Solar Energy
And Sustainable Development

Refereed, biannual scientific journal issued by:
The Libyan Center for Solar Energy Research and Studies

Hybrid System Modeling for Renewable Energy Sources

Laila A. Rtemi[1*], **Wedad El-Osta**[2], Ahmad Attaiep[3].

[1] Mechanical Engineering Department, University of Sabrata, Libya.
[2] The Libyan Center for Solar Energy Research and Studies,Tripoli Libya.
[3]Higher Institute for Science and Technology - Albayda, Libya.

E-***mail:*** [1] Lailaabogasem@gmail.com, [2] e_wedad@hotmail.com, [3] Garrash80@gmail.com.

ARTICALE INFO.

Article history:
Received 2 May 2023
Received in revised form 16 May 2023
Accepted 25 June 2023
Available online 12 July 2023

KEYWORDS

simulation, optimization, hybrid system, solar energy, wind energy.

ABSTRACT

The main goal of this study is to design optimize and design a hybrid wind/PV solar power system to provide the premises of the Libyan Center for Solar Energy Research Center (LCSERS) with the required energy and investigates its technical and economic feasibility. HOMER simulation program is used to design the off-grid and assess the feasible solution and economic cost. The power systems are optimized based on the electricity load, climatic data sources, the economics of the power components, and other parameters in which the total Net Present Cost (NPC) must be minimized to select an economically feasible power system. Moreover, other parameters like a renewable fraction, capacity shortage, Cost of Energy (COE), and excess electricity, were also considered to check the technical capability. Sensitivity analysis of the most influential variables has been considered in four scenarios of capacity shortage. In the off-grid hybrid system, the best option is the fourth scenario, where the capacity shortage is 5% of the 60,385.6 kWh/yr electric load, peaking at 43.45 kw, because the lowest COE is 0.222 $ and the NPC is 168,173 $. The system consists of a 20 kW PV, one turbine of 25 kW, and 72 Hoppecke batteries of 1500.Ah each. The annual share of wind energy was 77%, and solar energy was 22.9%. The estimated excess of electricity was 58.3%.

---

[*] *Corresponding author.*

DOI: -----------------------------

نمذجة نظام هجين لمصادر الطاقة المتجددة

ليلى الرتيمي[1]، وداد الأسطى[2]، أحمد الطيب[3].

[1] **قسم الهندسة الميكانيكية، جامعة صبراتة، ليبيا.**
[2] **رئيس تحرير مجلة الطاقة الشمسية و التنمية المستدامة، المركز الليبي لبحوث و دراسات الطاقة الشمسية.**
[3] **قسم الهندسة الميكانيكية، المعهد العالي للعلوم و التكنولوجيا – البيداء، ليبيا..**

ملخص: الهدف الرئيسي من هذه الدراسة هو تصميم وتحسين نظام هجين للطاقة الرياح / الكهروضوئية لتزويد مبني المركز الليبي لأبحاث الطاقة الشمسية (LCSERS) بالطاقة المطلوبة والتحقق من جدواها الفنية والاقتصادية. أستخدم برنامج محاكاة HOMER لتصميم منظومة غير موصلة بالشبكة الكهربائية وتقييم الجدوى الفنية والاقتصادية. تم تحسين منظومة الطاقة بناءً على الحمل الكهربائي للمركز ومصادر البيانات المناخية واقتصاديات مكونات منظومة الطاقة والمتغيرات الأخرى التي يجب فيها تقليل إجمالي صافي التكلفة الحالية (NPC) للحصول على منظومة طاقة مجدية اقتصاديًا. علاوة على ذلك ، تم النظر أيضًا في معايير أخرى مثل نسبة مساهمة الطاقة المتجدد وقصور السعة في تغذية الاحمال الكهربائية وتكلفة الطاقة المنتجة (COE) وفائض الكهرباء للتحقق من المقدرة الفنية لتلبية الطلب على الطاقة الكهربائية في المركز. وتم دراسة تحليل الحساسية للمتغيرات الأكثر تأثيراً في أربعة سيناريوهات لنقص السعة. في النظام الهجين الغير موصل بالشبكة الكهربائية، وكان الخيار الأفضل هو السيناريو الرابع ، حيث يكون النقص في السعة هو 5٪ من الحمل الكهربائي البالغ 60385.6 كيلوواط ساعة / سنة ، ويبلغ ذروته عند 43.45 كيلوواط ، حيث كان أدنى مستوى لتكلفة الطاقة هو0.222 دولارًا أمريكيًا ، واجمالي صافي التكلفة هو 168173 دولارًا أمريكيًا. يتكون النظام من 20 كيلوواط من الطاقة الكهروضوئية ، وتوربين واحد بقدرة 25 كيلوواط ، و 72 بطارية هوبيك بقدرة 1500 أمبير في الساعة لكل منهما. بلغت الحصة السنوية لطاقة الرياح 77٪ والطاقة الشمسية 22.9٪. وبلغ الفائض التقديري للكهرباء 58.3٪.

1. INTRODUCTION

Libya is an oil-producing country in North Africa with about 1,800 km of Mediterranean coastline. The area of the country is about 1,750,000 km^2, while 88% of the territory is desert. In this regard, most of the population lives along the coastline in very densely populated cities. The total population of the country in 2020 was 6.87 million people, a third of the population lives in the capital Tripoli [1]. Over the last decade, the Libyan renewable energy sector has planned several projects in relation to renewable energy. Solar and wind energy systems are mainly proposed to be used in the proposed projects, as these are the two best renewable energy alternatives in Libya. For example, Libya's average solar radiation is about 7.5 kWh/m^2/day, with about 3000–3500 hours of sunshine per year [1] [2]. The average speed of the wind is approximately from 6 m/s to 7.5 m/s at a height of 40 m [3], [4]. This huge amount of sunlight and wind which is distributed over an area of 1,750,000 km^2, could meet the future electricity needs of Libya and its neighbors, which could even be supplied to Europe via high-voltage direct current (HVDC) lines. [4]. Libya could generate about five times more energy from solar power than it currently does from crude oil, according to a study by Nottingham Trent University. The School of Architecture, Design, and the Built Environment researchers found that Libya could generate enough renewable energy to meet its own needs and "a significant portion" of global electricity exports." [5], [6]. Several research papers have been done on the design of a hybrid renewable energy system (HRES) using different renewable energy management and scaling approaches. A feasibility study for the construction of a hybrid wind-solar system is a task that depends on the collection of relevant information from various sources. Kanase-Patil et al [7]. studied off-grid electrification of seven villages in the Almorada region of Uttarakhand, India. In their study, sources of biomass, solar, hydro and wind energy were studied and analyzed using the LINGO and HOMER software. 68 computer tools for integrating renewable resources into different energy systems are compared. As a result, HOMER is ideal for sensitivity analysis, feasibility studies, and optimization of both off-grid and grid-connected micro-energy systems [8].

Shreif, H, et al [9]. Wind data was analyzed for a southern city in Libya (Hun) using various statistical models, and calculations were made to estimate the potential for wind power in this area. For the proposed site, a detailed analysis of wind data was performed using an Excel spreadsheet for the annual period (April 2011 to March 2012). Four heights (20 m, 40 m, 60 m, and 61 m) above ground level (a.g.l.) are used to collect wind data. In April, Nordex N100-2500 had a power factor of 41% and 83.7% availability, while Vestas V112-3000 had the highest power factor of 42% and 83% availability. Off-grid or wind farm projects utilizing wind energy will be feasible in this area.

Nassar Yasser F., et al [10]. This paper proposes a simple and efficient procedure for optimal sizing of PHS-integrated hybrid PV/Wind power system for providing sustainable supply of electricity to an urban community in Brack city, Libya. The energy production for various sizes of solar PV arrays and wind turbine farms was estimated by System Advisory Model (SAM) software using measured data of climate conditions and load demand. According to the Levelized Cost of Energy (LCOE), the ideal power capacity ratio for a wind farm with solar panels was 1:5. PHS contribute with a share of 15% in covering the annual load energy for the system of ideal size. Almaktar M., and shaaban M [11]. This report does a thorough resource assessment of the available RE potentials and offers a general overview of the current state of Libya's energy resources. In-depth research is done on the utilization status and development potential of different RE technologies in Libya, including solar energy, wind (onshore & offshore), biomass, wave, and geothermal energy. Including energy effectiveness (EE) and hydrogen storage. Over the regions of Libya, the average potential for solar PV and onshore wind is 400 W/m^2 and 1.9 MWh/kW/year, respectively. However, geothermal and biomass energy sources are probably going to work well together in this regard. ALaa F.M. Ali, et al [12]. This article recommends reliable and off-grid hybrid renewable energy (RES) with pumped storage pump (PHS) to meet the electricity needs of a coastal city in Egypt, Hurghada. The ideal configuration of the suggested system is chosen using the Minimum Levelized Cost of Energy (LCOE). According to the findings, combining RES and PHS is advantageous and trustworthy for supplying metropolitan areas with acceptable topographical features with a sustainable power supply. Al-Najjar H, et al [13]. This study examines the individual and overall performance of an 84.5 kW hybrid renewable system that is connected to the grid. Utilizing hourly data from simulated HOMER Pro trials over the course of a year. A range of solar energy, biomass, diesel generator, chemical storage, and utility network configurations may be chosen as the best option. Biomass and solar energy are used in the optimized system, along with a connection to the public grid. The capacity-using rate reached 99%, the productivity factor did not exceed 40%, and the penetration of renewable energy was 497 percent. Emrani A, et al [14]. With regard to technical and financial efficiency indicators, the suggested model in this work attempts to choose the best configuration for a hybrid renewable gravity energy storage system (RE-GES) and a hybrid renewable battery energy storage (RE Battery). 418 photovoltaic panels and 477 wind turbines with a 15 MWh hydropower capacity make up the ideal combination. According to the data, RE-GES energy costs between 0.3 and 0.018 euros per kWh, and REBattery costs between 0.25 and 0.05 euros per kWh. Al-Najjar et al [15]. In a residential sector of Gaza City, simulation experiments are run using the HOMER Pro software; the average daily consumption is approximately 1074 kWh/day, and the peak value is

84.5 kWh. The grid-connected system utilizes renewable resources by using a biogas generator and solar panels. With multiple load profile zones to reach the best biomass contribution solution, a preliminary mathematical model is presented. It shows a net present value (NPC) of at least $2.30 million and an energy cost (COE) of $0.438 per kWh.

In this study, an attempt was made to design an optimal hybrid power system for the Libyan Center for Solar Energy Research and Studies (LCSERS), Tajoura, Tripoli, where the wind speed and solar radiation measurements were made. The primary goals of this study are to determine the technical and financial viability of a hybrid wind/solar system to meet the center's electricity needs. By expanding the use of this hybrid system to additional buildings with a similar climate, the other research goals include achieving the exploitation of renewable energy resources (solar and wind) to generate electricity in Libya. Additionally, because of the rising need for electric energy from traditional energy sources, it will help reduce pollution.

2. METHODOLGY

Using HOMER software, a hybrid power plant with many configurations was created to power the Center. The necessary information was entered for the design. To achieve the best outcomes, simulation and optimization were carried out using HOMER software.

2.1. Case Study Methodology

The case study focused on the most effective hybrid power system architecture. The model was developed to reflect the current load in the real world. Power for the LCSERS electrical load is provided by Libya's national electrical network. It frequently suffered from interruptions, instability, and coverage gaps. The center is open from 8:00 a.m. to 3:30 p.m. on Sunday through Thursday, with peak summer hours of 9 a.m. to 14 p.m.

It can also be seen that during winter, for the same period, the consumption rate reduced from a peak of 12 kWh to a minimum of 354Wh. In addition, electricity consumption decreased from (26 kWh) in 9:00 am to (1.17kWh) at 3:00 pm. The main justification for selecting LCSERS as the study site for the installation of a renewable energy system is that it is a renewable energy research institute but is still supplied with electricity by the national grid, and the adoption of such a system would serve as a good example for other public and residential buildings.

The national electrical network of Libya supplies power to the LCSERS electrical load. Most of the time, it experienced frequent disruptions, instability, and coverage gaps. The center is open Sunday through Thursday from 8:00 am to 3:30 pm, with peak summer hours of 9 am to 14 pm. In addition, power consumption decreased from (26 kWh) at 9:00 am to (1.17kWh) at 3:00 pm, also it can be noticed that during winter, for the same period, the consumption rate decreased from 12 kWh peak to a minimum of 354Wh.

The main reason for choosing LCSERS as a study area to implement a renewable energy system is that it is a renewable energy research institute but it is still powered by the national electricity network and the implementation of such system would be a good example to other public and residential buildings. The maximum connected load power rating for the Center's electrical connected loads is 52 kW during the day and 3 kW at night, as stated in Table 1. The seasonal load profile can be summarized in table 2.

Due to its benefits, which include merging the majority of renewable energy sources, a quick optimization procedure, and sensitivity analysis, HOMER software was acknowledged as being the most extensively utilized among 19 simulation tools [16].

The Hybrid Optimization of Multiple Energy Resources (HOMER) tool was used in this work to develop and simulate a hybrid energy system for the LCSERS.

To build a hybrid system, it offers a variety of software tools and alternatives, such as economic analysis.

Table 1. Details of Electric Appliances.

Load Type	Rated Power (W)	Q.T.Y (pcs)	Under Operation	Total Power (W)
Air Conditioning	1200	30	25	30000
Refrigerator 1	150	6	6	900
Refrigerator 2	180	1	1	180
Computer	120	65	55	6600
Printer type 1	120	28	10	1200
Printer type 2	648	10	6	3888
Fluorescent Light	36	236	150	5400
Flash Light	280	4	0	0
Communication Station	4000	1	1	4000

Table 2, Summary of the daily load profile.

Period	Consumption (kWh/d)
Summer months	185
Winter months	84.8
Peak Weekend consumption	32
Average consumption	100.37

Different scenarios and configurations were used in the design simulation and optimization. The first configuration that was selected includes solar cells, wind turbines, electrical transformers, and electrical energy storage and is depicted in "Fig 1." This renewable energy system will not be connected to the national electrical grid (an independent system).

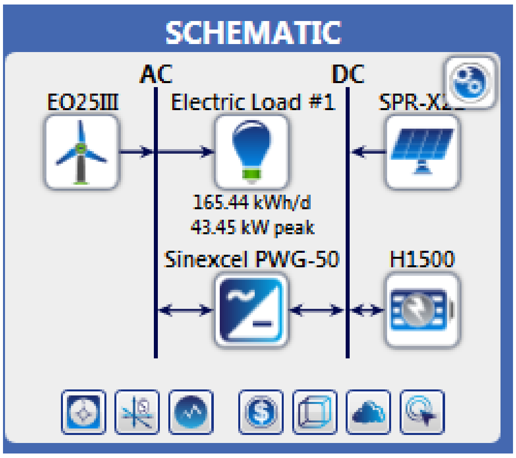
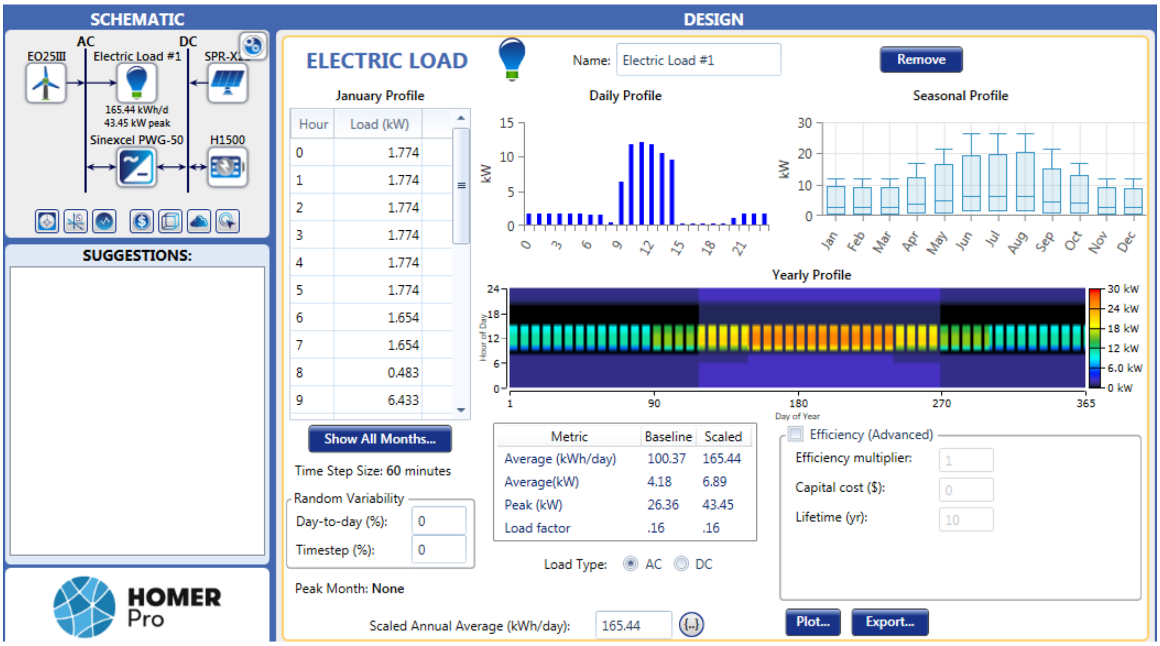


Figure 1. Hybrid off Grid Wind PV System.

2.2. Designing Hhomer System for LCSERS

The seasonal load profile of the proposed area is shown in "Figure 2". Energy consumed by the Centre is 165.44 kWh/day with a peak demand of 43.45 kW.

By performing a survey on the Center's electricity usage, the load profile is created. Due to the use of A/C throughout the summer, demand is strong.



ELECTRIC LOAD

Name: Electric Load #1

January Profile

Hour	Load (kW)
0	1.774
1	1.774
2	1.774
3	1.774
4	1.774
5	1.774
6	1.654
7	1.654
8	0.483
9	6.433

Time Step Size: 60 minutes

Random Variability
Day-to-day (%): 0
Timestep (%): 0

Peak Month: None

Scaled Annual Average (kWh/day): 165.44

Metric	Baseline	Scaled
Average (kWh/day)	100.37	165.44
Average(kW)	4.18	6.89
Peak (kW)	26.36	43.45
Load factor	.16	.16

Load Type: ● AC ○ DC

☐ Efficiency (Advanced)
Efficiency multiplier: 1
Capital cost ($): 0
Lifetime (yr): 10

Fig 2. Entered primary electrical load for LCSERS.

The renewable hybrid feeding system for the centre was designed using the HOMER program. The required electric load data and all other the necessary data were entered. AC loads were the kind of loads used in LCSERS. Given that many devices in the center remain operational throughout the whole week, the system was created to handle the basic maximum load needed both during the weekdays and weekends.

2.3. Identifying and Evaluating Renewable Energy Sources

It is vital to assess and choose the best renewable energy sources (such as solar or wind sources) that could feed the Center. For source evaluation and assessment, data on each of these sources ought to be accessible. The best technology solutions for those sources are then investigated and determined after the renewable energy sources have been found. The technologies used in this investigation were solar and wind.

2.4. Solar Resource

Data on solar energy resources is essential to this study since it is necessary to assess the potential annual output of solar energy from photovoltaic panels. One can find out how much solar radiation is there in a location by inputting the coordinates of the intended region into the HOMER software and using its application to import solar irradiance data from a NASA database. Figure 3 depicts the annual average daily solar radiation intensity at LCSERS. You may have noted that the daily solar radiation ranges between 2.77 and 3.66 kWh/m^2/day in January, February, November, and December. It fluctuates between 3.96 and 6.15 kWh/m^2/day in the months of March, April, September, and October. It ranges from 6.98 to 7.79 kWh/m^2/day and peaks in May, June, July, and August. Consequently, the annual average solar radiation at LCSERS is 5.11 kWh/m^2/day.

Wind resource data for the Centre was obtained using the HOMER program to determine the wind turbine capacity to be used in the design. After providing the coordinates of the study site, the NASA database was used to derive the monthly mean wind speed statistics for the Centre.

Choose Data Source: ● Enter monthly averages ○ Import from a time series data file or the library

Monthly Average Solar Global Horizontal Irradiance (GHI) Data

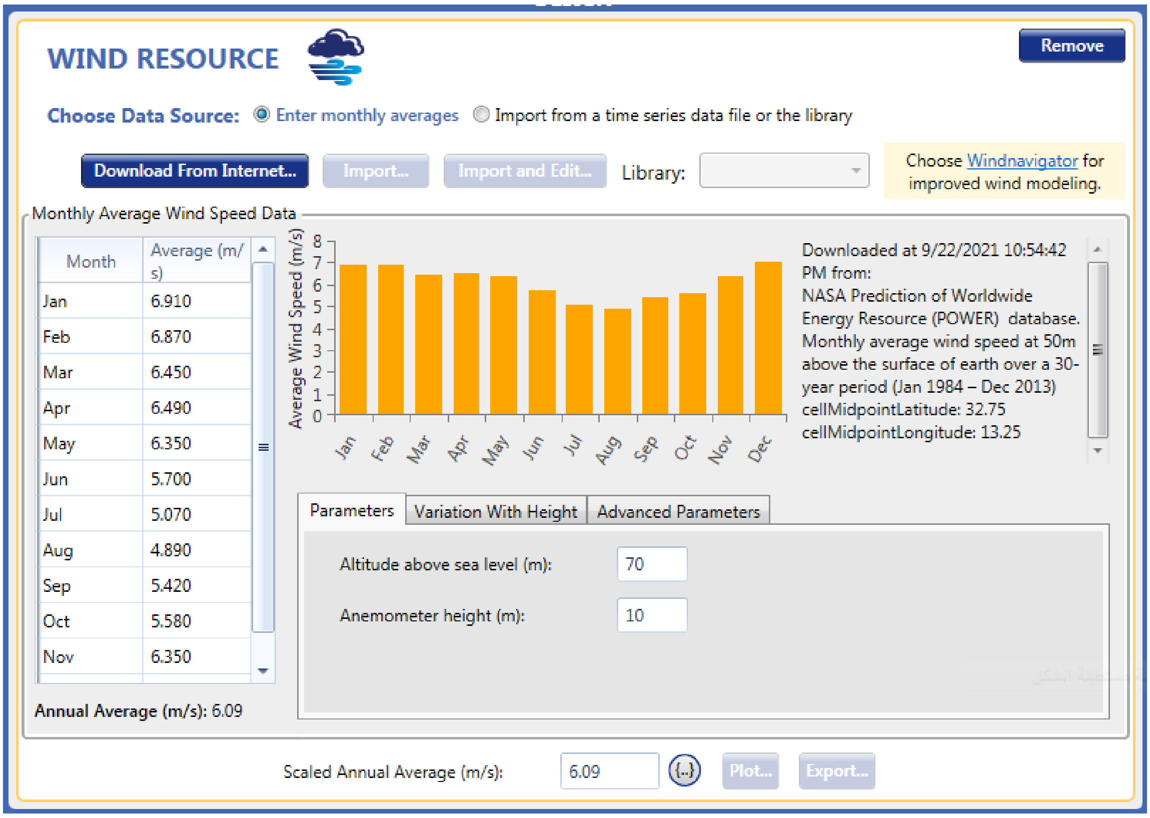
Month	Clearness Index	Daily Radiation (kWh/m²/day)
Jan	0.490	2.670
Feb	0.543	3.660
Mar	0.566	4.790
Apr	0.610	6.150
May	0.628	6.980
Jun	0.667	7.670
Jul	0.691	7.790
Aug	0.676	7.050
Sep	0.614	5.520
Oct	0.547	3.960
Nov	0.480	2.750
Dec	0.466	2.350

Downloaded at 9/22/2021 11:05:42 PM from:
NASA Prediction of Worldwide Energy Resource (POWER) database.
Monthly averages for global horizontal radiation over 22-year period (Jul 1983 - Jun 2005)
cellMidpointLatitude: 32.75
cellMidpointLongitude: 13.25

Annual Average (kWh/m²/day): 5.11

Scaled Annual Average (kWh/m²/da: 5.11

Fig. 3. Solar resource inputs values for the site of the LCSERS.



Choose Data Source: ● Enter monthly averages ○ Import from a time series data file or the library

Choose Windnavigator for improved wind modeling.

Monthly Average Wind Speed Data

Month	Average (m/s)
Jan	6.910
Feb	6.870
Mar	6.450
Apr	6.490
May	6.350
Jun	5.700
Jul	5.070
Aug	4.890
Sep	5.420
Oct	5.580
Nov	6.350

Downloaded at 9/22/2021 10:54:42 PM from:
NASA Prediction of Worldwide Energy Resource (POWER) database.
Monthly average wind speed at 50m above the surface of earth over a 30-year period (Jan 1984 – Dec 2013)
cellMidpointLatitude: 32.75
cellMidpointLongitude: 13.25

Altitude above sea level (m): 70

Anemometer height (m): 10

Annual Average (m/s): 6.09

Scaled Annual Average (m/s): 6.09

Fig. 4. Wind resource inputs values for the site of the LCSERS.

As a result of the incompleteness and inaccuracies in the data collection, which require work and an account to correct, no data were gathered from the research facility. The average monthly and annual wind speed for LCSERS is depicted in Figure (4). From a low of 5.07 m/s in July to a high of 6.91 m/s in January, the average wind speed varies. Thus, 6.09m/s is the approximate yearly average wind speed at the Center site. The average wind speed varies from a low of 5.07 m/s in July to a high of 6.91 m/s in January. As a result, the annual average wind speed at the Center site is approximately 6.09 m/s.

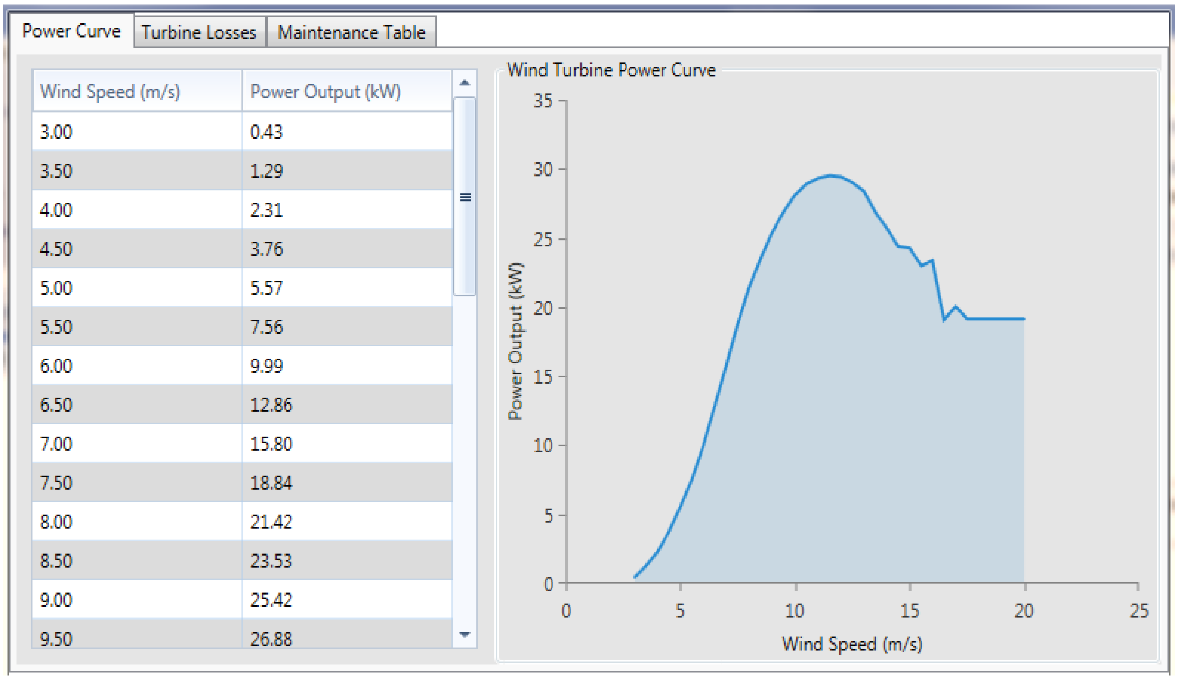
2.5. Component Inputs and Variables for LCSERS HERS

The selection of power system components is influenced by a variety of factors, including capital cost, operating and maintenance costs, component efficiency, and component life. When choosing power system components, these qualities should be taken into account. In the hybrid system design under consideration, the energy supply options include wind turbines, solar PV arrays, battery banks, and converters. The following sub-sections detail the qualities and prices of the system's components.

Table 3. Input to the HOMER software.

Component	**Capacity (kW)**	**Capital (USD)**	**Replacement (USD)**	**O&M USD/year**	**Life Time (Year)**
Wind Eocycle	25	45000/unit	30000/unit	800	25
PV	1	1771/kW	1240/kW	30	25
Converter	50	12154/unit	8500/unit	200	10
Battery Hoppecke	3	675/unit	470/unit	0	20
Prices are according to the Libyan Alqema company, the source of Alibaba. www.alqema.ly					

Numerous factors, including project location, site height restrictions, average wind speed, permissions, ease of installation and maintenance, initial capital cost, and power curve characteristics, have been taken into consideration while choosing the wind turbine capacity. To effectively use the low wind speed, a wind turbine with a rated power of EO25kW was chosen for the design. The power curve of the EO25 kW wind turbine is shown in Figure 5.



Wind Speed (m/s)	Power Output (kW)
3.00	0.43
3.50	1.29
4.00	2.31
4.50	3.76
5.00	5.57
5.50	7.56
6.00	9.99
6.50	12.86
7.00	15.80
7.50	18.84
8.00	21.42
8.50	23.53
9.00	25.42
9.50	26.88

Figure 5. (Eocycle EO25) Wind Turbine Power Curve [Homer software].

The cost of wind turbines varied from manufacturer to manufacturer at the same time.

To find out the cost of 25 kW wind turbines, which are suitable for meeting the site's load demand, we contacted a Chinese supplier online market store through Alibaba.

The capital cost will be $45,000 because the turbine costs $32,000, plus 25% for shipping, installation, transportation, and connections (much like the Derna wind energy project). When a wind turbine reaches the end of its useful life, it costs around 70% more to replace it than it does to operate and maintain it each year (1.5% to 2% of the original cost). The capital cost, replacement cost, and O&M costs in CSERS HERS are taken into consideration as data presented in Table 3. According to the local exchange rate that is now in effect, 1$=5LYD, the cost of every component of the system was estimated.

From the HOMER library, a 335W mono-crystalline silicon solar cell solar module was chosen. It has a 25-year lifespan and a 21% efficiency. The attributes of the PV panels used for the system are all represented in Table 4 together with the data that was introduced by the HOMER program. The estimated cost of installing a 1 kW PV array system will be $1771 USD, with operating and maintenance costs accounting for 1% of the overall investment in solar panels.

Table 4. Electrical characteristics of CAT 335W solar module.

Solar Panel Characteristics	
Cell type	**Mono-crystalline silicon solar cells**
Module dimensions	1640*990*40mm
Peak power (Pmax)	335W
15 panel in series	Cell configuration
Power tolerance	± 3%
Max. system voltage	1000 VDC
Open circuit voltage (Voc)	37.56 V
Short circuit current (Isc)	11.36 A
Max. power voltage (Vmp)	30.6 V
Max. power current (Imp)	10.46 A
Cell Efficiency	≥ 21%
Standard Test Condition (STD)	Irradiance:1000 W/m^2; cell temperature:25^{0}C
Manufacture	http://www.sunsolar.com.cn

The study looked at three different possibilities. The PV solar system's capacity ranged from 0 to 70 kW, the wind turbines' capacity ranged from 0 to 2, the batteries were each 3 kWh, and the inverter was 50 kW. Sensitivity analysis was conducted with regard to capacity shortages of 0.1%, 1%, 3%, and 5%.

2.6. Economic and Variable Inputs for CSERS HRES

Inputs and economic variables control the NPC for the project, also affecting the COE. Homers take into account these effects, which include the number of components used and their lifetime, project lifetime, and total cost. Some values have been entered for some project components, such as the number and length of wind turbines, and the lifetime of some project components, the constraints that must be added to the system are the maximum annual capacity shortage, varying from (0.1, 1, 3, and 5%). COE is inversely proportional to the increase in the life of the project. The performance of photovoltaic panels on cloudy days and the energy production from wind turbines, which changes depending on wind speed, are just two examples of how unstable renewable energy sources are and why Homer provides constraint input. On the other hand, energy production from renewable energy sources is not considered to be 100% achieved. The following Table 5 displays some of the constraint input values that have been modified in LCSERS. These modifications are taken into account in the program's calculations.

Table 5. The constraints input values for LCSERS

Economic Inputs	
Nominal discount rate	8%
Expected inflation rate	2%
Project lifetime	25 Years

3. RESULTS AND DISCUSSION

3.1. Simulation

By performing energy balancing calculations in each hourly time step of the year, HOMER simulated the functioning of a hybrid system that was suggested to the LCSERS. The energy supply that the system can deliver in a given time step is compared to the electric demand for each time step by HOMER. The energy flows to and from each system component are then calculated. These energy balancing computations are carried out by HOMER for each system configuration that was taken into consideration. It next decides if it is practical, that is, whether it can meet the electric demand under the given conditions, and it calculates the cost of installing and running the system over the project's lifetime.

In this study, four situations were taken into account. The PV solar system's capacity ranged from 0 to 70 kW, the number of wind turbines is 0 to 2, the batteries are 1200 W, and the inverter is 50 kW. Sensitivity analysis was conducted taking capacity shortages of 0.1%, 1%, 3%, and 5% into consideration.

3.2. Stand Alone (off-Grid) Hybrid System

3.2.1. Scenario A:

At the capacity shortage of 0.1%, the winning case with the lowest NPC is the hybrid system due to its lowest COE compared to the wind-only or PV-only renewable energy system. This configuration has a COE of 0.279 USD/kWh and an NPC value of 217,277 USD. The optimization results are shown in Table 6.

Table 6. Optimization Result of Scenario A

Case	**PV (kW)**	**Wind (25Kw)**	**H1500**	**NPC ($)**	**COE ($/kWh)**	**Excess Electricity %**
Case 1	40	1	72	217,277	0.279	65.5
Case 2	70		120	258,210	0.331	44.1
Case 3		2	192	278,598	0.358	71.9

In this scenario, there are three cases, the first case 40 kW PV and one 25 kW turbine with 72 batteries distributed over 3 series, the value of NPC ($ 217277), COE ($ 0.279) is the lowest value and thus is the best case, i.e. the optimal system where if Wind speed drops in summer, solar panels cover the shortage of electricity, and if the production of solar panels decreases in winter due to clouds, wind turbines cover the shortage. In the second case which consists of 70 kW PV with 120 batteries distributed over 5 series, where the NPC is $ 258210 and COE $ 0.331, this system has the least amount of excess electricity 44%, while the third case consists of 2 wind turbines with a capacity of 25 kW With 192 batteries spread over 8 series, NPC is $278,598, COE is $0.358 and this system has the highest electricity surplus value at 71.9% and largest COE, and NPC.

3.2.2. Scenario B:

In case of capacity shortage of 1%, the winning case with the lowest NPC is still the hybrid system due to its lowest COE compared to only one (PV or wind) renewable energy system.

This configuration has a COE of 0.250 USD/kwh and NPC value of 193,782 USD. The optimization results are presented in Table 7.

Table 7. Optimization Result of Scenario B.

Case	PV (kW)	Wind (25kW)	H1500	NPC	COE	Excess Electricity (%)
Case 1	30	1	72	193,782	0.250	61.9
Case2		2	120	225,687	0.292	72.1
Case3	60		120	236,184	0.305	35

3.2.3. Scenario C:

In the third scenario, a capacity shortage of 3% was considered. The winning case with the lowest NPC is the PV/wind/battery due to its lowest COE compared to only PV or wind system. This configuration has a COE of 0.245 USD/kWh and an NPC value of 187,199 USD, compared to the 2-wind turbine system which has NPC of 203,352 USD. The optimization results are shown in Table 8.

Table 8. Optimization result of scenario C

Case	PV (kW)	Wind (25kw)	H1500	NPC ($)	COE ($)	Excess Electricity (%)
Case 1	20	1	72	168,173	0.222	58.3
Case 2		2	96	200,619	0.266	73
Case 3	60		72	202,300	0.270	37.2

3.2.4. Scenario D:

Finally, in scenario D, a capacity shortage of 5% was considered. The winning case with the lowest NPC is PV/WIND/battery system (selected winning case) due to its lowest COE compared to the 2 wind turbine system. This configuration has a COE of 0.222 USD/kWh and an NPC value of 168,173 USD. The above scenarios are summarized in the following tables. It could be noticed that 2 wind turbines system would give a NPC of 200,619 USD. The optimization results are presented in Table 9.

Table 9. Optimization result of scenario D.

Case	PV (kW)	Wind (25kw)	H1500	NPC ($)	COE ($)	Excess Electricity (%)
Case 1	20	1	72	168,173	0.222	58.3
Case 2		2	96	200,619	0.266	73
Case 3	60		72	202,300	0.270	37.2

The four scenarios are summarized in Table 10.

Table 10. Summarized scenarios and selected winning case.

Scenario	Capacity shortage (%)	COE ($/kWh)	NPC ($)	Initial Capital($)	Configuration
A	0.1	0.279	217,277	174,801	PV/Wind/Battery
B	1	0.250	193,782	156,000	PV/Wind/Battery
C	3	0.245	187,199	152,907	PV/Wind/Battery
D	5	0.222	168,173	135,988	PV/Wind/Battery

Comparing the above four scenarios, it could be noticed that the winning case is the one that has the lowest NPC and COE. It consists of a Hybrid renewable energy source (WIND- PV) in addition to a battery system. From TABLE10. It could be noticed that scenario D is the Scenario with renewable energy resources that consists of 25kw wind turbines, 20kw PV, and 72 batteries. This configuration gives the cheapest costs. It has COE of 0.222 $/kWh and NPC value of 168,173 $ when the capacity shortage is considered as 5%. We note that scenario D has decreased its price by 77% compared to scenario A, and this shows the importance of knowing the capacity shortage that we need to reduce the size of the system, and thus its price decreases while preserving the provision of electricity to the site.

The total annual power generation from the PV/WIND system is 149,718kwh/y, where PV contribution is 34,222kWh/y and Wind contribution is 115,496kWh/y. The annual operation and production details, obtained from HOMER, are given in Table 11.

Table 11. Annual electrical summary and details of the proposed winning case PV/WIND (Capacity shortage 5%)

Components	Name	Size (kW)	Total Cost ($)	Production (kWh/y)
Solar Cell	Sun power X21-335-BLX	20	43,175.51	34,222
Wind Turbine	EO cycle EO25	25	59,516.18	115,496
Storage	Hoppeck12 OPzS1500	3	53,308.46	14,028
System Converter	Sin excel PWG-50	28	12,172.25	22,464
NPC ($)			168,173	
Levelized COE ($/kWh)			0.222	
CO2 Emissions (kg/yr.)			Neglected value	
Capacity Shortage (%)			5	

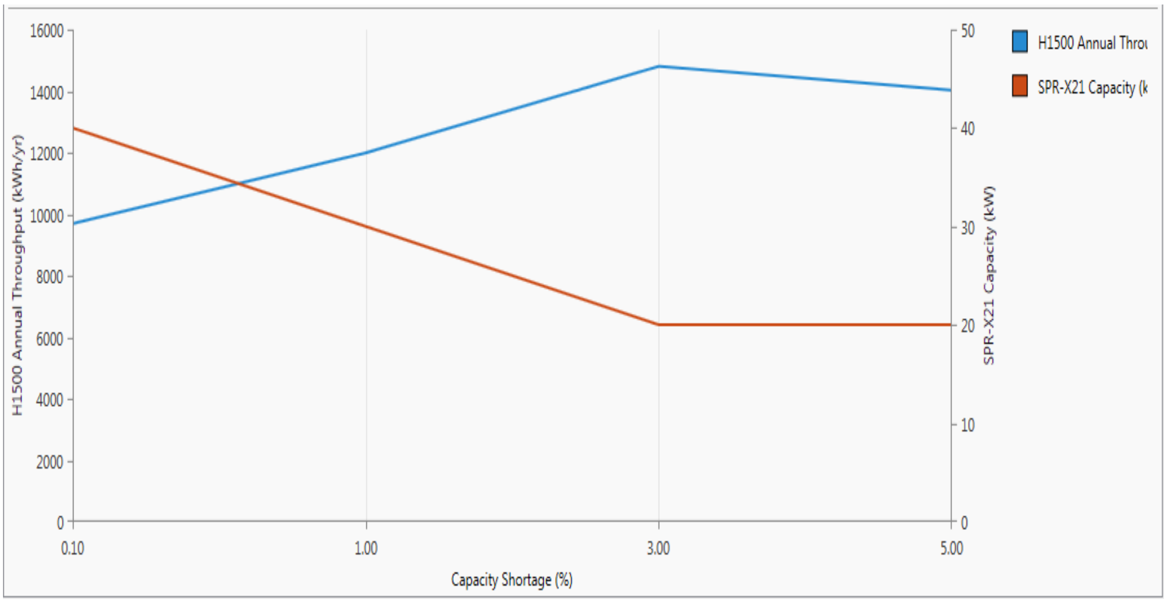
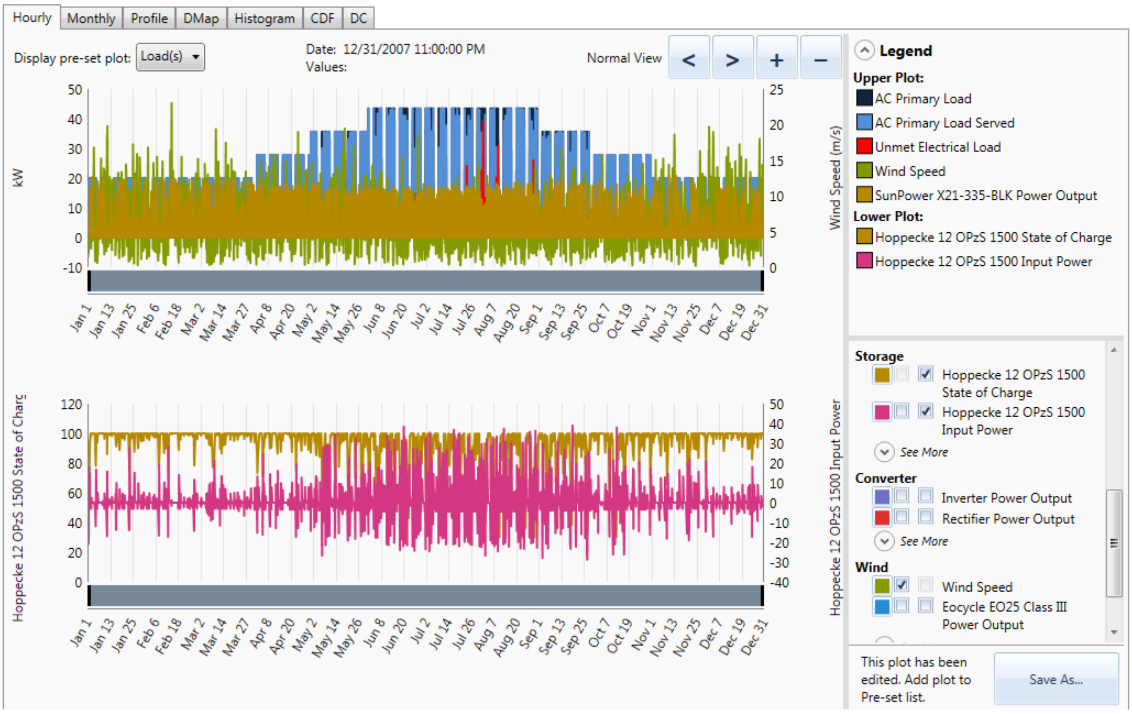


Figure 6. The sensitivity result for hybrid system off-grid between capacity shortage, H1500 Annual Throughput, and PV capacity.

With the exception of when the capacity was 3%, the size of the solar panels was the same when the capacity shortage was 5% but the annual production of batteries was lower. When comparing the four scenarios, as shown in figure 6, we observe that the larger the capacity shortage ratio, the smaller the size of the solar panels and the increase in the annual production of batteries By producing a row of batteries in sufficient quantity (24 batteries), the system's cost was reduced, lowering COE.

Figure 7 shows that the electrical load has been fully covered with a capacity reduction of 5% of the total load, or 3070 kWh/year (this number may be attained by not running just one air conditioner).

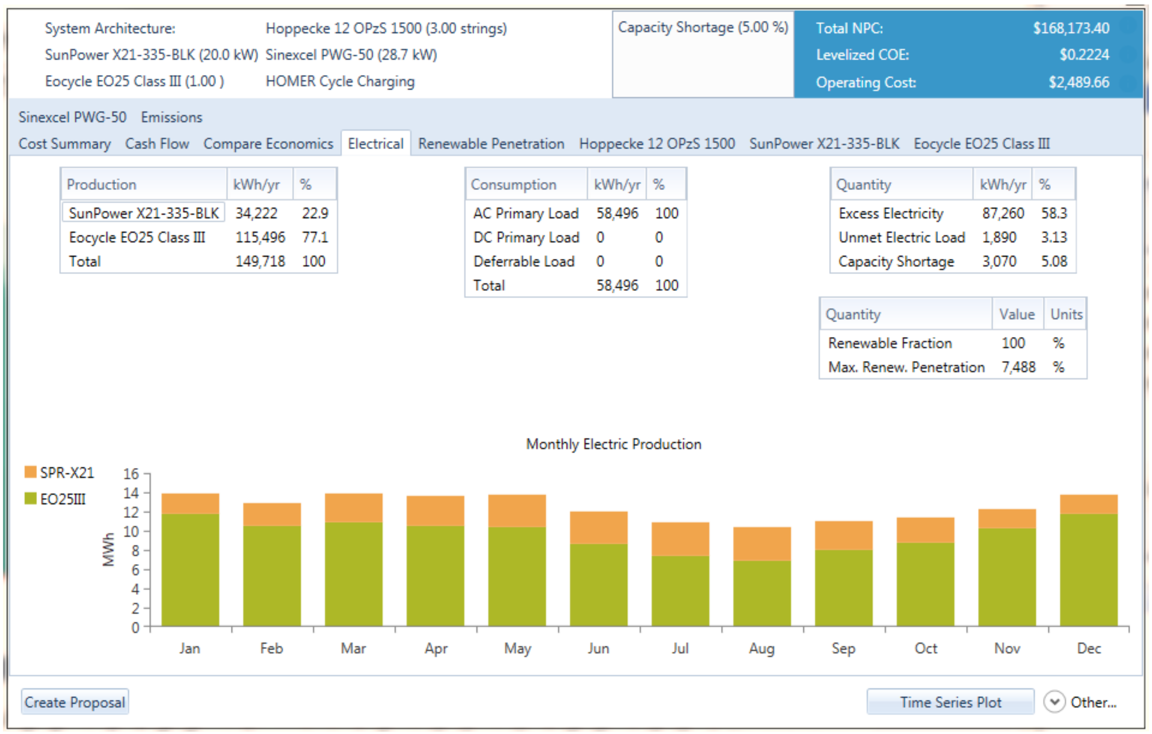


Display pre-set plot: Load(s)

Date: 12/31/2007 11:00:00 PM
Values:

This plot has been edited. Add plot to Pre-set list.

Figure 7. The primary load served, unmet electrical load and storage in battery.



System Architecture: Hoppecke 12 OPzS 1500 (3.00 strings)
SunPower X21-335-BLK (20.0 kW) Sinexcel PWG-50 (28.7 kW)
Eocycle EO25 Class III (1.00) HOMER Cycle Charging

Capacity Shortage (5.00 %)

Total NPC: $168,173.40
Levelized COE: $0.2224
Operating Cost: $2,489.66

Production	kWh/yr	%
SunPower X21-335-BLK	34,222	22.9
Eocycle EO25 Class III	115,496	77.1
Total	149,718	100

Consumption	kWh/yr	%
AC Primary Load	58,496	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	58,496	100

Quantity	kWh/yr	%
Excess Electricity	87,260	58.3
Unmet Electric Load	1,890	3.13
Capacity Shortage	3,070	5.08

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	7,488	%

Figure 8. Monthly electric production for stand-alone selected Winning case.

Figure 8 illustrates the annual energy production, which is 115,496 kilowatt-hours from one turbine with a 25 kilowatt capacity and 34,222 kilowatt-hours from solar panels (22.9%). The storage batteries take care of the remaining portion of the peak electrical load. Additionally, there is extra electricity due to inactivity during non-working hours. One of the negatives of employing a stand-alone system is excess electricity.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

This study sought to determine the techno-economic viability of meeting LCSERS's energy needs with renewable energy sources. Using HOMER software, various renewable energy sources were chosen to power the LCSERS. Along with data from the NASA database connected with HOMER, the facility also collected solar and wind data. The HOMER database was used to extract the technical characteristics of renewable technology. According to the simulation results, using a hybrid renewable energy system with energy from both sun and wind to power the center loads increases system stability and reduces carbon emissions. In this analysis, a hybrid off-grid system was taken into account, and four scenarios for capacity shortage—0.1, 1, 3, and 5%—were run. It was discovered that a hybrid wind-solar system with a battery is always the best choice. NPC (217,277; 193,782; 187,199; 168,173) $ and COE (0.279, 0.250, 0.245, 0.222) $ are the corresponding values. Lower NPC and COE are indicative of a higher capacity shortfall value (an inverse connection). The COE values decrease as the NPC values rise. (Positive relationship). The optimal choice of the off-grid hybrid system is the fourth scenario, where the capacity shortage is 5% because the lowest COE is 0.222 $ and NPC is 168,173$. The system consists of a 20 kW PV, one turbine of 25 kW, and 72 Hoppecke batteries. The wind turbine produces an annual energy of 115,496 kWh, with a share of 77%. The solar panels are 20kW and produce an annual energy of 34.222 kWh with a share of 22.9%, which means that the whole system produces 149,715 kWh/yr. It covers the entire electrical load of the Libyan Center for Solar Energy Research and Studies, which is (165.44 kWh/day). The excess electricity is 58.3%. It can be used to cover the labs' loads. The use of renewable energy reduces gas emissions from the traditional energy system, as a result of using the public electricity network, nitrogen oxides are emitted at a value of 80.9 kg/kWh/y, and sulfur dioxide at a value of 165 kg/kWh /y, and the largest pollution component in the traditional use of energy is Carbon dioxide at a value of 38,164 kg/ kWh/yr.

The HOMER program chooses the optimal system according to the lowest value of NPC, and COE. Therefore, according to this program, the optimal system is scenario D, with capacity shortage of 5%. Based on the results obtained in this study, which show reliance on renewable energy sources for power generation to LCSERS, it could be concluded that renewable energy sources (solar and Wind) can provide the center with a sustainable system to fulfil its demand. The findings of this study can be generalized to other sites with similar climate in the region.

4.2. Recommendations

It is recommended that such a study to be carried out at different commercial buildings to widen and explore the potential of using renewable energy sources in other parts of the country, integrate renewable in the national energy system and realize the benefits to the economic development of the country as well as environmental issues.

Author Contributions: All authors contributed to the study's conception and design. All authors are equal in material preparation, data collection, and analysis. The first draft of the manuscript was written by (Laila Rtemi) and (Wedad El-Osta). All authors have read and agreed to the published version of the manuscript.

Funding: This research did not receive any funds.

Data Availability Statement: This data sets are available at: HOMER Pro. Other data are available at request.

Acknowledgments: Author would like to express their appreciation to all support from the LCSERS and Subrata University. Also they appreciate the anonymous reviewers' helpful comments and revisions.

Conflicts of Interest: The authors declare no conflict of interest.

5. REFERENCES

[1] Al Senussi Mustafa, A. F. The untapped Potential of renewable energy in selected MENA countries: Government plans and strategies for solar thermal heating in Tunisia and Libya (Doctoral dissertation, Wien), 2021.

[2] NASA Atmospheric Science Data Centre, NASA Surface Meteorology and Solar Energy: Available from: http://eosweb.larc.nasa.gov/, Last Accessed 5th March 2013.

[3] Libyan climatic archives, Climate Department, Libyan National Meteorological Centre (LNMC), 2009.

[4] Asheibe, Ali, and Ashraf Khalil. "The renewable energy in Libya: Present difficulties and remedies." the Proceedings of the World Congress, 2013.

[5] Mohamed, A. M. A. Investigation into the feasibility of the utilization of renewable energy resources in Libya. Nottingham Trent University (United Kingdom), 2016.

[6] African Review, Libya can produce more energy from solar power than oil, says research. February 2013.

[7] Kanase-Patil A.B., Saini R.P., Sharma M.P., "Integrated Renewable Energy Systems for Off Grid Rural Electrification of Remote Area", Renewable Energy, Vol. 35, Issue 6, 2010, pp. 1342 – 1349.

[8] Connolly D., Lund H., Mathiesen B.V. and Leahy M., "A review of computer tools for analysing the integration of renewable energy into various energy systems", Applied Energy, Vol. 87, Issue 4, 2010, pp. 1059-1082.

[9] Shreif, Hiba, Wedad El-Osta, and A. Yagub. "Wind Resource Assessment for southern part of Libya: Case Study of Hun." Solar Energy and Sustainable Development Journal 8, no. 1 (2019): 12-33. https://doi.org/10.51646/jsesd.v8i1.18

[10] Nassar, Yasser F., et al. "Dynamic analysis and sizing optimization of a pumped hydroelectric storage-integrated hybrid PV/Wind system: A case study." Energy Conversion and Management 229 (2021): 113744.

[11] Almaktar, Mohamed, and Mohamed Shaaban. "Prospects of renewable energy as a non-rivalry energy alternative in Libya." Renewable and Sustainable Energy Reviews 143 (2021): 110852.

[12] Ali, Alaa FM, Ehab MH Karram, Yasser F. Nassar, and Ahmed A. Hafez. "Reliable and economic isolated renewable hybrid power system with pumped hydropower storage." In 2021 22nd International Middle East Power Systems Conference (MEPCON), pp. 515-520. IEEE, 2021. https://ieeexplore.ieee.org/abstract/document/9686233.

[13] Al-Najjar, H.; Pfeifer, C.; Al Afif, R.; El-Khozondar, H.J. Performance Evaluation of a Hybrid Grid-Connected Photovoltaic Biogas-Generator Power System. Energies 2022, 15, https://doi.org/10.3390/en15093151

[14] Emrani, Anisa, Asmae Berrada, Ameur Arechkik, and Mohamed Bakhouya. "Improved techno-economic optimization of an off-grid hybrid solar/wind/gravity energy storage system based on performance indicators." Journal of Energy Storage 49 (2022): 104163.

[15] Al-Najjar, Heyam, et al. "Hybrid grid-tie electrification analysis of bio-shared renewable energy systems for domestic application." Sustainable Cities and Society 77 (2022): 103538, https://www.sciencedirect.com/science/article/pii/S2210670721008040

[16] Sinha, S., and Chandel, S. S. Review of software tools for hybrid renewable energy systems. Renewable and Sustainable Energy Reviews, 32, 2014, pp. 192-205.