From Fig. 3, we observed that a load varies for different months. According to HOMER simulation results, the off-pick period runs from 12 a.m. to 6 a.m. and from 10 pm to 18 pm while the peak load time is 1 pm to 8 pm

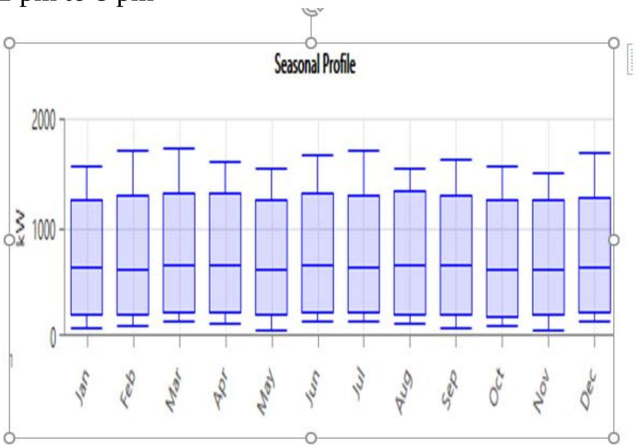

Fig. 4 Monthly load demand profile of Bahir Dar

The monthly average load profile of our system is presented in figure 4. From this diagram, we can observe that the maximum value achieved in March with a value equal to 1725.50 kW. For May, June, November, and July the value is low and is around 1400KW.

3.1.2 Meteorological Data Assessment

In this simulation, we considered mainly the resources of wind speed, Temperature and Solar radiation. The resource analysis is described below:

3.1.2.1 Solar Radiation and Clearness index

The solar insolation of Bahir Dar at a location of 11^o $34.5^{'}$ N latitude and 37^o $21.7^{'}$ E longitude was obtained from the NASA meteorological and solar energy wave sight. Based on the value of the average radiation, the month of the year, and the latitude, HOMER calculates the clearness index which indicates the fraction of the solar radiation striking the top of the atmosphere that makes it through the atmosphere to strike the Earth's surface. The high solar radiation appears in February, March, and April while the low is in July and August. The large value of the clearness index appears within October to May with the maximum value of 0.694 in February. July and August have the least clearness index of 0.495. Fig. 5 and Fig. 6 explain the solar radiation and clearness index of the month.

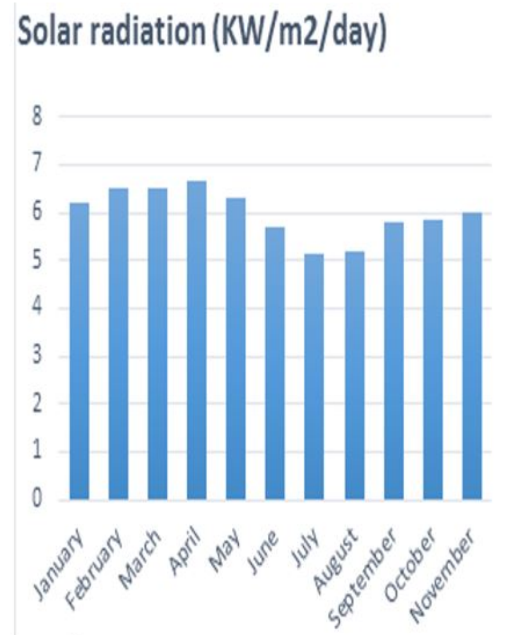

Fig. 5 monthly solar radiation

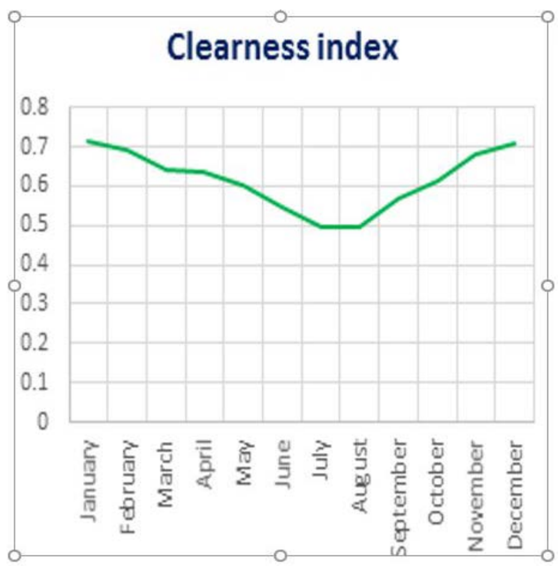

Fig. 6 clearness index of Bahir Dar

3.1.2.2 Temperature

The monthly average temperature of Bahir Dar, which is required for HOMER Software simulation, is obtained from NASA surface meteorology. The annual average temperature of the site is 18.77 ^{o}c. Fig. 7 shows the average monthly temperature of Bahir Dar, Ethiopia.

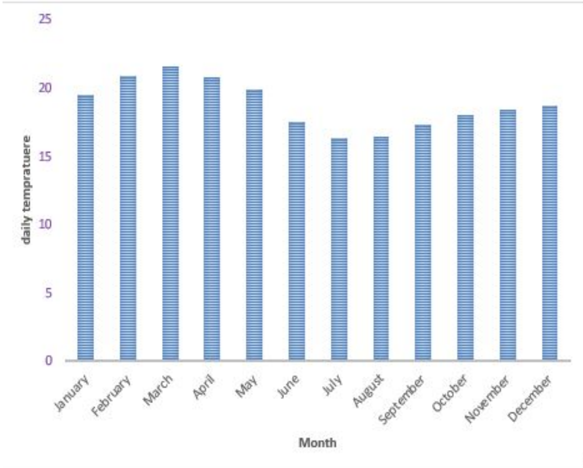

Fig. 7 Average Monthly Temperature Resource of Bahir Dar

3.1.2.3 Wind Resources

On the basis of the longitude and latitude of Bahir Dar, the average monthly wind data from an average of ten years were taken from the NASA database website. The location's average annual wind speed is 3.78 m / s with the 50 m height of the anemometer. Fig. 8 below shows the monthly average wind speed.

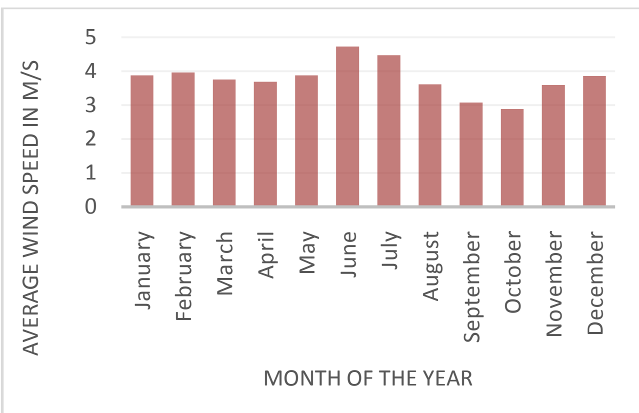

Fig. 8 Wind energy resources (monthly average)

3.1.3 Component Details

The microgrid components are used to generate, convert, store, and supply electrical energy. They are chosen from HOMER Add/Remove window. For the big grid power system, the microgrid is equivalent to a controllable unit, which solves the problem of large-scale grid-connected of clean energy. The study comprises a Photovoltaic panel, wind turbine, Power converter, storage device, and grid as described below.

3.1.3.1 Photovoltaic Panel

In this paper, Generic Flat Plate PV are connected in series. It is manufactured by Generic with efficiency, lifetime, initial capital cost, and operation & maintenance cost of 1KW PV; is taken as 13%, 25 years, $ 1200 , and $ 0 respectively. The derating factor considered for PV is 80 % for each panel for the varying effects of temperature and dust.

3.1.3.2 Wind Turbine

For this paper, Generic 10kw horizontal axis wind turbine, the hub height of 34m, and a lifetime of about 20 years, the initial capital cost of $4,320 and operation and maintenance costs of $400 is considered. The amount of electricity produced by the wind turbine is highly dependent on wind speed availability and variations.

3.1.3.3 Power Converter

The converter's capital cost, replacement cost, and O&M costs for 1 kW systems are respectively estimated to be $700, $550 and $100/year [20].The converter's lifespan is 15 years, 90% inverter efficiency and 85% rectifier efficiency.

3.1.3.4 Battery Storage

Batteries are used in the network as a backup and for maintaining a constant voltage during peak loads or a power shortfall. In this study, lead Acid battery manufactured by Generic with a capacity of 2.4KWh, and 66 V, the initial cost of $300/kwh, operating and maintenance cost $10/kwh, and a lifetime of 20 years is considered.

3.1.3.5 Grid System

The Grid system is used as a backup power element or surplus power absorber. The main grid system feeds power when there is not adequate power from Renewable energy sources such as Solar PV and Wind to meet the energy demand and grid consumes power when excessive power is generated. The selling price of the electricity from the grid is estimated at 0.04$/kWh and the selling back price of electricity from the microgrid is estimated at 0.05$/kWh [21].

3.2.4. Homer Pro Software

HOMER Pro software developed by the U.S, the national renewable energy laboratory (NREL) is a microgrid optimization tool for technical and financial assessments. It is established to model both grid-connected and isolated microgrid using renewable and conventional energy sources to supply loads [22]. To obtain accurate and optimized component sizes, HOMER needs input information such as solar insolation, wind speed, load data, storage, and microgrid component details with their corresponding costs.

4 Optimization Results and Discussion

From the HOMER analysis, the optimum size of microgrid components for our system is mainly selected based on the lowest values of Net Present Cost (NPC), CoE (Cost of Energy), and the Operation and maintenance (O&M) cost. The total NPC of this simulation is $5,912,997. This is the values of all costs incurred during their lifetime minus the present values of all the income it earns during its lifetime. The included costs are capital costs, replacement costs, O&M costs, fuel costs, and emission penalties. So that HOMER calculates the NPC by summarizing the cumulative discounted cash flows in the contract life of each year. On the other hand, COE is the average cost per KWh of energy produced by the system. Homer estimates the Cost of Energy (COE) of the system by using equation (2).

$$\mathrm{COE} = \frac{AnC - Cs}{WT} \qquad (2)$$

Where; AnC - is annualized cost; Cs - is the cost of serving, and WT - is electric energy production. And the HOMER simulation output of COE is then, 0.27217 $/kWh which is indicated in table 2 below. The combination of penalty for capacity shortage and penalties for emissions of pollutants are called O& M cost.

To calculate maintenance and operation cost of a system, the software uses equation (3).

$$C_{om,other} = C_{om,fixed} + C_{cs} + C_{emissions} \qquad (3)$$

Where: $C_{om\ fixed}$ – is the system fixed O&M cost [$ / yr.]; Ccs- is the penalty for capacity shortage [$/yr]; and Cemmissions- is the penalty for emission [$/year]. The operation and maintenance costs (O&M) of our system are $207,355. Table 1 shows NPC, COE and M& O cost values of the system simulated by HOMER pro software.

Table 1. Cost of the optimal system

Costs	Description	Value
Cost of Energy (COE)	Cost per KWh or per unit of energy	$0.27217
Net Present Cost (NPC)	Total life cycle cost for the full lifetime of the project	$5,912,997
Operation and maintenance (O&M)	Cost for operations and maintenance	$207,355

Based on the optimal costs of the system as seen in Table1, the optimal sizing of the components of the Microgrid system is selected from the optimization result of HOMER and depicted in Table 2.

Table 2. Optimal Sizing of the Proposed Microgrid components

Microgrid component	Capacity	Type
PV	750KW	Flat plated PV panel 1Kw type
Wind	500KW	Generic 10kw type
Battery	33String, 2.4KWh	Lead Acid Battery
Converter	650KW	System Converter
Load	1,735.6KWp	Peak Load
Grid	6000KW	Grid

Fig.9 below presents the average monthly electricity production by each microgrid components such as PV, wind and grid. It is clear that all wind energy, solar energy and grid power output vary from season to season, but they always produce enough energy to meet the required city load demand. From the input data it can be estimated that this system generated maximum electricity of 6,399,042kWh/yr from wind, solar and grid and the consumption power by the load is 6,337,657 kWh/yr. The yearly production of electricity by the solar PV, Wind , and Grid system as well as electricity consumption by the load are provided in the Appendix.

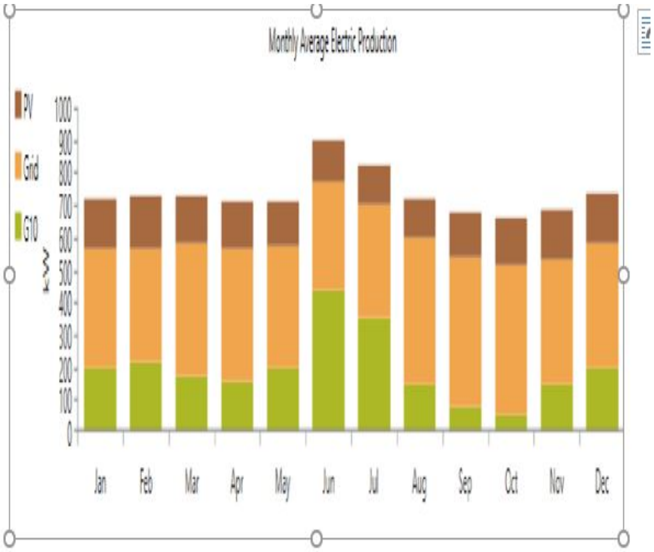

Fig. 9 Monthly average electricity production

5 Conclusion

In this study, the utilization of renewable energy resources including solar PV and wind turbine based grid-connected microgrid system for Bahir Dar city is modelled and sized using HOMER Pro software. There are several parameters taken into consideration when proposing a microgrid system for the city. The residential loads, commercial loads, and community loads are modelled depending on a total load of Bahir Dar city of 15,467kWh per day is determined. Homer Pro is used to optimize the size of microgrid components for solar PV, wind turbine, and storage battery using MATLAB simulation. The simulation process procured in to account the lifetime of the component, cost of the component from manufacturer's websites as well as the available solar insolation, wind speed and temperature of Bahir Dar was downloaded from NASA database with HOMER resource window. Additionally in HOMER pro system, sizing of the components, system configuration, lifecycle of the system, Net Present cost (NPC), Cost of energy (COE), Operation and maintenance (O&M) costs, annual operating cost of the microgrid power system is considered in determining the optimum sizing of microgrid components to meet total modelled load of the city. The simulation results obtained indicate that the grid-connected microgrid system is capable of powering the total estimated load of the city and serve as an appropriate solution to the energy need of Bahir Dar city.

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Appendix

Cost Estimation of Residential, Community, and Commercial loads of the proposed system

Table 4: Total Estimated Load consumption for Bahir Dar City

No	Types Of Load	Total Number	Power Rating	Operating Time	Consumption Kwh/Day
1). Residential Purposes					
1	Lighting	8	60	6	2.88
2	TV	1	120	8	0.96
3	ceiling fun	1	105	8	0.84
4	computer/laptop	1	150	2	0.3
5	Refrigerator	1	150	24	3.6
6	Coffee Maker	1	1000	0.3	0.3
7	Ethiopian Electric Mitad	1	1000	1	1
8	Washing machine	1	400	0.5	0.2
9	water heater	1	3000	0.5	1.5
10	Rice cooler	1	220	1	0.22
11	Iron smoothing	1	1000	1.5	1.5
Considered number of houses		**1500**			
2). Community purposes					
	a). Primary School				
1	Lighting	20	40	6	4.8
2	Security lamps	12	60	12	8.64
3	Submersible water pump	1	420	4	1.68
4	Refrigerator	1	80	8	0.64
5	Television	1	120	7	0.84
6	VCR	1	500	0.5	0.25
7	Space heating and cooling	1	1200	1	1.2
9	Radio communications	1	40	0.5	0.02
10	printer	1	100	1	0.1
11	Computer	1	100	1	0.1
12	Photocopy machine	1	1000	1.5	1.5
	Considered Number of schools	**20**			
	b). Primary health clinic				
1	Vaccine refrigerator	1	60	12	0.72
2	Security lamps	20	60	12	14.4
3	Lighting	20	40	10	
4	Submersible water pump	1	420	4	3.25
5	Refrigerator	1	120	1	0.12
6	Television	1	80	1	0.08
7	Microscope	1	140	1	0.014
8	Medical centrifuge	1	250	1	0.25
	Desk top computer	1		1	200
9	Radio communications	1	40	0.5	0.02

10	Water pump (1500 liters/day	1	100	6	0.6
11	Electric sterilizer	1	1500	2	3
12	25” Color TV	1	130	4	0.52
	Considered number of clinics	**30**			
	c). Churches and Mosques				
1	Lightings	60	60	4	14.4
2	Ceiling Fan	4	50	4	0.8
3	Sound system	8	200	4	6.4
4	PC	4	200	4	3.2
5	LCD	2	270	3	1.62
6	Charger	10	10	4	0.4
		20			
	Considered Number Chu.& Mos.				
3. Commercial and agricultural purposes					
1	Shops	10	500	8	40
2	Small manufacturing units	4	2000	12	96
3	Street lights	5	30	10	1.69
4	Hotel and Restaurants	10	800	8	67
5	Water pump	8	745.6	5	29.824
6	Irrigation pump	4	1491.2	5	29.786
Considered number		**8**			

Yearly Electrical energy production of the proposed system

Table 1 Production and consumption scenario

a). Electricity Production summary		
Component	Production (KWh/yr)	Percent
Generic flat plate PV	1,227,703	19.2
Generic 10KW	1,701,431	26.6
Grid Purchases	3,469,909	54.2
Total	6,399,042	100
b). Electricity Consumption summary		
Component	Consumption (KWh/yr)	Percent
AC primary load	5,645,455	89.1
DC primary load	0	0
Grid sales	692,203	10.9
Total	6337,657	100