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DECENTRALIZED RENEWABLE ENERGY OPTIONS FOR WESTERN GHATS

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ABSTRACT

Electricity is essential for economic and social development of a region. Dependence on the fossil fuel resources for electricity generation is eroding the resources at faster rate apart from large scale pollution of land, water and air environment. Electric energy generation from renewable energy resources (wind and solar) plays a pivotal role in the region's development, while combating global warming through the reduction of greenhouse gas (GHG) emissions. The current communication explores the potential of available renewable energy resources in Western Ghats (WG) with undulating terrains and relatively good vegetation cover. Most taluks in the WG region with solar insolation>5kWh/m^{2}and hilly terrain experiencing wind >3 m/s are most suited to decentralized electricity interventions, which would ensure livelihood prospects through availability of electricity throughout the year. Sufficient land is available as the estimate indicate about 1-2% of current wasteland is adequate to deploy decentralized electricity generation for meeting the current electricity demand. High wind power density can meet peak power deficiency in the states of WG region. Seasonal variability analysis of solar insolation and wind speeds across taluks gives the insight to generation scheduling and optimum grid operation. Decentralised energy generation using available wind and solar energy resources can meet the regional demand by reducing the transmission losses and stress on central grid.

The government support and encouragement for decentralized rooftop generation using Solar Photovoltaic (SPV) would significantly contribute to meet the present and future electricity demand of the region. A Generation Based Incentive (GBI) would encourage decentralized electricity generation at individual rooftops. Some of the other initiatives to *be taken are 1) solar public and road lighting, 2) Renewable Energy (RE) based generation in government organizations and infrastructure, 3) implementation of solar rooftop generation in existing govt. building and financial encourage for the same. Switching over to RE technologies would also help in bringing down GHG emission and pressure on dwindling stock of fossil fuels.*

KEYWORDS: Insolation, land use, wasteland, thermal and photovoltaic, photoelectric effect, semiconductor device.

INTRODUCTION

Electric energy accounts for the major part of total energy consumption in India. Electricity plays a pivotal role in all sectors of the society, which significantly contributes to the human comfort, industrialisation and economic growth of the region[1]. Electricity has wide range of applications as it is clean and easier to transport and convert. Per capita electric energy consumption in India is about 879 kWh (2012) and the source of electricity generation plays a significant role in energy management and conservation. Electricity generation has been largely dependent fossil fuels (coal) which are mostly centralized. Centralized generation and sparsely located loads are the prime reasons for un-electrified rural households with higher transmission and distribution (T & D) losses. Electrical power transmission and distribution network encounters higher losses (~24%) compared to other countries (China-6%, Australia-5%, Bangladesh-10%, Germany-4%) and world average (~10%) due to un-metered electricity supply, un-authorized expansion, theft and pilferage at the distribution side [2].Decentralized generation (DG) with micro-grid are technically feasible and economically viable options to reduce the T and D losses. It also optimises locally available RE sources, stabilises the voltage, improves power quality, assists remote area electrification, reduces pollution and hybridisation of RE sources would promise a reliable supply of electricity. Utilisation of RE resources for electricity generation not only brings down the GHG emission, but also addresses energy deficiency issues. Demand for electricity has increased manifold due to urbanisation, industrialisation, etc. [2]. This cumulated demand causes the peak load on generating stations and also stresses the transmission lines. Any failure in generation or line outage will keep the load out of service or may lead to cascading of line outages. Blackout affects human comforts and economy of the country while restoring the grid. Integration of RE based generation will help in meeting the increasing peak demand on the grid which will decrease the energy demand gap[3]. Harvested electricity from RE sources can be supplied directly to the local loads bypassing the grid (Standalone generation) or can be synchronised with the existing grid (Grid integration).

Though renewable energy sources are widely available, they are intermittent and variable in nature. The potential assessment of available RE sources is essential, prior to installation of generation plants. Solar energy is one of the widely available RE resource which can be directly converted to electricity using photo-voltaic (PV) cells. Photoelectric effect is the phenomenon which generates electricity (electrons), when solar radiations fall on PV cells. Number of PV cells are connected in series and/or parallel to meet output requirement (Voltage and current). External circuit will be connected to the end user/loads through inverters (to convert DC to AC), transformers (to maintain required voltage level) and security components (circuit breakers, fuses, surge arrestors etc.). Solar energy can also be used for thermal applications and electricity is produced through steam turbines. Solar cookers, dryers, water heaters, concentrated solar power (CSP) plants are some of the examples of thermal energy utilization. However, PV cells produce electricity from solar radiations which is more convenient for installation and user friendly[4, 5].

Wind is being used for mechanical applications such as water pumping, grinding etc. Innovation of electricity generation boosted up the wind turbine installation to generate electricity, all over the world. Currently, more than 200 GW of power is obtained from wind across countries, which is the leading RE resource. Winds are generated due to the rotation of the earth and temperature gradient in the atmosphere. Energy generation from wind is highly variable which depends on potential variability, wind speed, etc. Since the output power of the wind turbine directly proportional to the cube of the wind velocity, any variation in wind speed will cause power output deviation. Drastic changes in the output will create stress on transmission lines due to unmet loads. This also decreases the plant load factor leading to lesser electric energy supply. To avoid transmission line stressing and to keep the load connected to the grid, forecasting of available wind potential is essential in order schedule the generation. This necessitates the potential assessment of available wind resource which also will help in plant installation planning and optimised scheduling of electricity generation. Forecasting of wind speed requires extensive mathematical (probabilistic approach) modelling. High potential areas assessed from spatial data will promise certain number of high wind speed days which decreases the complexity of prediction[6, 7].

The present study deals with the available wind and solar energy potential assessment of taluks in the WG, One among 34 biodiversity hotspots in the world. WG is a repository of diverse endemic flora and fauna and also receives higher solar insolation for about 300 days in a year. The high altitude taluks in the region experience greater wind speed which are the high wind energy potential areas. Taluks in the planes and northern region of WG receives higher insolation which encourages the solar power plant installation. Seasonal variability across the taluks and seasons have been analysed, which helps in optimising the generation and selecting the best location for plant installation. Wind energy potential compliments the lower solar insolation during monsoon in the region. This ensures the reliable electricity generation throughout the year by hybridising the energy resources.

The month wise analysis of solar and wind energy resources help in mapping the high potential regions and also to predict the probable energy output. Using the available renewable potential in the states, it is estimated that the annual electric energy demand and the peak power demand can be met by installing solar and wind power plants in the fraction of available waste land. Renewable energy sources require more land area compared to conventional power plants. Rooftop SPV installation and utilisation of feasible wasteland in the region can address the land requirement issue[8]. This also avoids aggregation of generation plants at a particular region and promotes dispersed generation. Present centralised electricity generating plants are located far away from remotely located load centers. Due to this, length of the transmission and distribution (T&D) line increases and leads to higher infrastructure cost and T & D losses. Distributed generation through micro-grids in the load centers, would reduce the distribution losses and also the sudden aggregation of load on central generating stations. Location and capacity optimisation can be done with the help of pre-assessed energy potential data of the particular region. Hence, regional level energy potential assessment is the primary step to build micro-grid architecture, to decide high energy potential region and to optimise the hybrid energy generation to ensure the reliable generation of electric energy[9]. The study exclusively discusses the renewable energy potential assessment using spatiotemporal data using open source Geographical Information System (GIS) platform.

STUDY AREA AND METHOD

Study area: WG comprising of undulating terrain is located in the western part of India, along the coast, from Kanyakumari to Tapti valley covering about 1,490 km and spreads over 1,29,037 km^2 area in Kerala, Karnataka, Goa, Maharashtra and Gujarat states. Taluks wise solar and wind energy potential analysis is carried for the WG region to analyse the seasonal variability and to identify the locations with high potential suitable for exploitation.

Method: Spatio-temporal data are used for energy potential assessment using open source GIS platform, which also gives the seasonal and geographical variability of the energy resources. Long term data sets acquired from NASA SSE and Climate Research Unit (CRU) are reliable and depicts the seasonal variability which are closely correlated with ground measurement.

Solar energy potential assessment: NASA SSE Global insolation data sets are obtained from a physical model based on the radiative transfer in the atmosphere considering its absorption and scattering properties. The model considers visible and infrared radiation, cloud and surface properties, temperature, perceptible water, column ozone amounts and also the atmospheric variables includes temperature and pressure measured using various satellite instruments. The long wave and shortwave solar radiations recorded in the satellite sensors along with the effecting parameters are studied to generate global insolation for different locations and durations. The 0.1°X0.1° spatial resolution SSE global insolation data derived from NASA SSE web portal (http://eosweb.larc.nasa.gov/sse/),for a period of 22 years (July 1st, 1983 to June 30th, 2005) were validated (RMSE of 10.28%) with Baseline Surface Radiation Network (BSRN) data available as daily, monthly and annual averages obtained from measured values every 3 hours [10, 11].

In this study, NASA SSE monthly average Global insolation data is collected for more than 900 grids which optimally cover the entire topography of India within the latitudes 8° to 38°N and longitudes 68° to 98°E. Further, grids which essentially covers the entire Western Ghats region are extracted and a geo-statistical Inverse Distance Weighting (IDW) interpolation is employed to produce monthly average Global Hourly Insolation (GHI) maps for the region. The Direct insolation is given by

$$I = (G - D)/\sin \Phi \qquad (1)$$

where, G is the Global insolation, D is the diffuse component and Φ is the sun's elevation angle.

Wind energy potential assessment: Synthesized wind data is available from various sources, which provides overview of the wind regime of a region. Depending on the physiographical features and climatic conditions, these data help to assess wind potential in the region of interest which can be validated by long term surface wind measurements.

From earlier studies it is evident that CRU data are reliable and closer to the Indian Meteorological Department (IMD) surface data, which is used in the present study [12]. CRU at the University of East Anglia maintains a record of climatic average data sets of meteorological variables which also contains wind speed data for the period between 1961 and 1990, compiled from different sources. Further, inter and intra variable consistency checks are performed to minimize data consolidation errors. The Global Land One-km Base Elevation project (GLOBE) data of the National Geophysical Data Center (NGDC) were re-sampled into 10'×10' (ten minute spatial resolution or 0.16°X0.16°) elevation grids where every cell with more than 25% land surface represents the average elevation of 100~400 GLOBE elevation points. Those below 25% are considered water bodies. The climatic average of wind speeds measured at 2 to 20 m anemometer heights (assumed to be standardized during collection) collated from 3,950 global meteorological stations together with the information on latitude, longitude and elevation were interpolated based on a geo-statistical technique called thin plate smoothing splines. Elevation as a co-predictor considers topographic influence on the wind speed, whereas, proximity of a region to the measuring station improves the reliability of the interpolated data. During interpolation, inconsistent data were removed appropriately. This technique was identified to be steadfast in situations of data sparseness or irregularity [13]. The 10'×10' spatial resolution wind speed data as climatic averages were available for all global regions (excluding Antarctica) [14].

RESULTS AND DISCUSSION

Solar potential in Western Ghats: Figure 1 shows the taluk wise distribution of solar insolation in WG region, which highlight the availability of ample solar insolation to harvest energy for meeting the local electricity demand. Annual average insolation received in the region ranges from 5.3 to 5.9 kWh/m^2/day. Taluks in the eastern and northern part of the WG receive more isolation (5.7 - 5.9 kWh/m^2/day) compared to the southern taluks (5.3 - 5.5 kWh/m^2/day). However, grid connected SPV systems are not viable in taluks with thick canopy vegetation (Evergreen/semi-evergreen). Rooftop SPV modules are viable options to meet the fundamental requirement of electricity for domestic purpose.

Figure 3 gives the seasonal distribution of solar insolation across the taluks. In summer (February to May), insolation ranges from 5.5 to 7.5 kWh/m^2/day. Southern taluks receive higher insolation (6 – 6.6 kWh/m^2/day) in early summer (February), which moves towards northern region as summer progresses. In March and April, WG receives higher insolation in the year which ranges from 5.9 to 7.4 kWh/m^2/day in all the taluks. During monsoon (June to September), insolation ranges from 3.5 to 6.1 kWh/m^2/day, in which July receives lower insolation (3.9 to 5.6 kWh/m^2/day). From August, solar energy reception in southern taluks increases (5 - 6 kWh/m^2/day), which slowly moves towards central region as the winter approaches. In winter months (October to January), distribution of solar insolation varies from 4.1 to 6 $kWh/m^2/day$. In December and January, most of the central and southern taluks receive higher insolation (5.2 to 6 $kWh/m^2/day$) compared to the northern region (4.6 to 5 $kWh/m^2/day$). As the winter recedes, insolation reception increases (>5.8 $kWh/m^2/day$). The seasonal solar potential maps of WG reveals that, distribution of solar insolation follows a pattern which move from southern region to northern taluks (from monsoon to summer), which gives the insight for generation scheduling and secured plant operation. Forecasting of the generation from solar PV plants (in grid connected system), contributes to decide the dynamic range of grid operation and security limits. However, village level study may reveal better information to decide the precise grid operation constraint to keep the grid stress free and connected to the load reliably.

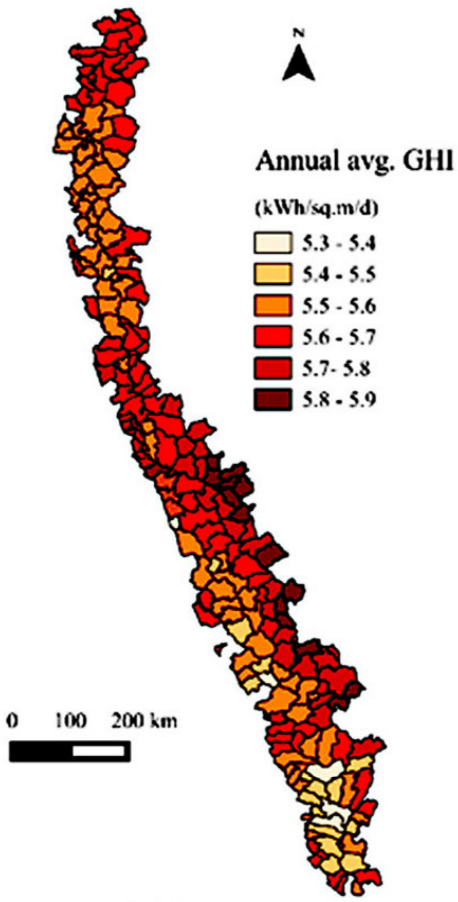


Figure 1: *Taluk wise annual average solar insolation in WG region*

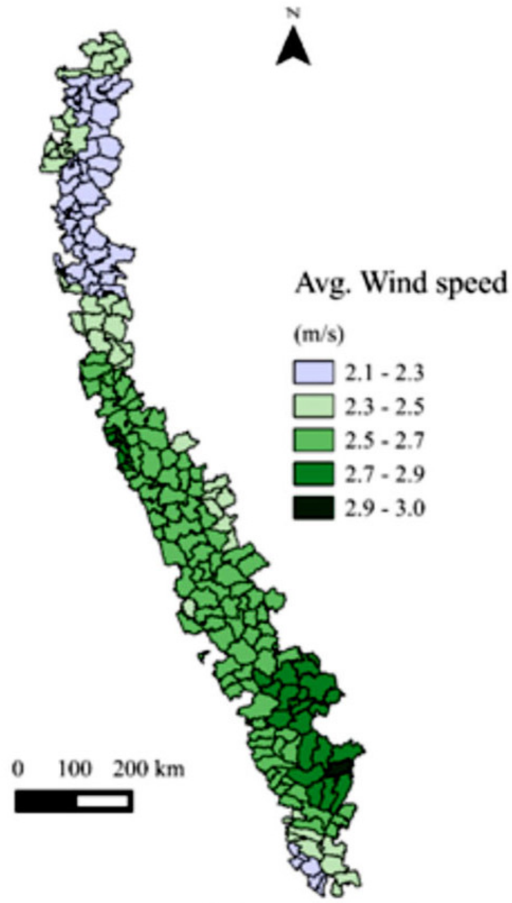


Figure 2: *Taluk wise annual average wind speed in WG region*

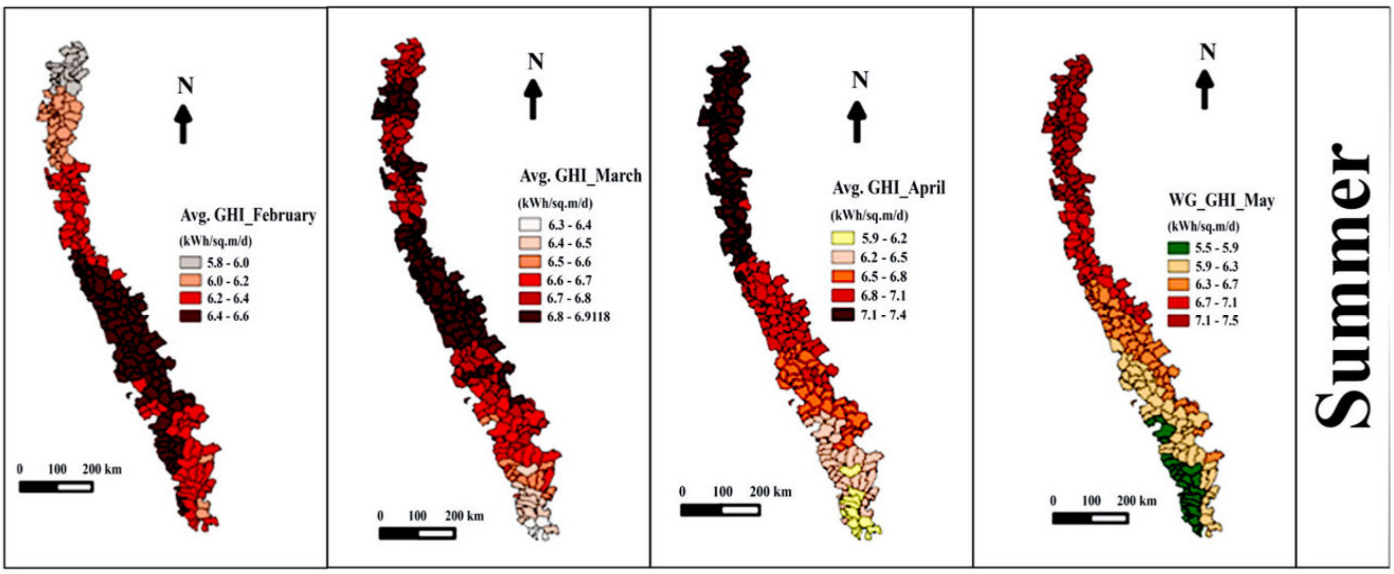
Wind potential in Western Ghats: Taluks in the higher altitude and planes experience higher wind speed compare to the interior and costal region. Annual average wind speed ranges from 2.1 to 3 m/s throughout the region, where taluks in the south-eastern region experience higher wind speed (2.7 to 3 m/s). Figure 2 shows the taluks wise wind regime of the WG region. Taluks in the central and southern region experience higher wind speed (2.5 - 3 m/s) compared to the northern region (2.1 - 2.5 m/s), annually.

Taluk wise seasonal distribution of wind speed is given in Figure 4, which also gives the high potential areas. During summer (February to May), wind speed varies from 1.5 to 3.37 m/s, where the northern taluks experience lower wind speed (1.5 to 2.1 m/s) compared to central and southern region (2.3 to 3.37 m/s). WG region experiences higher wind speed in monsoon season (June to September) due to the south-west monsoon. Speed of wind ranges from 2.5 to 4.1 m/s (in June, July and August) which decreases (in September, 1.9 to 2.9 m/s) as monsoon recedes. The central taluks of WG receives swift winds (3.7 to 4.1 m/s) which are high potential areas. However, change in the direction of wind is not suitable for power plant installation, which gives the extreme power outputs. During winter months (October to January), average wind speed in the region varies from 1.3 to 3.1 m/s, in which northern taluks experience lower wind speed (1.4 to 1.9 m/s). Nevertheless, central and southern taluks experience higher wind speed ranging from 2 to 3.1 m/s annually. The seasonal wind speed maps of WG reveals the taluk wise energy potential in the region. The south-eastern taluks consistently showed higher potential which also include some of the hilly regions including Ooty, Elivaimalai, Perumal peak, Annamudi, Munnar and valley at Palaghat. Many of these regions are rich in biodiversity, have rare endemic flora and associated fauna. Since the wind power plants need vast disturbance free area, open area such as coast, planes are to chosen instead vegetated regions. However, potential analysis shows the harvestable energy of the region which gives the scope for generation forecasting, scheduling and to enhance the plant security. It also helps in village level plant installation to meet the community demand in a decentralised manner.

Seasonal variability in solar and wind potential: RE sources are intermittent in nature and the variation cause the variation in the output. Optimisation of RE resources requires the understanding of seasonal variability including diurnal variation. Figure 5 gives the taluk wise variability in solar and wind potential in WG region. Annual average insolation in Maharashtra during monsoon (Figure 5 (a)) shows high variability compared to other states. Goa experiences lower variability in insolation reception compared to other taluks annually. Insolation reception is almost same during summer across the states, however

Gujarat shows higher potential. Wind speed shows high variability and higher energy potential in all the states during monsoon months (Figure 5 (b)) compared to other seasons. Overall, wind speed is highly variable in all the season which also varies the harvestable energy potential of the region. Figure 6 shows the monthly variation of wind speed and solar insolation in WG region, which infers that higher wind speed potential compliments the lower insolation reception from June to September (monsoon). This also shows that solar insolation reception from January to May compliments the lower wind speed. This endorses the hybridisation of energy resources to have the reliable energy generation throughout the year. Study using higher resolution wind speed data may provide precise wind regime for regional level (village level) to analyse the energy potential variability analysis.

Energy generation from solar potential using available wasteland: Electric energy can be harvested directly from solar radiations using SPV cells (modules). These SPV modules can be mounted on rooftop (domestic supply) or can be installed in an outdoor area (wasteland/barren land) for higher capacity of generation which shall meet the irrigation and commercial electric energy demand. Land use by power plants is one of the major factors to be considered in the early stage of planning of any power plant. The assessment shows that land required to setup 1 kW solar power plant (SPV based) is about 10 sq.m. Scope for solar energy is assessed considering the present energy demand and extent of wasteland available in the state.



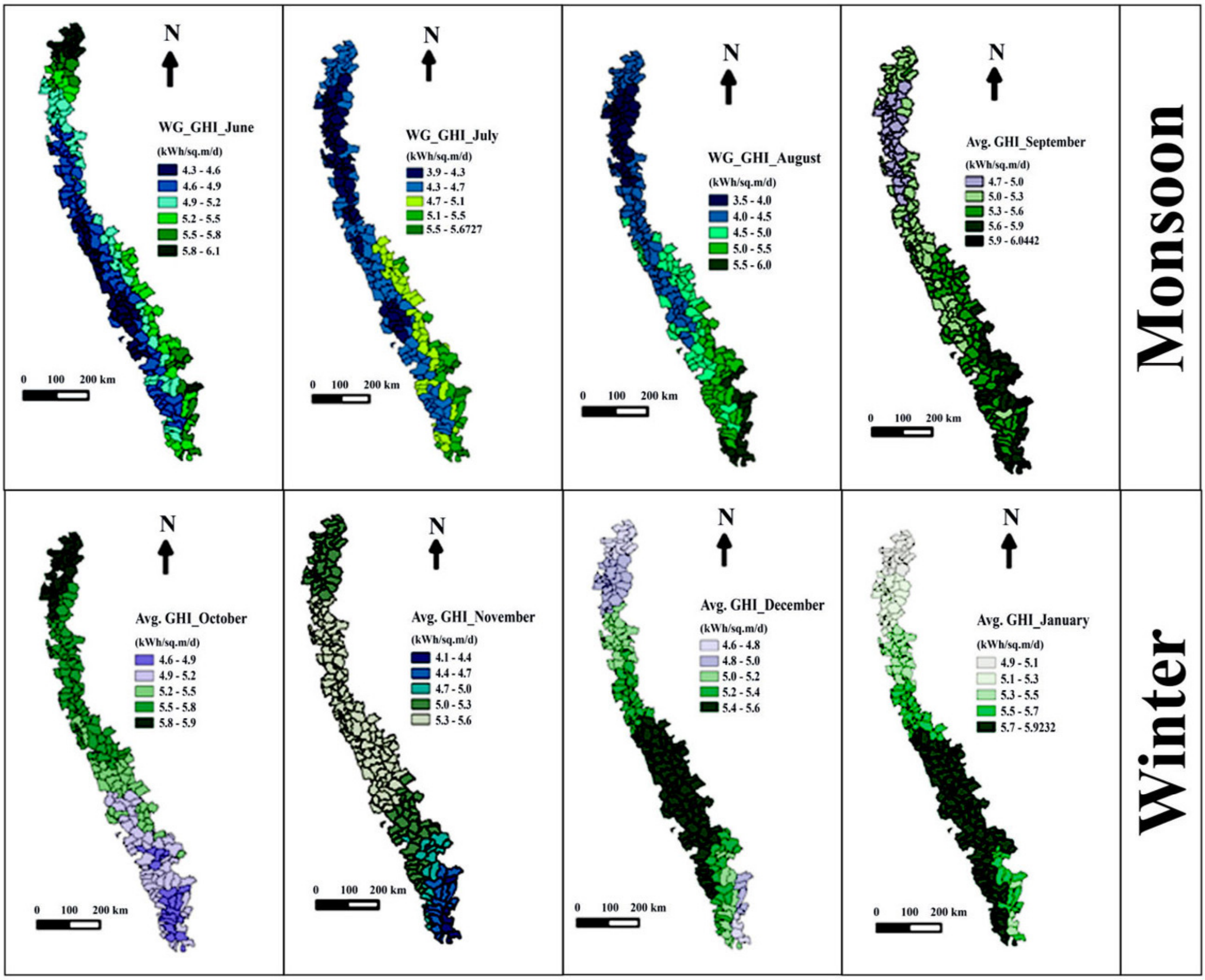
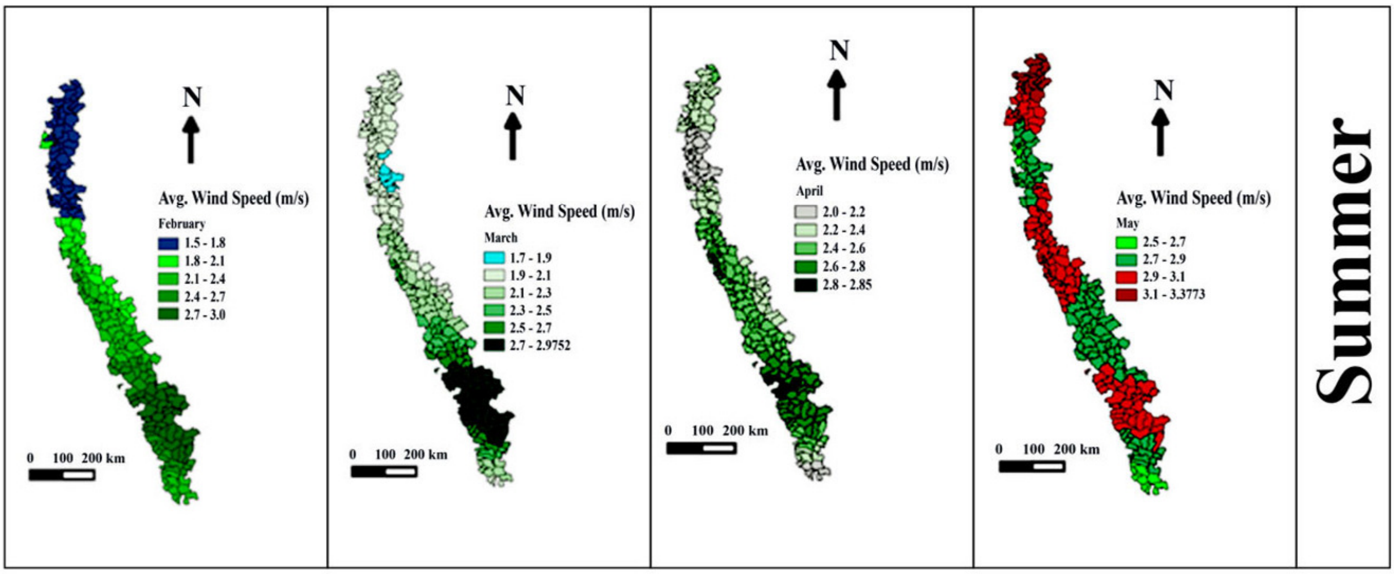


Figure 3: *Seasonal distribution of solar insolation across the taluks in WG region*



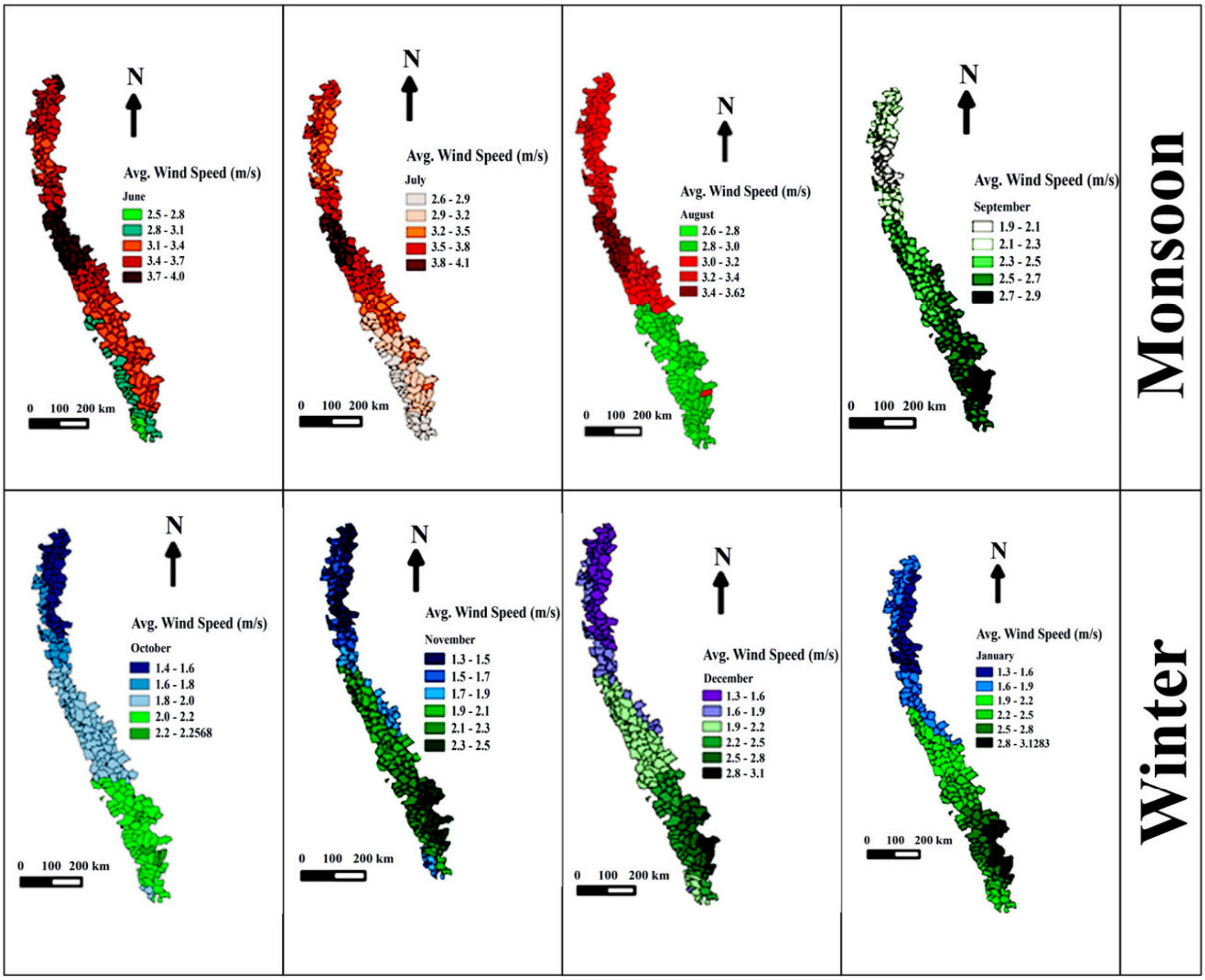


Figure 4: *Seasonal distribution of wind speed across the taluks in WG region*

Figure 7 shows the month wise electric energy that could be generated using a fraction of wasteland area (Gujarat - 2%, Maharashtra - 1.5%, Goa - 2%, Karnataka - 2% and Kerala - 3%) and the monthly electric energy demand. The electric energy consumption in the states of WG region varies seasonally. Electricity consumption is more during summer months while the solar insolation received is also higher. Energy consumption decreases during monsoon, where the insolation is lower. The figure shows that the electricity required follows the solar energy potential in all the states. Table 1 gives the wasteland area required to meet the electricity demand in all the states of WG region.

Wind energy density map shows that peak power deficiency in Maharashtra, Karnataka and Kerala occur when the wind density is high. Harvesting wind would help in meeting the peak demand. The assessment shows that wind power potential can significantly contribute in supplying the peak power demand from March to August.

Table 1: *State wise annual electric energy and wasteland required to supply using solar potential*

State	Available Wasteland (km^2)	Total energy consumption in 2011 (Gwh)	Required wasteland to meet the demand (km^2)
Gujarat	20108.06	86485	402.16 (2%)
Maharashtra	37830	127488	567.45 (1.5%)
Goa	489.08	2785	9.78 (2%)
Karnataka	13030.62	64519	260.6 (2%)
Kerala	2445.63	20943	73.36 (3%)

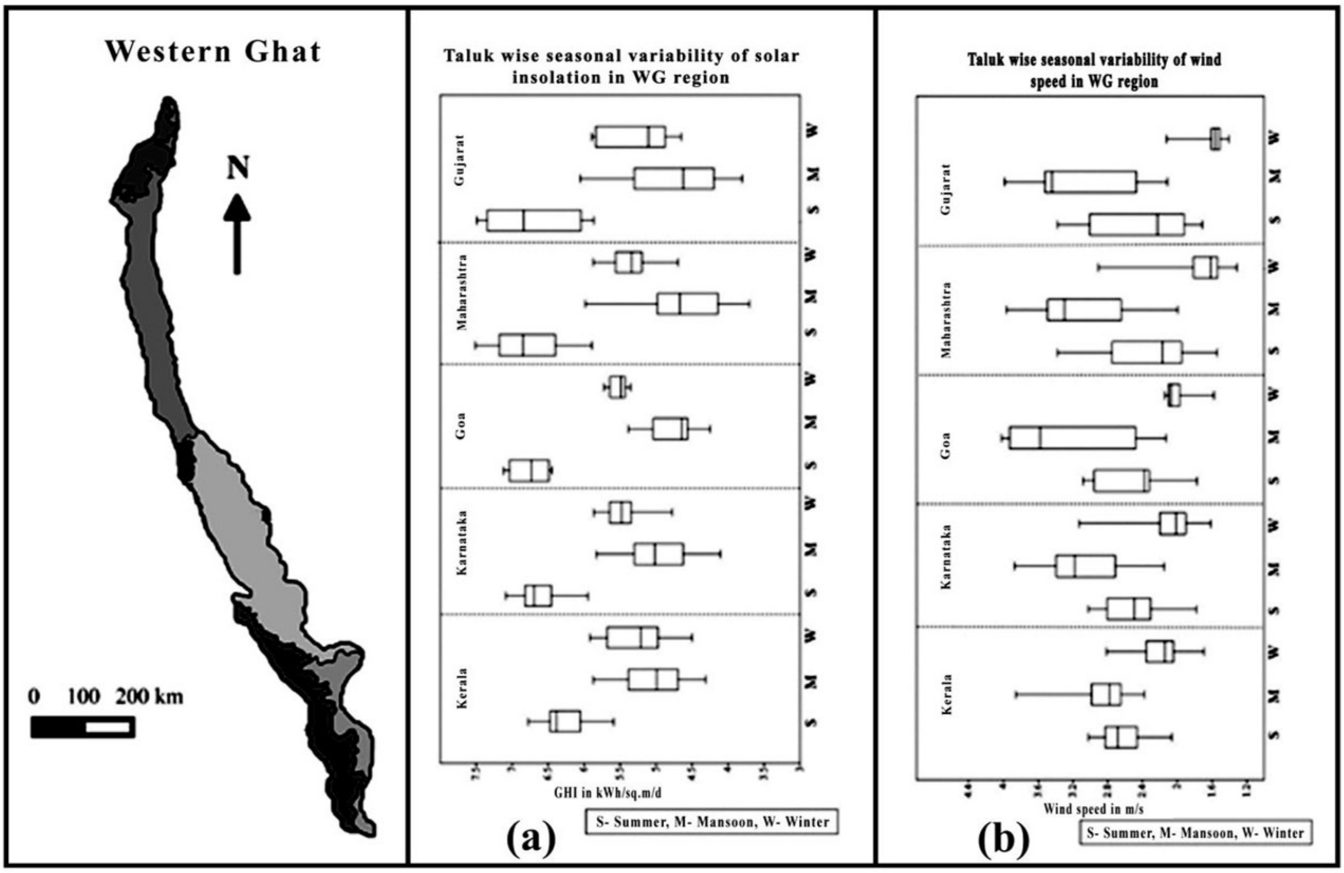


Figure 5: *Variability in solar energy and wind speed potential in WG region*

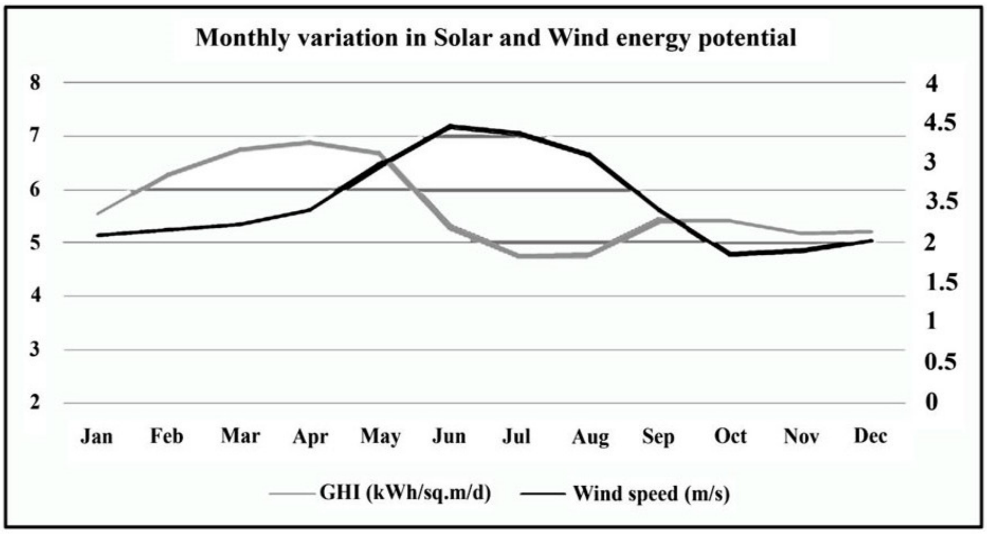
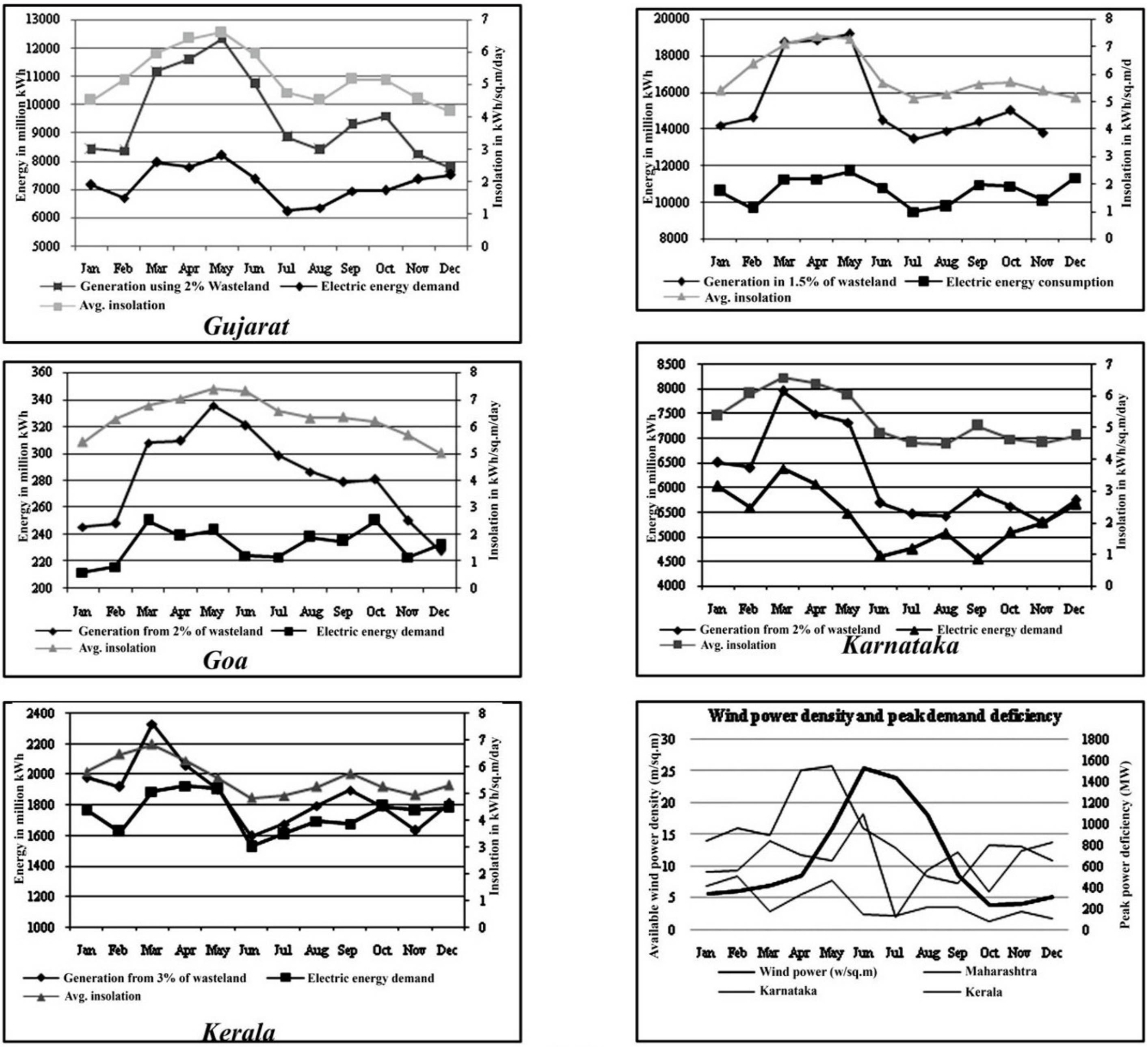


Figure 6: *Monthly variation of solar insolation and wind speed in WG region*



SOLAR ENERGY INCENTIVES IN WESTERN GHATS STATES

Most of the Indian states have come up with GBI and Feed in Tariff (FIT) mechanism to promote electricity generation from solar energy and to connect the solar power plants to grid. Solar policies and tariff structure for grid connected solar plants in WG states are discussed in Table 2.

Table 2: *Tariff structure for grid connected solar plants*

Gujarat[15]			
Commissioning period	29 Jan 12 to 31 Mar 13	1 Apr 13 to 31 Mar 14	1 Apr 14 to 31 Mar 15
Levelised tariff for 25 years on 1 kW - 1 MW capacity solar PV power plants			
With accelerated depreciation	INR 11.14/kWh	INR 10.36/kWh	INR 9.63/kWh
Without accelerated depreciation	INR 12.44/kWh	INR 11.57/kWh	INR 10.76/kWh
Levelised tariff for 25 years on > 1 MW capacity solar PV power plants			
With accelerated depreciation	INR 9.28/kWh	INR 8.63/kWh	INR 8.03/kWh
Without accelerated depreciation	INR 10.37/kWh	INR 9.64/kWh	INR 8.97/kWh
Levelised tariff for 25 years on solar thermal power plants			
With accelerated depreciation	INR 11.55/kWh		
Without accelerated depreciation	INR 12.91/kWh		

Maharashtra[16]	
Levelised tariff for 25 years on > 1 MW capacity solar PV power plants	
With accelerated depreciation	INR 14.95/kWh
Without accelerated depreciation	INR 17.91/kWh
Levelised tariff for 25 years on 1 kW - 1 MW capacity solar PV power plants	
With accelerated depreciation	INR 15.45/kWh
Without accelerated depreciation	INR 18.41/kWh
Levelised tariff for 25 years on solar thermal power plants	
With accelerated depreciation	INR 12.85/kWh
Without accelerated depreciation	INR 15.31/kWh

Goa[17]	
Levelised tariff for 25 years on solar PV power plants	
With accelerated depreciation	INR 7.01/kWh
Without accelerated depreciation	INR 7.74/kWh
Levelised tariff for 25 years on solar thermal power plants	
With accelerated depreciation	INR 10.73/kWh
Without accelerated depreciation	INR 11.88/kWh

Karnataka[18]	
Levelised tariff for 25 years on > 1 MW capacity solar PV power plants	
INR 8.40/kWh	
Levelised tariff for 25 years on 1 kW - 1 MW capacity solar PV power plants	
With 30% capital subsidy	INR 7.20/kWh
Without subsidy	INR 9.56/kWh
Levelised tariff for 25 years on solar thermal power plants	
INR 10.92/kWh	

Kerala[19]
Levelised tariff for 25 years on > 1 MW capacity solar PV power plants
INR 10.41/kWh
Levelised tariff for 25 years on 100 kW - 1 MW capacity solar PV power plants
INR 12.49/kWh
Levelised tariff for 25 years on 1 kW - 100 kW capacity solar PV power plants
INR 12.49/kWh

RECOMMENDATIONS FOR SUSTAINABLE ENERGY DURING 21ST CENTURY

Solar energy based generation seems promising and environmental friendly option to meet the growing demands. India is blessed with the good solar potential and harvesting this potential would minimize the environmental implications associated with the fossil fuels. Solar PV technology has the potential to meet the domestic and irrigation demands in the decentralized way. Appropriate policy incentives might help in the large scale deployment of solar devices at household levels. There is a need to focus on energy efficient decentralized electricity generation technologies with micro grid and smart grid architecture, which would go long way in meeting the energy demand. In this regard, suggestions are:

1. Electricity generation using SPV and CSP technologies would bridge the demand supply gap as India receives abundant solar energy of more than 5 $kWh/m^2/day$ for about 300 days in a year. The adequate potential with mature technologies and apt policy incentives would help in meeting the electricity demand in a region.

2. Roof top based SPV would help in meeting the household energy demand in rural as well as urban households. Rural household require about 70-100 kWh per month and to meet this requirement 5-6 m^2 rooftop is adequate (at η=10%, and insolation of 5 kWh/m^2/day) and the average rooftop in rural locations in Karnataka is about 110 m^2 and about 115 m^2 in urban localities.
3. Adequate barren /waste land is available in Karnataka as the available waste land is about 7% of the total geographical area less than 1% area is sufficient to generate electricity required for irrigation and domestic sector through SPV installation.
4. SPV installation in waste/barren lands supports decentralized electricity generation and enables multi utilization of the area for activities such as grazing, livestock farming, etc. About 45 million households are still not electrified in India, which have potential to generate enough electricity from rooftop SPV installation; rooftop SPV installation would be the revolutionary method of rural electrification.
5. Rooftop SPV installation is the most adoptable technology in highly populous countries like India, where the monthly electricity consumption of a household ranges from 50 to 100 kWh. Encouragement for roof top SPV based electricity generation rather than centralized generation through incentives, financial aid for initial installation and tax holidays.

To supply electricity to households in remote areas entails investment on infrastructure apart from transmission and distribution (T&D) loss of electricity. Current assessment reveals that T&D loss in Karnataka is about 19.5% resulting in the loss of 7,210.16 GWh (annual demand is 36,975.2 GWh in 2010-11) of energy. Cost of energy loss ranges from Rs.1,514.13 crores (@ Rs.2.10/kWh) to Rs.5,047.11 crores (@ Rs.7/kWh) depending upon the tariff (in the respective state).

Decentralized generation of electricity through SPV would help in meeting the respective household's electricity demand apart from the removal of T&D losses [15]. Generation based incentives (GBI) would herald the decentralized electricity generation, which would help in boosting the regional economy. Considering the current level of T & D losses in centralized system, inefficient and unreliable electricity supply, it is necessary to promote decentralized energy generation. Small capacity systems are efficient, economical and more importantly would meet the local electricity demand [15]. The incentive could be

- Rs.4.00 per unit for first five years (comparable to subsidies granted to mini hydel projects, the power purchase at Rs.3.40) and Rs.3.50 for the next two years for the electricity generated from roof top solar PV.
- Buyback programmes for the electricity generated at household level and in micro grid -GBI of Rs.5 to be provided for electricity generation (< 5 kW) feeding to the grid by SPV.
- Free solar home lighting (with LED lamps) under the Chief Minister's Solar Powered Green House Scheme (CMSPGHS), Government of Karnataka or JNNSM (Jawaharlal Nehru National Solar Mission, Government of India).
- All street lights and water Supply installations in local bodies to be energized through solar power (or hybrid mechanism) in a phased manner
- Install solar rooftops in all new government/local body buildings - implementation of solar rooftops could be in a phased manner in the existing government/local body buildings, etc.
- Exemption from payment of electricity tax to the extent of 100% on electricity generated from solar power projects used for self-consumption/sale to utility to be allowed for at least10 years.
- Fixing of standards for quality installation.

6. Commercial lighting in advertisement boards should only be from SPV panels. Complete ban on usage of grid electricity for these purposes.
7. Impetus to energy research through generous funding for the R and D activities to ensure further improvements in the grid, technologies, two way communication energy meters (to connect rooftop generation with existing grid), efficient luminaries' production, low cost wiring, switch gears, appliances, etc.
8. Energy education (focusing mainly on renewable energy technologies, end-use energy efficiency improvements, energy conservation) at all levels. School curriculum shall include RE concepts.
9. Awareness about energy independence and the necessity of RE sources in the present gloomy energy scenario to the consumers
10. Education and awareness about applications and importance of renewable energy sources.
11. Capacity building of youth through technical education for installation and servicing of SPV panels.

12. Diploma /ITI courses with hand-on training on renewable energy technologies in all taluks
13. Setting up service centers in block development offices to meet the requirement of service support for RE technologies (Solar, biogas, energy efficient Chulas, etc.).
14. Periodic revision of FIT structure and incentives to encourage the consumers.
15. Mandatory one week capacity building / training programmes to all bureaucrats and energy professionals at the initial stages of the career. This is essential as lack of awareness/knowledge among the bureaucrats is the major hurdle for successful dissemination of renewable energy technologies in India

CONCLUSION

GHG emissions of fossil fuel based centralized large-scale power plants (thermal, etc.) have resulted in serious environmental contamination apart from increasing carbon footprint. DG using locally available RE resources with micro-grid are viable options to reduce the T and D losses and meet the regional electricity demand. It also optimizes locally available RE sources, stabilizes the voltage, improves power quality, remote area electrification, reduces pollution and hybridization of RE sources would promise a reliable supply of electricity. Taluks in the Western Ghats region receive higher solar insolation (> 5.5 $kWh/m^2/d$) and also wind (2- 3 m/s) suitable for decentralized applications. Electricity harvesting by exploiting available renewable energy potential could also help the preservation of bio-diversity of the region. A small fraction of available wasteland (1-3%) in each state is sufficient to meet the present electricity demand using SPV installation. Available wind power density shows that, peak demand deficiency can be met with wind power potential of the region. Study analyses the variability of wind and solar energy resources which also maps the taluk wise available potential of WG region. Decentralised electricity generation using renewable energy resources is the sustainable option to meet the future demand in an environmental friendly way.

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