Energy Prospects for Sustainable Rural Livelihood in Vijayapur District, Karnataka India

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1 Introduction

Agriculture and its allied sectors significantly require electricity for irrigation and farm mechanization [1]. However, grid supply in rural India lacks both in quality and quantity [2]. It is hampering income generating activities. Moreover, women and children in rural area are spending 3–5 h/day on collection of basic needs. More often, they are exposing too many threats like; health hazards, assaults and snake bites, etc. Indeed, a sound technology which could provide sustainable energy for rural consumers is essential infrastructure to improve their livelihood [3].

Renewable energy-based power supply: Solar photovoltaic (SPV) and small wind turbine generator (SWTG) are gaining due importance in current scenario to supply power for remote and rural demands [4]. Energy use and its management are closely linked to climatic and socio-economic status of that place. Furthermore, designing and planning of power supply depend on the current and future programs. Thus, energy approaches for sustainable development should not only be compatible with, but also contribute towards regional development [5].

Rural energy provisions certainly necessitate sound strategy and administration judgments on three factors such as resources, economics and environment. In this regard, a study is conducted in rural areas of Vijayapur district (East latitude 15° 50′–17° 28′, North longitude 74° 59′–76° 28′) Karnataka India. Vijayapur district is one of the agricultural potential regions of Karnataka and endowed with natural

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resources. District needs attention to boost up the sustainable livelihood in the rural areas [6]. Major infrastructure essential to carry out the agri and its allied sectors is a reliable power supply. Thus, the objectives of this study is: to identify on-farm and off-farm opportunities for sustainable livelihood, to understand their energy consumption patterns, assess renewable resource potential for power generation and finally propose a sustainable energy option for rural applications.

2 Methodology

Renewable resources potential assessment and consumers' power demand with annual consumption pattern are essential aspects for designing techno-economical viable power supply. The necessary meteorological time-series data includes solar radiation, wind speed and temperature data is collected from automatic weather station at regional agricultural research station (RARS), Vijayapur, Karnataka India. Electricity consumption data composed from field survey. MATLAB is used to analyse real-time meteorological time-series data, and findings are explored according to [7]. The results of solar and wind resources analysis are used in HOMER software [8] to obtain optimal size of solar photovoltaic (SPV), small wind turbine generator (SWTG) and solar-wind hybrid energy (SWHE) systems for electrification of typical farmhouse load.

2.1 Solar Power Potential in Vijayapur

The time-series solar radiation data for past five years (2015–2019) is processed to study the solar potential in the Vijayapur location [7]. Statically processed monthly variation of temperature and mean solar potential at study location is presented in Table 1. District experiences 320–330 clear sunny days around a year and temperature variation observed between 7.1 and 41.3 °C. In brief, an average solar energy varies from 3.2 to 6.78 kWh/m^2/day, and it is available for 10–11 months over the year. Solar data analysis also depicts that, in study location, August–September is lean period for application solar potential.

Variation of average solar potential over five years is processed, and findings are presented in Table 2. Table 2 depicts that, seasonal variation of solar radiation is approximately same for most of the months over five years, except during year 2017, it is low (2.89 kWh/m^2/day) (Table 2).

Table 1 Monthly variation of solar potential and temperature at Vijayapur

Month	Solar energy potential kWh/m^2/day	Temp (°C)	
		Low	High
Jan	5.29	8.2	35.2
Feb	5.81	12.9	37.1
Mar	6.51	20.5	39.6
Apr	6.64	21.6	40.7
May	6.34	21.0	41.3
Jun	4.94	20.9	34. 1
Jul	3.86	20.3	33.2
Aug	3.96	21.1	32.7
Sep	3.78	18.3	33.1
Oct	4.46	19.3	33.4
Nov	4.55	20.3	31.2
Dec	4.79	7.1	32.7

Table 2 Monthly variation of daily solar potentialand temperature at Vijayapur

S. No.	Season	Total horizontal radiation (kWh/m^2/day)				
		2015	2016	2017	2018	2019
1	Summer	6.32	6.37	5.85	5.92	6.22
2	Monsoon	4.01	3.9	2.89	3.8	4.12
3	Winter	5.20	5.13	4.77	5.2	5.10

2.2 Wind Power Potential in Vijayapur

The statically processed wind potential characteristics of Vijayapur resource at 10 and 20 m heights are presented in Table 1. It presents monthly and annual mean wind speed, Weibull parameters and wind power density at Vijayapur resource. From Table 1, it is found that annual mean wind speed 4.55 m/s and wind power density 109 W/m^2 designate that resource is good for power applications. The monthly mean wind speeds over a year are >3.3 m/s, including all other parameters: $k > 2$, c=5 m/s, $V_{max} = 7.1$ m/s and power density 110 W/m^2 presents that, Vijayapur resource is feasible for wind power applications. In addition, the wind regime is fair enough at 20 m height.

Table 3 Monthly and annual mean wind speed, Weibull parameters and wind power density at Vijayapur resource

Month	Mean wind speed (m/s)		k-parameter		c-parameter (m/s)		V_{max} (m/s)		WPD (W/m^2)	
	10 m	20 m	10 m	20 m	10 m	20 m	10 m	20 m	10 m	20 m
Jan	3.26	3.47	1.61	1.91	3.42	4.02	5.63	5.86	45.82	65.37
Feb	3.28	3.69	1.6	1.89	3.66	4.31	6.08	6.32	58.42	67.67
Mar	3.73	4.45	1.67	1.97	4.17	4.91	6.71	7.03	77.34	92.16
Apr	4.25	4.33	2.19	2.59	4.54	5.28	6.12	6.58	62.83	88.49
May	4.83	5.73	2.89	3.41	5.42	6.27	6.51	7.18	99.34	159.94
Jun	5.57	6.61	2.88	3.4	6.06	7.01	7.28	8.03	145.06	191.82
July	7.00	7.57	3.1	3.66	7.69	8.9	9.04	10.02	248.28	364.3
Aug	6.45	6.67	2.78	3.28	6.91	8.2	8.4	9.24	188.73	273.08
Sep	5.38	5.79	2.31	2.73	6.07	7.05	7.96	8.63	144.24	222.74
Oct	3.74	4.56	1.5	1.77	4.14	4.9	7.3	7.52	88.8	130.08
Nov	3.51	4.42	1.52	1.79	3.89	4.6	6.77	6.99	63.8	92.37
Dec	3.42	3.73	1.27	1.51	3.45	4.14	7.24	7.25	74.43	77.59
Annual	4.55	5.18	2.11	2.49	4.98	5.8	7.08	7.55	108.09	152.34

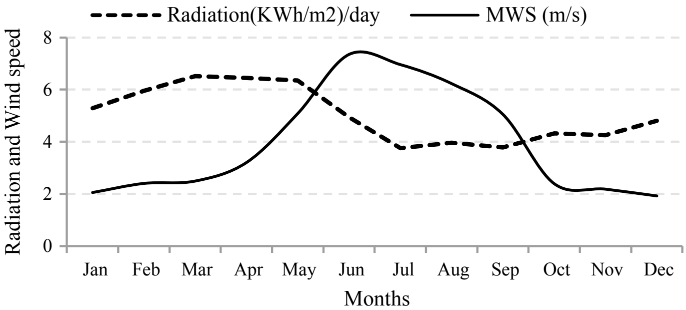

Fig.1 Complementary nature of wind and solar potential

2.3 Wind-Solar Hybrid Energy Potential in Vijayapur

From the wind and solar resource analysis, it is found that both the potentials are fortunately complementary in nature over the day and year. Variation of wind and solar potential is shown in Fig. 1. This kind of opportunity can be effectively utilized by integrating them in SWTG-SPV hybrid energy system. The power system can exploit inter dependent strengths of both SPV and SWTG systems [8].

2.4 On-Farm and Off-Farm Opportunities

In the study area, there are ample of small-scale opportunities that have potential to generate employment and sustainable livelihood for rural population. Prospectus suitable for rural public has been identified both on-farm and off-farm sectors and are listed as:

On Farm Activities: The sustainable agricultural allied activities in the study area include:

- Animal husbandry: The climatic conditions and resources are ideal for dairy development. Dairy value chain is currently not organized and underdeveloped potential in the district. The waste land development and water management programs are necessary for developing more of fodder areas to support the dairy sector in the region.
- Poultry: Resources such as waste land, barren land and meteorological conditions are in favour of poultry farming. However, poultry farming is not planned and developed in the district. Its development could bring speedy economy and social transformation among rural culture.
- Horticulture: Potential land, water supply and excellent climatic conditions are more suitable for fruits and vegetable farming. In the district, there is a scope for vineries, jam, packed fruit and vegetables.

- Floriculture: Access to the flower trading places nearby, small landholdings and water resources in the district are suitable for flower cultivation.
- Fisher: Five rivers in the district provide huge scope of inland and fresh water for fishing. There is scope for ornamental fish breeding. Sericulture: Climatic conditions and small landholdings are suitable for mulberry cultivation and silk-worm rearing.
- Food and Beverages processing: Man power and agri-resources such as crops, vegetables and fruits support this sector.

Load demand and energy consumption pattern of above-listed activities are collected during walk-in survey. The load demand and energy consumption pattern of cattle farming (animal husbandry) are discussed, and it is presented in subsection E.

Non-farm Activities: The major off-farm activities are listed with major electric fixtures required to process the activity. The average power demand for lighting and cooling fixtures is between 500 and 1000 W.

- Milling and grinding: Major electric fixture is grinder of capacity 2–5 HP.
- Tailoring and sewing: Major electric fixture is universal motor of 50 W.
- Repairing and servicing: Form requires welding and soldering machines of 1 kW.
- General shop including grocery: Arrangement requires major equipment refrigerator for cold drinks (1 kW).
- Health clinic: Essential equipment in setup is sterilizer (1 kW).
- Education and training centres: TV, computer, printer and photocopier are the necessary gadgets (2 kW) in the system.
- Home restaurant, mix-grinder and refrigerator are the major appliances (1.1 kW).
- Carpentry shop: saw, vertical saw, levelling and drilling machines (1–2.5 kW), wood and metal grinders with 1–2.5 HP motors.

The listed sectors need minimum infrastructure, manpower and financial support. The qualified unemployed youth capacity in the district is more appropriate to run the sectors. The reliable electric supply and training are bottle neck to achieve self-employment in the region.

3 Electricity Consumption Pattern

Load demand and electricity consumption patterns are paramount in designing renewable-based power systems. Representative electricity consumption pattern in cattle farmhouse located near Vijayapur is considered for the present study. Farming requires water stock of 2000–2500 L/day, and it is more during summer season. The peak load of farmhouse on the utility grid is 2 kW. The electric gadgets with power rating and working duration are presented in Table 4.

The energy consumption pattern is simple and almost fixed. Load profile at 30 min time resolution over 24 h on typical day in summer season is shown in Fig. 2. The

Table 4 Electric appliances in farmhouse with capacity and consumption over a day

Sl	Electric appliance	Quantity	Power rating	Total watt	Duration (h)
1	CFL	8	11	88	8–10
2	CFL	5	5	25	6–8
3	Fluorescent tube	4	40	160	5–7
4	Ceiling fan	5	60	300	0–12
5	Mix grander	1	175	175	20–30 min
6	Television	1	100	100	2–5
7	Refrigerator	1	100	100	50% duty cycle
8	Water pump	1	740	740	1–2
9	Other	1	100	100	2
	Total	27	–	1788	–

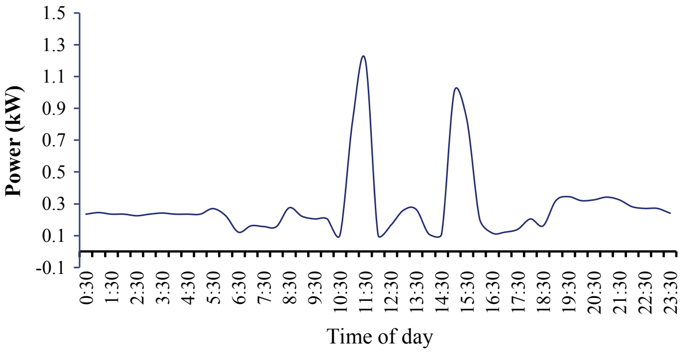

Fig. 2 Hourly load demand during typical day in summer

monthly energy consumption pattern depends on seasons around a year, and it is more during summer season. Monthly energy consumption pattern during year 2018 is shown in Fig. 3.

4 Design and Techno-Economic Analysis of Power Systems

Techno-economic analysis is paramount to promote technology for power applications. HOMER software is used to obtain optimal size of renewable energy-based standalone SPV, SWTG and wind-solar hybrid energy systems [9, 10]. The power systems are designed for the load demand of farmhouse load discussed in subsection D. The loss of power supply probability (LPSP) is estimated to analyse the technical viability of the power systems. It is evaluated using Eq. (1).

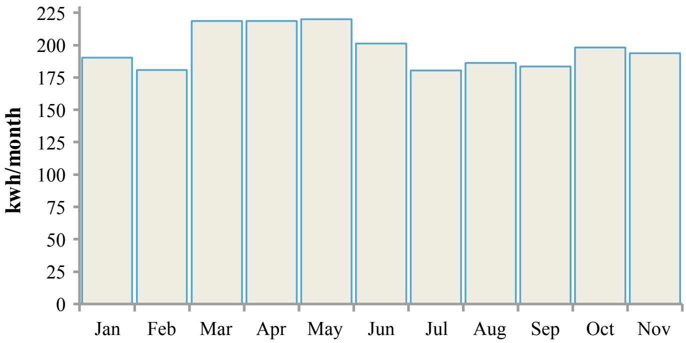

Fig.3 Monthly energy consumption at farmhouse

$$\text{LPSP} = \frac{\text{Total power dificit over a year}}{\text{Total power produced over year}} \tag{1}$$

Economic analysis is crucial in promotion of renewable power system for standalone applications. The well-known cost parameters such as capital cost (CC), life cycle cost (LCC), annualized capital cost (ALCC) and unit cost of energy (UCE) parameters are estimated [9]. The cost and other necessary parameter used in the system configuration and cost estimation model are for FY: 2018–19 and no benefits from the government are considered. The whole capital costs of systems are assumed to be furnished from the loan. The optimum size of SPV, SWTG and hybrid system in terms of number of SPV modules, SWTGs and battery bank required to satisfy loss of power supply probability (LPSP) required by costumer are obtained.

HOMER software is used to design standalone SPV, SWTG and wind-solar hybrid energy systems. The optimal system configurations having number of SPV modules (NPT), SWTG (NWT) and batteries (NBT) at desired value of LPSP are evaluated. The optimal sizing results obtained at 2% loss of power supply probability (LPSP) for standalone SPV, SWTG and hybrid power system with different cost parameters are presented in Table 5.

Table 5 Optimum sizing results for standalone SPV, SWTG and hybrid systems

System type	System configuration			Hybrid system costs				LPSP (%)
	N_{PT}	N_{WT}	N_{BT}	CC (Lakh)	LCC (Lakh)	ALCC (Lakh)	UCE (Rs./kWh)	
SPV	12	Nil	18	5.52	13.81	1.31	10.50	1.91
SWTG	Nil	10	14	9.12	15.84	1.14	26.18	1.98
Hybrid	8	2	6	3.59	6.26	0.43	9.10	1.72

5 Results Analysis and Discussion

District endowed with rich solar and wind potential. Wind and solar potential are compliment in nature. Vijayapur district has plenty of opportunities in small-scale farm and non-farm sectors. During survey, it is observed that in the district, rural families spend around 10% of their income on domestic energy need, about 80% of rural population distrust the grid supply and around 25% of them are willing to pay Rs. 6–10/kWh for reliable electricity. Ultimately, the lack of access to viable electric supply significantly diminishes the opportunities. Thus, there is a need of assured electricity for income generation to ensure sustainable livelihood and environmental security in the district.

HOMER software is used to design standalone solar photovoltaic (SPV), small wind turbine generator (SWTG) and wind-solar hybrid energy systems. The optimal system configurations having number of SPV modules (N_{PT}), SWTG (N_{WT}) and batteries (N_{BT}) at desired value of LPSP and other system constraints are obtained. The optimal sizing results obtained at 2% loss of power supply probability (LPSP) for standalone SPV, SWTG and hybrid power system are presented in Table 6.

Capital cost (CC), life cycle cost (LCC), annualized capital cost (ALCC) and unit cost of energy are estimated and presented in Table 5. It is obvious from Table 5 that both SPV and SWTG system configurations resulted in a higher annualized capital cost (ALCC) compared to the wind-solar hybrid energy system. The critical analysis made on these options highlights that the wind-solar hybrid system seems to be more feasible in terms of techno-economic performance.

The costs of electricity produced by hybrid system are relatively less (9.10 Rs./kWh) as compared to SPV and SWTG systems (Rs. 10.50/kWh and Rs. 26.18/kWh, respectively) in realizing same LPSP. Further, hybrid energy system requires smaller size of renewable generators and less battery capacity. Thus, hybrid system is techno-economically feasible for electrification of farmhouse.

In renewable energy technologies, local skills and knowledge can play essential factors to finance, install, operate, maintain and repair the equipment. It lowers the production and maintenance costs, creates prosperity within the benefited community and increase the social acceptance of the developed technology. It certainly creates self-employment and prevents the migration of youth in to nearby states. Furthermore, it helps in overcoming the cultural barriers and empowers the poor, cutting the reliance on subsidies and hand-outs from NGOs.

6 Conclusion

Electricity to ensure sustainable livelihood in rural areas is essential infrastructure. Study conducted on renewable resources at Vijayapur highlights that study area is endowed with rich wind and solar potential. Techno-economic performance analysis on SPV, SWTG and hybrid system revelled that the climatic condition is viable for promotion of SPV and wind-solar hybrid energy system for rural small-scale power applications. The proposed power systems require low/no maintenance cost, but initial investment is unaffordable for rural potential consumers. Financial support from the government for installation of power system is essential.

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References

1. A. De1, Renewable energy sources for the development of rural India. Int. J. Eng. Sci. Invent. **3**, 2319–6734 (2014)
2. Department of Agricultural Research and Education by Ministry of Agriculture, April, 2018.
3. D.K. Subramania, T.V. Ramachandra, Aspects of Agriculture and Irrigation In Karnataka Energy Research Group Centre For Ecological Sciences, Researcg article Indian Institute of Science, Bangalore 560 012, India (2016)
4. J. Charles Rajesh Kumar, M.A. Majid, Renewable energy for sustainable development in India: Current Status, future prospects, challenges, employment, and investment opportunities. Energy Sustainab. Soc. **10**, Article number: 2 (2020)
5. T.V. Ramachandra, Ecologically sound energy planning strategies for sustainable development (IISc)", Humanity Development Library, Versio - 2.0
6. District Profile- Vijayapur, Karnataka Global Agribusiness & Food Processing Summit (2019)
7. T.V. Ramachandra, Solar energy potential assessment using GIS. Energ. Educ. Sci. Technol. **18**(2), 101–114 (2007)
8. G.L. Johnson, *Wind Energy Systems* (Prentice Hall Inc. Englewood Cliffs, N.J., 1985); J.V. Seguro, T.W. Lambert, Modern estimation of the parameters of the Weibull wind speed distribution for wind energy analysis. J. Wind Eng. Industr. Aerodynam. **85**(3):75–84 (2002)
9. M.A. Mohamed, A.M. Eltamaly, A.I. Alolah, Sizing and techno-economic analysis of stand-alone hybrid photovoltaic/wind/diesel/battery power generation systems. J. Renew. Sustainab Energy, **7**, Article ID 063128 (2015)
10. M. Kolhe, Techno-economic optimum sizing of a stand-alone solar photovoltaic system. IEEE Trans. Energy Convers. **24**(2), 511–519 (2009)