Supplementary Materials

Hybrid Renewable Energy Microgrid for a Residential Community: A Techno-Economic and Environmental Perspective in the Context of the SDG7

Power Curve of Wind Energy System

The wind turbine converts the kinetic energy of the wind into direct current (DC) or alternating current (AC) electricity by a particular power curve. A graphical representation of power output versus wind speed at hub height is generally called a power curve. Figure S1 shows the typical power curve characteristics of a wind turbine [55,59].

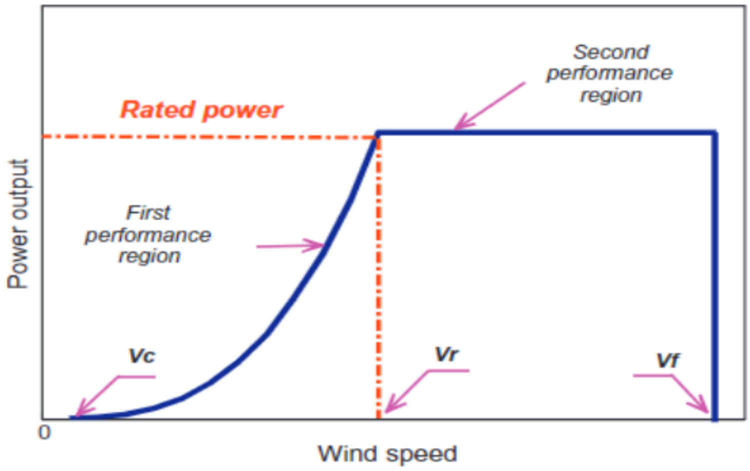

Figure S1. The power curve of a wind turbine representing wind turbine performance characteristics.

Data Inputs for Simulation

When modeling and designing a hybrid renewable energy microgrid (HREM), a detailed assessment of the site is required considering the electrical load data, available potential renewable data, cost, and technical data of the components.

Load Assessment

The hourly load profile for the whole year is shown in Figure S2, which also shows a peak load of 20.46 kW for January.

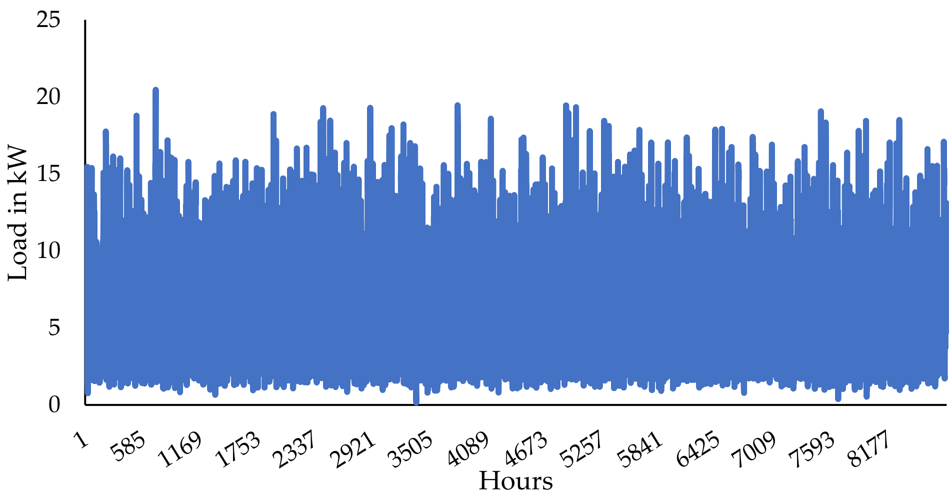

Figure S2. Hourly load profile of the community for the whole year.

Resource Assessment

The hourly profile for solar radiation is shown in Figure S3, and it is understood that the solar radiation potential is highly variable, and in some hours of the day, the recorded solar radiation is quite low. For further understanding of this variation, the DMap of solar radiation was plotted for the study location and is shown in Figure S4. From the DMap, it is observed that approximately 9–11 hours of solar radiation is possible on any given day in a year, and the hourly variation was observed to be in the range of 0.004 kW/m² to 1.6 kW/m².

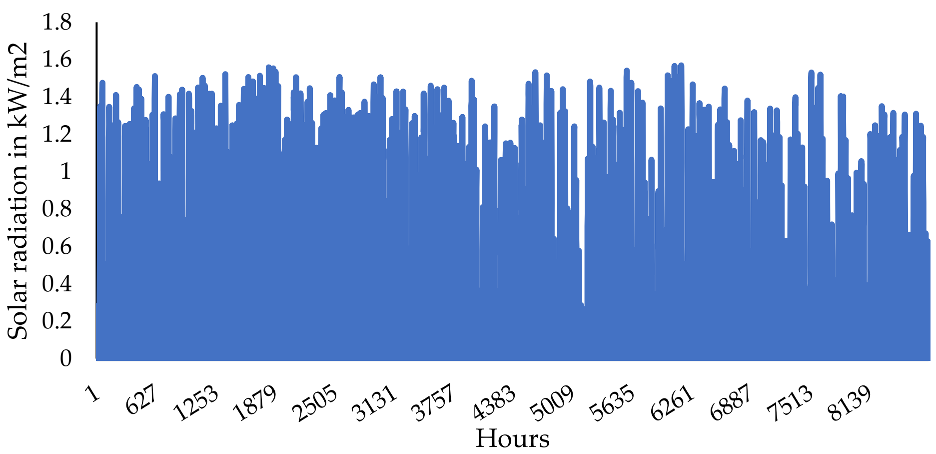

Figure S3. Hourly solar radiation potential for the whole year.

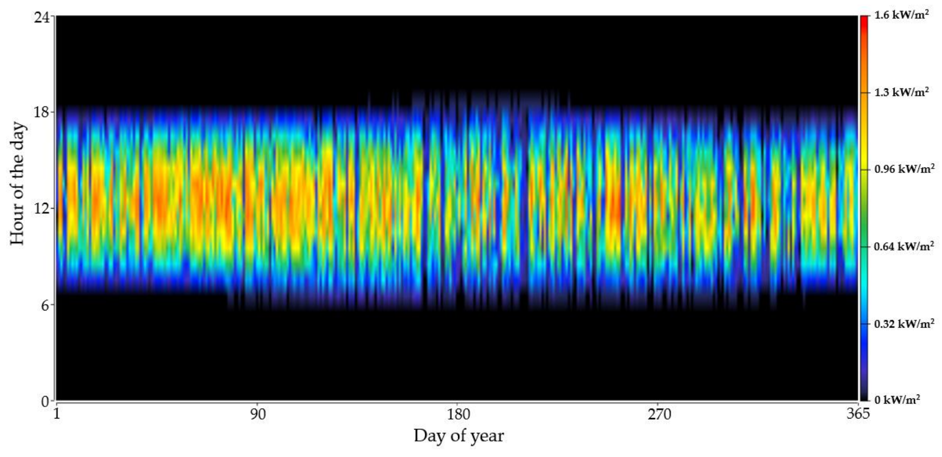

Figure S4. DMap showing the solar radiation potential in hours.

The hourly profile for the wind speeds is shown in Figure S5. It is understood that the wind potential is highly variable. For further understanding of this variation, in Figure S6, the DMap of wind speed for the study location is given. From the DMap, it was observed that wind speeds are possible throughout the day but with a huge variation. The range of variation in wind speeds was observed to be between 0.05 m/s and 11.11 m/s for a given day.

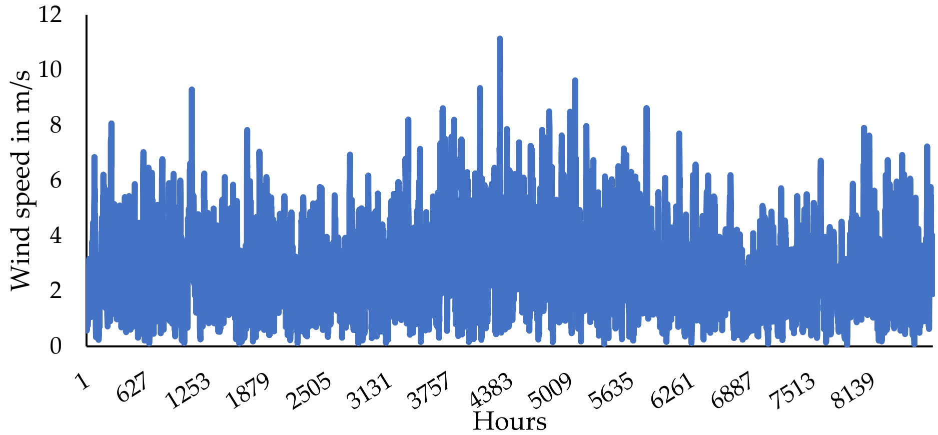

Figure S5. Hourly wind speeds available for whole year.

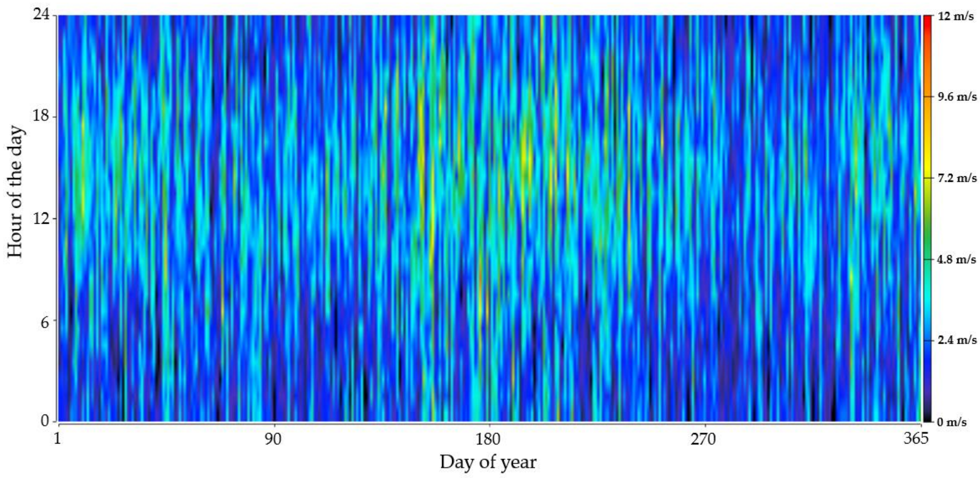

Figure S6. DMap showing the wind potential in hours.

HREM Components Input Data for Simulation

For carrying out the techno-economic optimization in HOMER, the simulation tools demand the the technical and cost data of the various components used in HREM (see in Table S1).

Table S1. Technical and cost details of the components used in designing the HREM.

Parameter	Values with units
PV system	
Model	Generic flat-plate PV
Peak power	1 kW
Derating factor	80%
Slope	11.28 °
Azimuth	0° W of S
Ground reflection	20%

Temperature coefficient	−0.5%/°C
Nominal operating temperature	47 °C
Efficiency at the standard test condition	13%
Lifetime	25 years
Capital cost	$2500
Operating and maintenance cost	10 $/kW
Replacement cost	2500 $/kW
Wind turbine	
Model	Generic wind turbine
Rated power	3 kW
Hub height	17 m
Lifetime	20 years
Capital cost	$18,000
Operating and maintenance cost	$180
Replacement cost	$18,000
Battery	
Model	Generic Lead Acid
Nominal capacity	1 kWh
Nominal voltage	12 Volts
Maximum capacity	83.4 Ah
Roundtrip efficiency	80%
Capital cost	$300
Operating and maintenance cost	$10
Replacement cost	$300
Lifetime	10 years
Diesel generator	
Model	Auto size Genset
Input fuel	Diesel
Lifetime	15,000 hours
Capital cost	500 $/kW
Operating and maintenance cost	0.030 $/operational hour
Replacement cost	500 $/kW
The density of input fuel	820 kg/m^3
Carbon content in input fuel	88%
Sulfur content in input fuel	0.4%
The lower heating value of input fuel	43.2 MJ/kg
Inverter	
Model	Generic system inverter
Capacity	1 kW
Efficiency	95%
Lifetime	15 years
Capital cost	$300
Replacement cost	$300
Rectifier	
Model	Generic system rectifier
Relative capacity	100 %
Efficiency	95%
Capital cost	$300
Replacement cost	$300

Results

The net present cost (NPC) method is usually used to understand the economics of the HREM configurations. NPC for each component used in each the HREM configuration is shown in Figure S7.

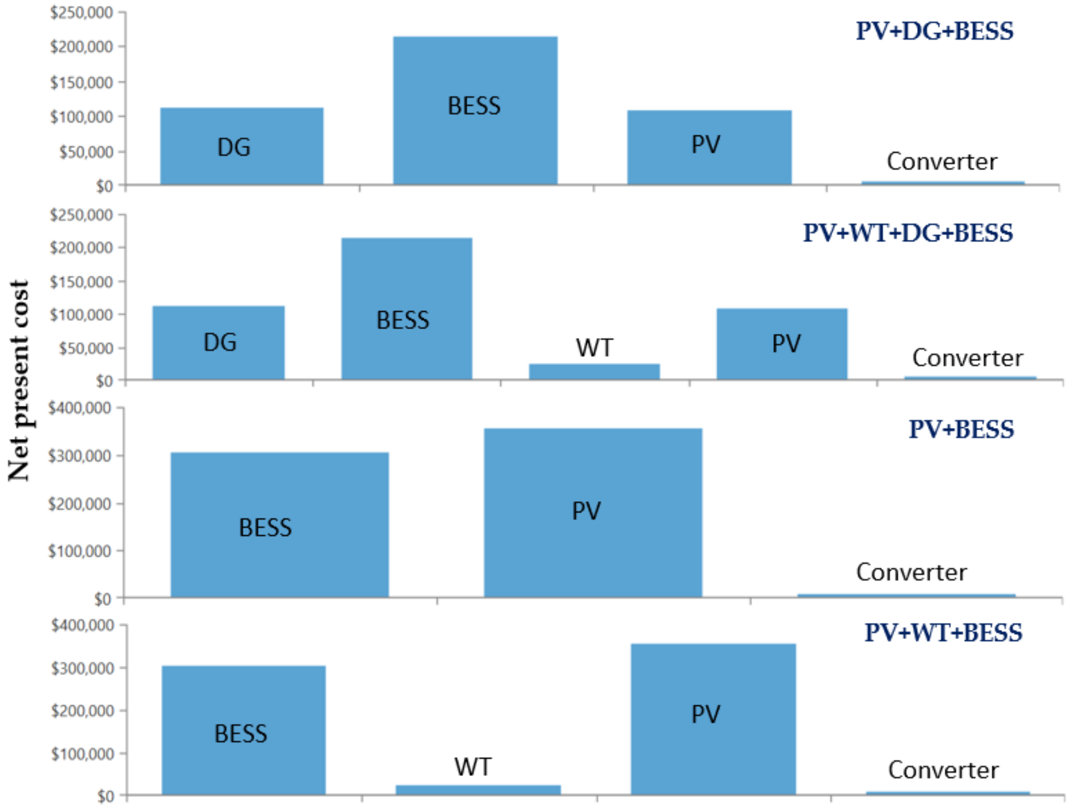

Figure S7. The net present cost of the four feasible HREM configurations.

In Figure S8, the primary load in kW and the load served by the proposed HREM are given. From Figure S8, it is observed that the AC primary load of the community was clearly served by the HREM with the PV + DG + BESS configuration.

The DMap shown in Figure S9 shows that the PV power production is mostly in between 06:30 and 18:00 each day. It is also observed that the PV array had a mean output per hour and per day of 8.6 kW, and 206 kW, respectively. The PV array was operated with a capacity factor of 21.3%. The total operating hours of the PV array were 4387 h/y, and its total energy production was 75,317 kWh/y. Overall, the PV penetration was observed as 125%, and the levelized cost of electricity for PV alone was observed as 0.0817 $/kWh.

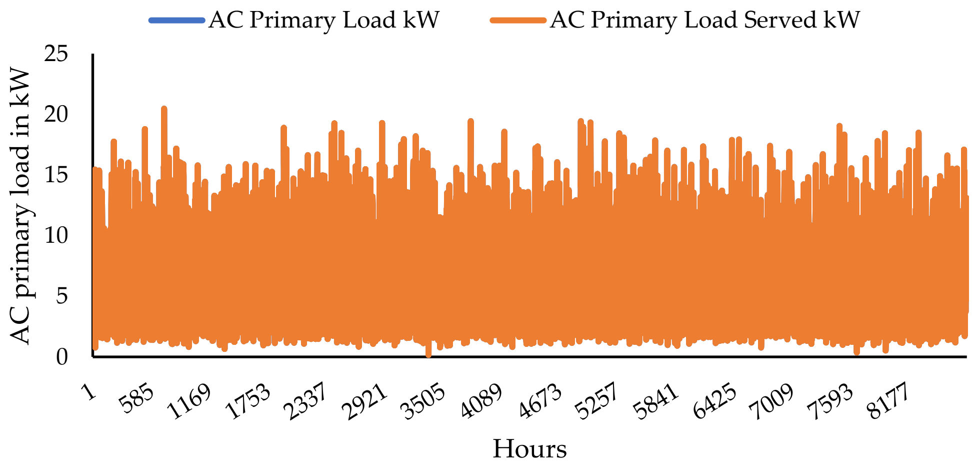

Figure S8. Primary load and primary load served patterns by the PV + DG + BESS HREM configuration.

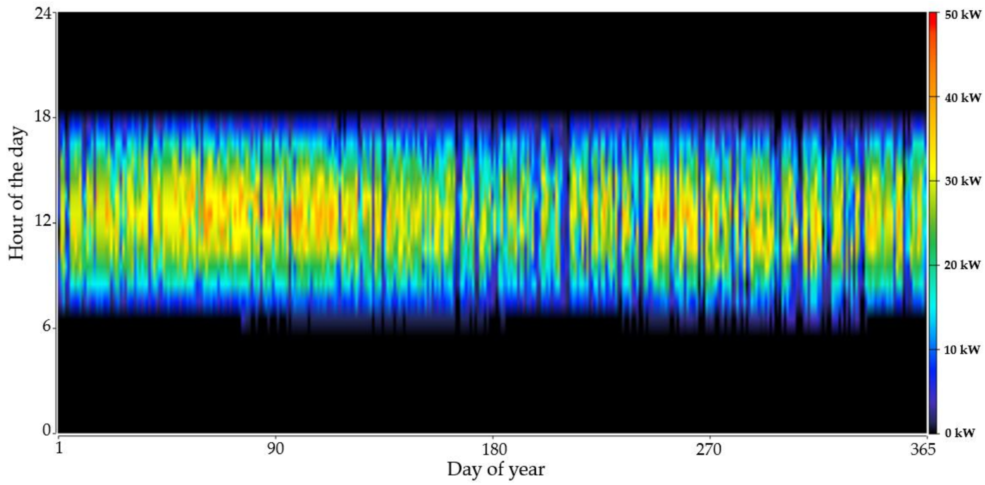

Figure S9. DMap showing the solar PV power production hours in the PV + DG + BESS HEEM configuration.

The operating hours of a DG were illustrated in DMap and are shown in Figure S10. The daily profile of diesel fuel consumption is shown in Figure S11 for each month. It is observed that approximately 4415 L of fuel was consumed.

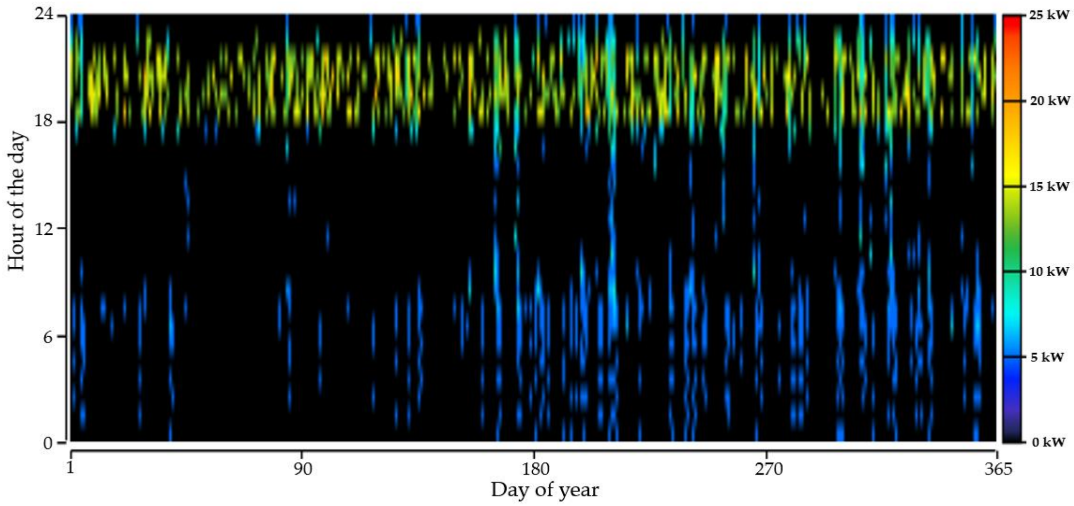

Figure S10. DMap showing the power production hours from the diesel generator.

Figure S11. Diesel fuel consumption in the PV + DG + BESS based HREM configuration.