*, vol. 83, pp. 96–107, 2014, doi: 10.1016/j.jclepro.2014.07.031.

[5] M. A. A. Nnamdi S. Okombe, Ujunwa Nduanya, Olaniyan O. Moses, Candidus O. Okwor, "Design and implementation of intelligent energy-saving streetlight system using one shot pulse generator," *Ftst J.*, vol. 2, no. 1, pp. 202–207, 2017.

[6] W. Islam, S. Rahman, M. M. Rahman, and O. Islam, "Economic Feasibility of Solar Powered Street Lights," no. December, 2011, doi: 10.13140/2.1.4951.6804.

[7] 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 (English Transl. Geliotekhnika)*, vol. 53, no. 2, pp. 138–151, 2017, doi: 10.3103/S0003701X17020086.

[8] L. Al-Kurdi, R. Al-Masri, and A. Al-Salaymeh, "Economical Investigation of the Feasibility of Utilizing the PV Solar Lighting for Jordanian Streets," *Int. J. Therm. Environ. Eng.*, vol. 10, no. 1, pp. 79–85, 2015, doi: 10.5383/ijtee.10.01.012.

[9] A. M. Abdilahi, A. H. Mohd Yatim, M. W. Mustafa, O. T. Khalaf, A. F. Shumran, and F. Mohamed Nor, “Feasibility study of renewable energy-based microgrid system in Somaliland’s urban centers,” *Renew. Sustain. Energy Rev.*, vol. 40, pp. 1048–1059, 2014, doi: 10.1016/j.rser.2014.07.150.

[10] B. C. Black, “Burning Up: A Global History of Fossil Fuel Consumption by Simon Pirani,” *Technol. Cult.*, vol. 61, no. 2, pp. 700–702, 2020, doi: 10.1353/tech.2020.0042.

[11] DOE, “Solar renewable energy,” no. November 2015, pp. 0–4, 2014, [Online]. Available: http://energy.gov/eere/renewables/solar.

[12] P. A. Owusu and S. Asumadu-Sarkodie, “A review of renewable energy sources, sustainability issues and climate change mitigation,” *Cogent Eng.*, vol. 3, no. 1, pp. 1–14, 2016, doi: 10.1080/23311916.2016.1167990.

[13] T. A. Allery, A. Martino, M. Org, and S. Begay, “Solar Street Lighting : Using Renewable Energy for Safety for the Turtle Mountain Band of Chippewa,” pp. 1–21, 2018.

[14] O. Ogunmodimu and E. C. Okoroigwe, “Concentrating solar power technologies for solar thermal grid electricity in Nigeria: A review,” *Renew. Sustain. Energy Rev.*, vol. 90, no. May 2016, pp. 104–119, 2018, doi: 10.1016/j.rser.2018.03.029.

[15] M. A. Hannan, M. M. Hoque, A. Mohamed, and A. Ayob, “Review of energy storage systems for electric vehicle applications: Issues and challenges,” *Renew. Sustain. Energy Rev.*, vol. 69, no. September 2015, pp. 771–789, 2017, doi: 10.1016/j.rser.2016.11.171.

[16] A. M. Pal, S. Das, and N. B. Raju, “Designing of a Standalone Photovoltaic System for a Residential Building in Gurgaon, India "Designing of a Standalone Photovoltaic System for a Residential Building in Gurgaon,” *Sustain. Energy*, vol. 3, no. 1, pp. 14–24, 2015, doi: 10.12691/rse-3-1-3.

[17] H. Ullah, *Implementation of Charge controller & Inverter for a Solar Panel*, no. February 2012. 2017.

[18] F. Leccese, “Remote-control system of high efficiency and intelligent street lighting using a zig bee network of devices and sensors,” *IEEE Trans. Power Deliv.*, vol. 28, no. 1, pp. 21–28, 2013, doi: 10.1109/TPWRD.2012.2212215.

[19] I. S. Mardikaningsih, W. Sutopo, R. Zakaria, M. Nizam, and E. A. Kadir, “Evaluation and designing street lighting with solar cell: A case study,” *2016*

2nd Int. Conf. Ind. Mech. Electr. Chem. Eng. ICIMECE 2016, pp. 186–191, 2017, doi: 10.1109/ICIMECE.2016.7910455.

[20] E. D. E. Gray, "(12) United States Patent gi : R," vol. 2, no. 12, 2017.

[21] G. Oliveti, L. Marletta, N. Arcuri, M. De Simone, R. Bruno, and G. Evola, "Solar energy," *Green Energy Technol.*, no. 9783319030739, pp. 159–214, 2014, doi: 10.1007/978-3-319-03074-6_4.

[22] S. V. Mitrofanov and D. K. Baykasenov, "To the issue of increasing the energy efficiency of photovoltaic installations," *Proc. - 2020 Int. Conf. Ind. Eng. Appl. Manuf. ICIEAM 2020*, 2020, doi: 10.1109/ICIEAM48468.2020.9111985.

[23] A. Dolara, E. Donadoni, S. Leva, G. Magistrati, and G. Marchegiani, "Performance analysis of a hybrid micro-grid in Somalia," *2017 IEEE Manchester PowerTech, Powertech 2017*, pp. 3–8, 2017, doi: 10.1109/PTC.2017.7980867.

[24] C. O. Okoye and B. C. Oranekwu-Okoye, "Economic feasibility of solar PV system for rural electrification in Sub-Sahara Africa," *Renew. Sustain. Energy Rev.*, vol. 82, no. July 2016, pp. 2537–2547, 2018, doi: 10.1016/j.rser.2017.09.054.

[25] C. A. Hossain, N. Chowdhury, M. Longo, and W. Yaïci, "System and cost analysis of stand-alone solar home system applied to a developing country," *Sustain.*, vol. 11, no. 5, 2019, doi: 10.3390/su11051403.

[26] R. Osei-Kyei and A. P. C. Chan, "Review of studies on the critical success factors for public-private partnership (PPP) projects from 1990 to 2013," *Int. J. Proj. Manag.*, vol. 33, no. 6, pp. 1335–1346, 2015, doi: 10.1016/j.ijproman.2015.02.008.

[27] A. Energy and W. Group, *Life Cycle Cost Assessment of Photovoltaic Systems in the APEC Region*, no. April. 2019.

[28] A. Walker *et al.*, "Model of Operation-and-Maintenance Costs for Photovoltaic Systems," *Nrel*, no. June, 2020.

[29] T. Lambert, P. Gilman, and P. Lilienthal, "Micropower System Modeling with Homer," *Integr. Altern. Sources Energy*, pp. 379–418, 2006, doi: 10.1002/0471755621.ch15.

[30] P. M. Chimwamurombe, L. N. Kazembe, H. Wanke, A. Dunkeloh, and P. Udluft, "International Science and Technology Journal of Namibia," vol. 2, no. January, pp. 1–19, 2013.

[31] N. A. N. S. U. M. O. N. A. Ung and Z. A. W. H. T. E. T. M. Yint, "Design of Stand-Alone Solar Street Lighting System with LED," vol. 03, no. 17, pp. 3518–3522, 2014.

[32] N. Das, N. Pal, and S. K. Pradip, "Economic cost analysis of LED over HPS flood lights for an efficient exterior lighting design using solar PV," *Build. Environ.*, vol. 89, pp. 380–392, 2015, doi: 10.1016/j.buildenv.2015.03.005.

[33] H. C. Lee and H. Bin Huang, "A Low-Cost and Noninvasive System for the Measurement and Detection of Faulty Streetlights," *IEEE Trans. Instrum. Meas.*, vol. 64, no. 4, pp. 1019–1031, 2015, doi: 10.1109/TIM.2014.2361551.

[34] F. Outferdine, L. Bouhouch, M. Kourchi, M. Ajaamoum, and A. Moudden, "Feasibility of Substitution of the Conventional Street Lighting Installation by the Photovoltaic Case Study on a Municipality in Agadir in Morocco," *Int. J. Electr. Comput. Eng.*, vol. 7, no. 5, p. 2287, 2017, doi: 10.11591/ijece.v7i5.pp2287-2299.

[35] S. Katyara, L. Staszewski, J. Ansari, A. Soomro, and F. Akhtar, "Techniczne i ekonomiczne aspekty ośiwtlenia ledowego ulic," *Prz. Elektrotechniczny*, vol. 94, no. 1, pp. 157–162, 2018, doi: 10.15199/48.2018.01.39.

[36] K. Ajao, O. Oladosu, and O. Popoola, "Using HOMER power optimization software for cost benefit analysis of Hybrid-solar power generation relative to utility cost in Nigeria," *Int. J. Res. Rev. Appl. Sci.*, vol. 7, no. 1, pp. 96–102, 2011, doi: 10.1017/CBO9781107415324.004.

[37] A. Alwaeli, M. T. Chaichanp, H. A. Kazemp, P. Aedah, M. J. Mahdyp, and A. A. Al-Waeely4, "Optimal Sizing of a Hybrid System of Renewable Energy for Lighting Street in Salalah-Oman using Homer software," *Int. J. Sci. Eng. Appl. Sci.*, no. 2, pp. 157–164, 2016, [Online]. Available: www.ijseas.com.

[38] A. N. Al-shamani *et al.*, "Design & Sizing of Stand-alone Solar Power Systems A house Iraq," *Recent Adv. Renew. Energy Sources*, no. January, pp. 145–150, 2013, [Online]. Available: https://pdfs.semanticscholar.org/ac10/c05f8a9e233407132e0e86161f47c4840e98.pdf.

[39] U. A. Saleh, Y. S. Haruna, and F. I. Onuigbo, "Design and Procedure for Stand-Alone Photovoltaic Power System for Ozone Monitor Laboratory at Anyigba , North Central Nigeria," *Int. J. Eng. Sci. Innov. Technol.*, vol. 4, no. 6, pp. 41–52, 2015.

[40] G. M. Shafiullah and C. E. Carter, “Feasibility study of photovoltaic (PV)-diesel hybrid power systems for remote networks,” *Proc. 2015 IEEE Innov. Smart Grid Technol. - Asia, ISGT ASIA 2015*, 2016, doi: 10.1109/ISGT-Asia.2015.7387123.

[41] W. Sutopo, I. S. Mardikaningsih, R. Zakaria, and A. Ali, “A model to improve the implementation standards of street lighting based on solar energy: A case study,” *Energies*, vol. 13, no. 3, pp. 1–20, 2020, doi: 10.3390/en13030630.

[42] 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.