DECENTRALISED ELECTRICITY SUPPLY THROUGH RENEWABLES

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ABSTRACT

Decentralised electric energy generation using available renewable energy resources can meet the regional demand by reducing the transmission losses and stress on central grid. The current communication explores village wise availability of renewable energy resources in Uttara Kannada district in the central Western Ghats region. All the taluks of the district receive solar insolation >5 kWh/m^2/day annually and coastal and hilly terrain experiences wind speed >3 m/s are most suited for decentralised energy harvesting. Integrated energy system would ensure elevate the livelihood with reliable electricity supply throughout the year. A fraction of (2-10%) available rooftop is adequate to mount solar panels to supply domestic electricity. Sufficient land is available as the estimate indicates less than 5% of current wasteland is sufficient to deploy decentralised electricity generation for meeting the current domestic and irrigation energy demand. Most of the villages in the district are blessed with abundant bioenergy of more than 10000 million kWh/annum which can suffice the heating and electric energy requirement. Similarly, 0.1 to 0.5 million kWh of biogas energy available in most of the villages which can be used for cooking and electricity generation. The annual energy requirement of the villages in the district can efficiently supplied from locally available resources in decentralised way.

Keywords: Renewable energy, solar energy, rooftop PV, Uttara Kannada

INTRODUCTION

Energy is the fundamental need of human being for all activities. Energy harvesting is dependent on the available resources, type of end use, cost of the resource and conversion process, maturity of energy technology and the social acceptance. However, electricity is the widely used energy form which effects the economic and social development of a region. Electric energy generation from renewable energy resources (wind and solar) is evolving which can play a pivotal role in the region's development, while combating global warming through the reduction of greenhouse gas (GHG) emissions [1].

The present centralised system of electricity generation has caused enormous environmental pollution through GHG emission, waste water discharge and changing the landscape [2]. Transmission and Distribution losses due to sparsely located load centers, theft and pilferage of electricity is one of the major issues affecting the reliability of the electricity supply. Figure 1 gives the T&D losses in the country form last 4 decades. It has gradually increased from 17.5% (in 1970-71) to 24.1% (in 2011-12), leading to large supply and demand gap of electricity [3].

The other important short coming of centralised generation is reaching the remotely located loads. There are about more than 78,000 villages in the country of which 7.4 crore households are not yet electrified [4]. Demand for electricity has been increasing due to rapid urbanisation and industrialisation with globalisation and relaxation in Indian market. Coupled with these, rural electrification has widened the supply demand gap, necessitating exploration for viable energy alternatives. Electricity generation in India mainly depends of fossil fuels (Coal – 59%, Gas - 9%, Nuclear – 2%) and Hydro resources (17%). Renewable energy constitutes about 12% in the total installed capacity [5]. Exploitation of fossil fuels have led to degradation of environment while mining, transportation and burning emitting poisonous pollutants to atmosphere. The life cycle carbon dioxide (CO_2) emission is highest in coal based power plants, ranges from 960-1050 $gCO_2eq./kWh$ followed by diesel (778 $gCO_2eq./kWh$), natural gas (443 $gCO_2eq./kWh$) and nuclear fuelled power plants (15 $gCO_2eq./kWh$). These generating plants also emit significant amount of SO_2 and NO_x, while letting high concentrated effluent to the water resources [6-8]. There has been a significant progress through renewable sources towards cleaner electricity generation options, which is likely to revolutionise, if dissemination of these technologies is done at decentralised levels.

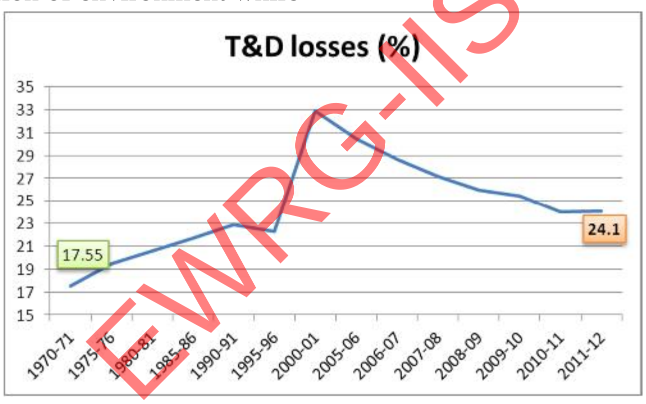

Figure 1: T & D losses from 1970-71 to 2011-12

The current emphasise to meet the domestic energy demand is through renewable resources harvested at decentralised level and efficient distribution through micro grids. Exploiting locally available renewable energy resources to meet the regional electricity demand is being attempted in many regions [9]. Hybrid systems through integration of locally available renewable energy resources is a feasible technique to address the seasonal variability and ensure the reliable energy supply. Grid connected micro grid seems viable option as many federal governments have opted the payback tariff for supplying to the grid [10]. A standalone and grid connected distributed generation (DG) would reduce the transmission and distribution requirement of energy by supplying the load locally while reducing T & D losses significantly. Since, DG integrates renewables to the grid which increases the installed capacity. RE sources are mostly environmental friendly, which also solves GHG emission issues [11]. The present study tries to identify the villages with higher renewable energy where DG can be proposed and also the annual energy availability. The study gives insights to DG planning and monitoring in village level of Uttara Kannada district.

DATA AND METHOD

Study Area: Uttara Kannada with the spatial extent of 10,291 km^2 is located between 74°9′-75°10′ E and 13°55′-15°31′ N in the mid-western part of Karnataka state, India (Figure 2). The regions with undulating hills, rising steeply from a narrow coastal strip bordering the Arabian Sea to a plateau at an altitude of 500 m, with occasional hills rising above 600 to 860 m lies in the central part of Western Ghats [12]. Topographically, the district lies in three distinct zones namely narrow and flat coastal zone, abruptly rising ridge zone and elevated flat eastern zone. The coastal zone is thickly populated with coconut clad villages. Ridge zone is a part of the main range of Western Ghats, which runs north to south, parallel to the coast. The flat eastern zone joins the Deccan plateau. The taluks, which comprises the narrow flat coastal zone, are: Karwar, Ankola, Kumta, Honnavar and Bhatkal. Similarly, taluks, which comprises the ridge zone, are: Supa (Joida), Haliyal, Yellapur, western Sirsi, and western Siddapur. Flat eastern zone includes Mundgod, eastern Sirsi and eastern Siddapur. Four agro-climatic zones based on geography and climate are coastal, evergreen, dry deciduous and moist deciduous. There are 1291 villages, 7 towns, 5 city municipal corporations/town municipal corporations/outward growth/census towns and 2 reservoirs in the district [http://uttarakannada.nic.in/].

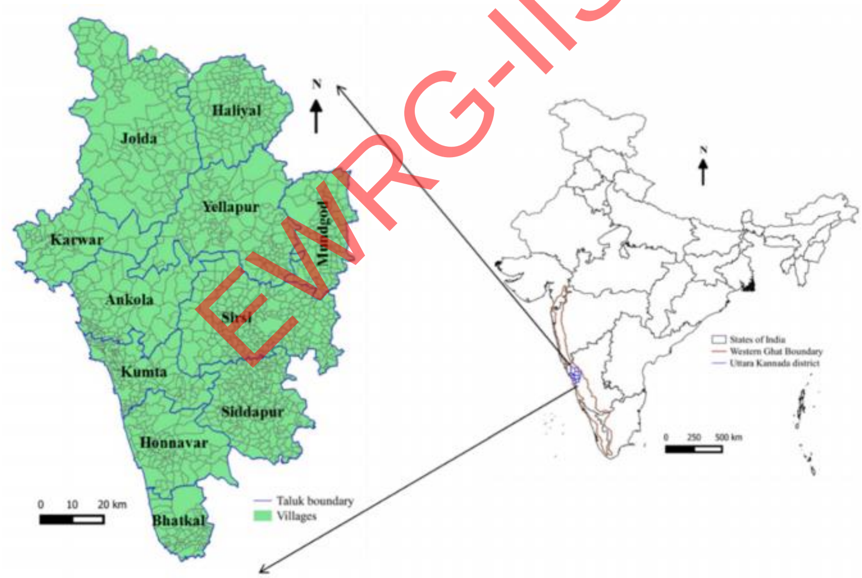

Figure 2: Study area – Uttara Kannada district, Karnataka

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 is closely correlated with ground measurement.

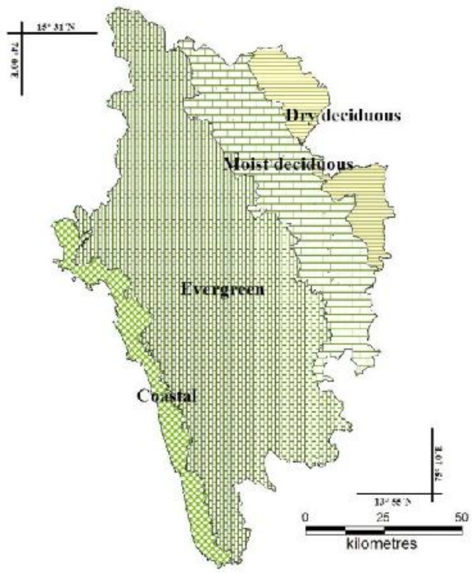

Figure 3: Extent and types of forest cover in the district

Solar Energy Potential Assessment: NASA SSE Global insolation datasets 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 [13, 14]. 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 cover the entire district 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 Climate Research Unit (CRU) data are reliable and closer to the Indian Meteorological Department (IMD) surface data, which is used in the present study [15]. CRU at the University of East Anglia maintains a record of climatic average datasets 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° X 0.16°) 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 standardised 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 [16]. The 10'×10' spatial resolution wind speed data as climatic averages were available for all global regions (excluding Antarctica) [17].

Bio-energy Assessment: Uttara Kannada district is a part of central Western Ghats, where 75% of the area is covered with forest. The geographical heterogeneity is responsible for the diverse growth of vegetation in the district. Taluks of the district are categorized under 4 different types of forests which are

- Evergreen forests normally found in Sirsi, Siddapur, Yellapur, Joida and eastern hilly regions of Honnavar, Kumta and Ankola Taluks.
- Semi evergreen and moist deciduous forest, found in slopes of Ankola, Kumta, Karwar, Honnavar, Siddapur and Sirsi.
- Deciduous forests (dry) are mostly found in Haliyal, Supa and Mundgod region.
- Forests in the coastal region, normally found in Kumta, Honnavar, Ankola, Karwar and Bhatkal region.

Figure 3 gives the climatic zones and forest types of Uttara Kannada. Extent of the forest cover and type of forest has a major effect on bio-energy supply. Evergreen forest found in most of the places in the central region followed by moist and dry deciduous forests. Bio-energy status assessment is done based on the resource availability and bio-energy requirement in the district. Having the knowledge of current bio-energy usage pattern in different agro-climatic zones, demand for bioenergy is estimated. Energy consumption sampling in few villages complimented the estimated values. Bio-resource mainly depends on the land use pattern, forest cover and yields of various crops. Using the earlier energy survey data and by spatio-temporal land use dynamics analysis, availability of resources and corresponding demands are computed. All the estimations are done taluk wise and aggregated for each agro-climatic zone.

Biogas Resource Assessment: Livestock a vital component of agrarian ecosystem provides milk and manure. Other uses of livestock are wool, meat, transportation and for ploughing (or sowing). Animal residues from livestock aid in recharging the essential nutrients of soil. It also enhances the quality of organic manure which increases the soil fertility. Farmers in Uttara Kannada are prominently dependent on livestock for their agriculture and horticulture practices. Animal residue is the main feedstock for the production of biogas as well as manure. There are about 3,66,949 cattle, 1,18,669 Buffaloes, 2,702 Sheep and 11,994 Goats in Uttara Kannada (Cattle Census 2001). Other members of livestock are Pigs (900), Dogs (93,403) and Rabbits (277) which are in a smaller number. Total livestock population in the district is about 5,94,929 and poultry population is 3,61,351. Dung available from each cattle varies from 3-4 kg to 8-10 kg (from coastal to hilly region). Similarly average dung produced from a buffalo is 12-15 kg and from a hybrid one is 15-18 kg. About 0.036 m^3 of biogas can be produced per kg of dung; is assumed in the biogas resource estimation.

RESULTS AND DISCUSSION

Table 1 shows (Figure 4) the village-wise monthly average domestic electricity consumption based on the data compiled from electricity distribution company (HESCOM) and from sampled households. Average monthly energy consumption of electricity for domestic purposes is about 34±8 kWh/month/household and irrigation requirement is about 3218±2412 kWh/hectare/year. Monthly domestic electricity consumption ranges from 23 (Haliyal) to 44 kWh (Honnavar). The region wise electricity demand for domestic and irrigation purpose computed which shows that coastal taluks (Ankola, Kumta, Karwar, Bhatkal and Honnavar) have higher household electricity consumption. Siddapur and Sirsi taluks with vast extent of horticulture crops lead in the per hectare consumption of electricity for irrigation. A large part of Uttara Kannada district, except the coast practice rain fed agriculture and hence do not rely on irrigation. The electricity consumption for irrigation ranges from 1,000 - 5,000 kWh/month. From figure 5 it is seen that in most of the villages, total roof area available is less than 10,000 m^2 or it is about 10,000 to 25,000 m^2. There are very few villages where the total roof area is more than 50,000 m^2. The knowledge of total number of households in the particular village helps in assessing the available rooftop area of each household.

Table 1: Domestic electricity consumption

Taluk	Electricity consumption: Household (kWh/month)	Electricity consumption: Agricultural (kWh/ha/year)
Ankola	34	2900
Kumta	42	3200
Karwar	40	3100
Bhatkal	40	3100
Honnavar	44	1800
Haliyal	23	1800
Mundgod	37	2100
Siddapur	26	7700
Sirsi	34	7900
Yellapur	25	900
Supa	25	900
max	44	7900
min	23	900
average	34	3218
std.	8	2412

Scope for Rooftop PV Systems to meet Domestic Electricity Demand: The domestic electricity demand of the district can be met through solar rooftop PV system, which ensures reliable and better quality supply of electricity compared to the present grid connection. Rooftop area requirement for PV modules was computed and mapped with the knowledge of region-wise household electricity demand considering the solar PV panels of efficiency (η) 14% with modules of quality factor (Q) 0.5. In most of the regions, except towns, less than 10,000 m^2 of rooftop area is sufficient to meet the village's household electricity demand. Figure 6 shows the PV capacity required to meet their demand. Most of the villages require installations within 1,000 kW while towns need larger installations up to 14,000 kW. Figure 7 shows the share of available rooftop area required to meet household electricity demand. It can be seen that, fraction (less than 7%) of the roof area is sufficient to meet the electrical energy demand of the household using rooftop PV system in the district. Villages in the coastal region and planes (Mundgod and eastern part of Sirsi) require rooftop area 3% to 8.5% whereas the villages of Western Ghats (Sahyadri) need lower rooftop area (1% - 2%) to meet the domestic electricity demand through solar. However, less than 8.5% of the available rooftop area in any village would meet its household electricity requirement using solar PV system [18].

Solar Energy for Irrigation: Village-wise land use pattern was estimated using IRS (Indian remote Sensing) P6 data of 5.6 m spatial resolution. This analysis provided the details of the extent of wasteland in each village of the district. The proportion of wasteland required to meet electricity demand for irrigation was calculated, which is given in Figure 8, considering SPV Standalone panels of efficiency (η) 14% and quality factor (Q) 0.5. Villages in the coastal zone can support the irrigation demand with less than 0.5% of the available waste land area. In most of the villages in the coastal taluks, the land requirement is less than 0.5% of wasteland area to meet the electricity demand for irrigation. In few places land area required is more than 0.5% of the total waste/open land area available (villages of Sidapur, Sirsi and Mundgod). However, in all the villages of the district, less than 10% of waste land can meet the total irrigation electricity demand of the village by installing PV modules.

Bioenergy from Forest Biomass, Agriculture and Horticulture: Figure 9 gives the annual energy available from agricultural, horticultural and forest residues in the district, which ranges from less than 10,000 GWh to about 3,00,000 GWh per year. Majority of the villages in Siddapur, Haliyal, Mundgod and coastal taluks have bioenergy potential less than 10,000 GWh/annum from all the sources. Some villages in Ankola, Karwar, Sirsi, Yellapur and Supa have annual bio-energy ranging from 10,000 to 2,00,000 GWh per year. From the figure 9 it is evident that, villages in the dense forest region have higher bio-energy potential compared to other villages [19].

Biogas Potential: Figure 10 gives the annual biogas production from livestock residues in Uttara Kannada. It is apparent that in majority of the villages, annual biogas energy generated from biogas ranges from 0.1 to 0.5 GWh. In 340 villages of Mundgod, Haliyal, Karwar and Siddapur taluk, biogas energy generation is 0.5 to 1 GWh. Few villages in Bhatkal, Honnavar and Mundgod taluk have biogas based energy production of 1-12 GWh per annum. The available energy from biogas is adequate to meet the cooking fuel demand in the region. Biogas combustion is more efficient, produces less emission and after the production of biogas from the residues, nutrient rich slurry can be used for manure generation. Ministry of New and Renewable Energy (MNRE), Govt. of India (GoI) supports biogas plant installation through schemes like Central Finance Assistance (CFA) providing 50% of the cost and also by implementing the National Biogas and Manure Management Programme (NBMMP) [20]. However, community participation is indeed required to elevate the installation of biogas plants in the rural areas of the country.

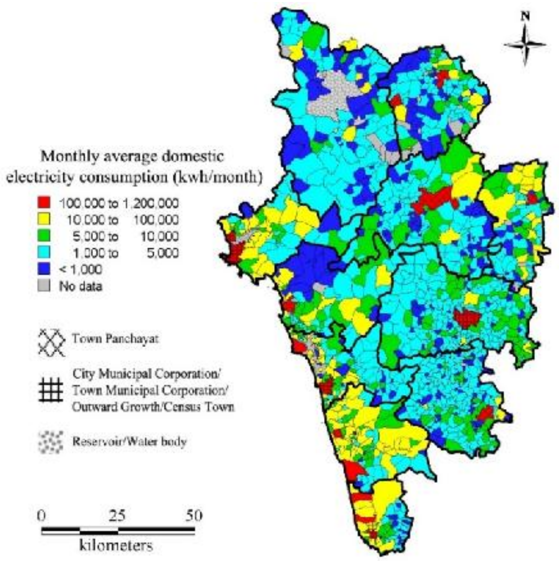

Figure 4: Domestic electricity consumption

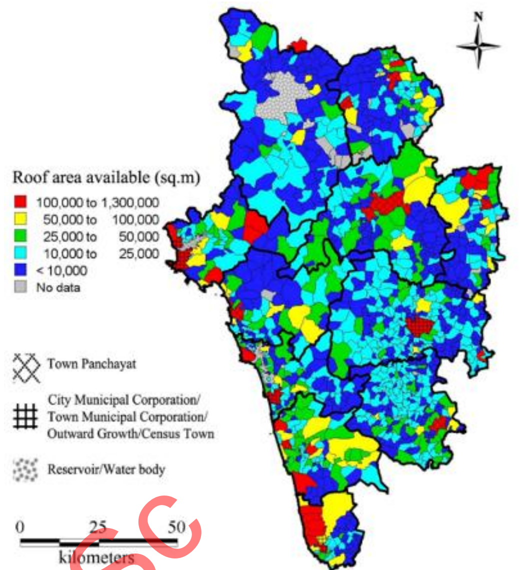

Figure 5: Village wise rooftop area available

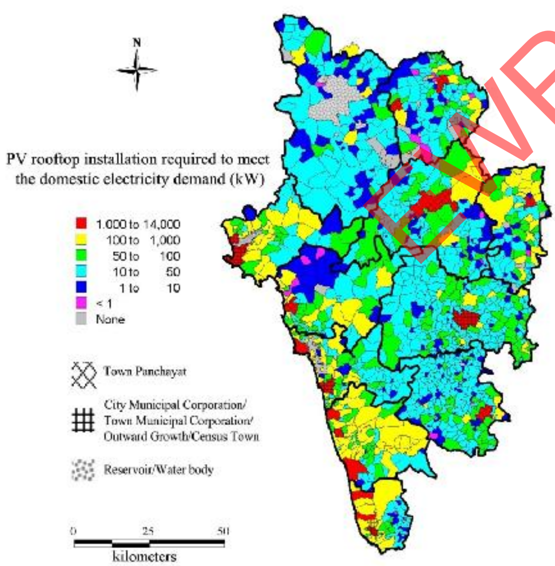

Figure 6: Village wise PV rooftop installation capacity required to meet the household electricity demand

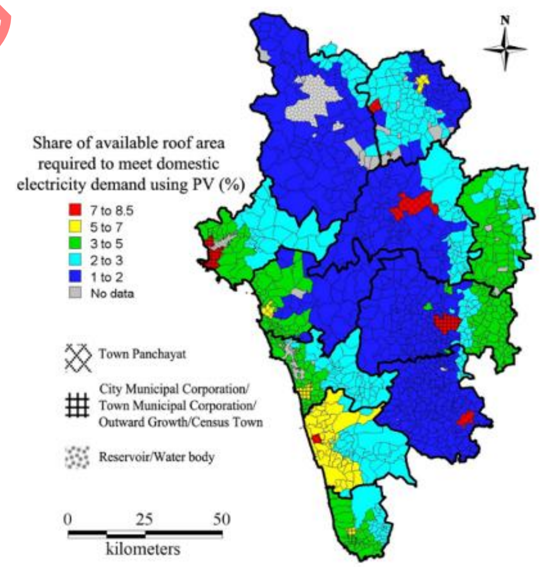

Figure 7: Share of rooftop area required to meet household electricity demand

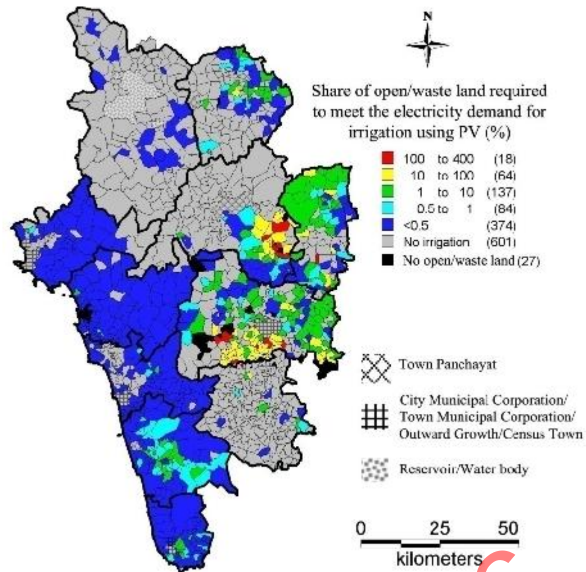

Figure 8: Share of waste land area required to meet electricity demand for irrigation using PV

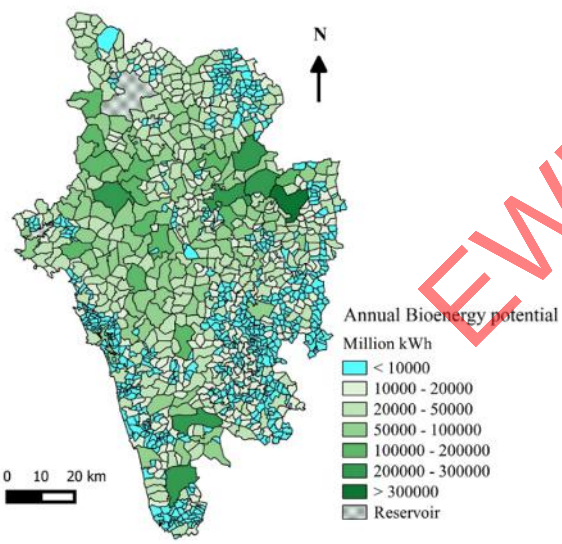

Figure 9: Village wise bioenergy availability

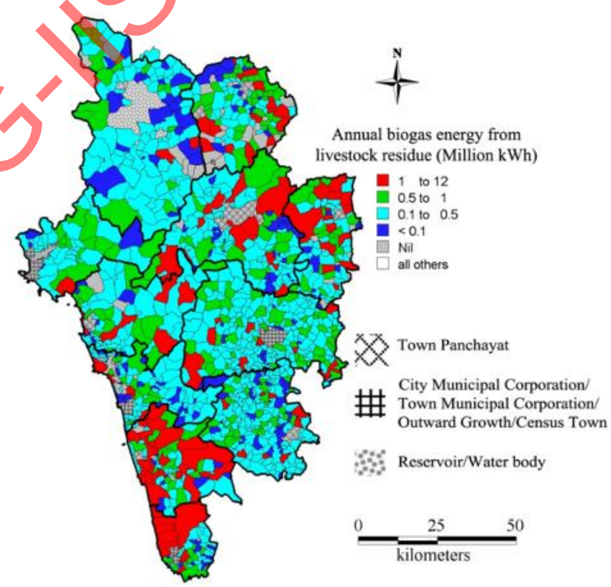

Figure 10: Annual biogas energy availability

Wind Power Density Assessment: Village wise wind power density analysis is carried out in order map the high wind energy potential regions for distributed energy planning. Figure 11 gives the variation in annual average wind power density in the district. Wind speed in the district ranges from 1.7 to 4 m/s where wind power density is about 3 to 39 W/m^2.It is apparent that, coastal villages experience higher wind power density (> 11 W/m^2) compared to hilly area and planes. However, low speed wind generators are suitable for the region, which can be integrated with other energy sources.

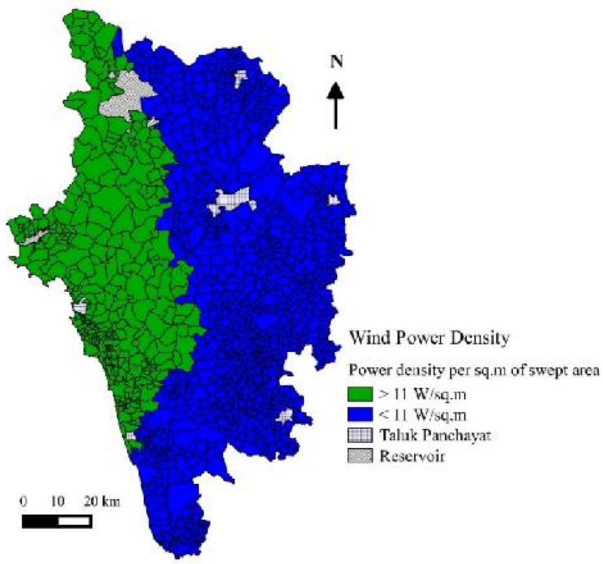

Figure 11: Village wise wind power density in Uttara Kannada

Coastal villages experience higher wind speed (Karwar, Kumta, Ankola, Bhatka, and Honnavar) followed by hilly areas (Sirsi, Siddapur, Yellapur and Supa) and plane regions. Installation of Wind Energy Conversion Systems (WECS) near the coastal belt of the district would be optimum because it has the highest potential. Since the wind turbines need a larger disturbance free area, the coastal belt from Karwar to Bhatkal is best suited for installation. This also adds attraction to the natural scenic beauty of the region. Also, with improvement in technology, integration with other systems and optimisation would reduce the operating cost of the system [21].

Regions at higher altitude in the district (Sahyadri) experience high wind speeds particularly in monsoon, which can compensate for the lower solar insolation. Since these regions lie in Western Ghats which shelters abundant endemic flora and fauna, site selection for wind energy systems must be done without any ecological disturbance. Micro and pico level installation or hybridising wind resource with solar and biomass is a technically feasible and economically viable option in this region. Planes also have enough potential for wind power which could meet the local energy demand particularly through wind pumps and mills. Wind pumps can reform irrigation practices by producing continuous water without depending on grid electricity.

CONCLUSION

Uttara Kannada district receives abundant solar insolation throughout the year which varies from 3.9 to 7.2 $kWh/m^2/day$. Annual average insolation in the district is about 5.42 $kWh/m^2/day$ where, it experience more than 5.2 $kWh/m^2/day$ for about 300 days. Village level energy potential maps were generated which gives the insights for distributed generation from rooftop level to installation in barren lands. Study shows that, fraction of rooftop (< 8%) and barren land (<1%) area is sufficient to meet the household domestic demand and irrigation electricity demand respectively.

District is blessed with abundant bioenergy where the 70% of the geographical area is under rich vegetation. Most of the people practice agriculture in the region which also yields bioenergy through agro-horti residues. Quantification of bioenergy is carried through land use land cover analysis, which shows that about 29368 GWh energy available annually. Similarly, district has good number of cattle and buffalo population which can generate about 230 GWh of energy from biogas annually. Energy from biomass and biogas can be utilised for low and medium temperature heating and also for electricity production.

District experiences wind from west coast which varies from 1.9 to 4 m/s where coastal villages have higher wind power potential (>11W/m^2). Low speed wind turbines are most suitable for the region which can be used for irrigation and electricity generation. Wind energy generation systems can also be integrated with solar and biomass gasifier based generator for reliable electricity production. However, ecologically sensitive regions shall be avoided during the site selection for wind systems.

Adopting renewable energy technologies can address the environmental and energy crisis issues in the developing countries like India. Rooftop electricity generation using SPV panels can electrify remote household supplying the energy for lighting and other minimal domestic applications. Electricity harvesting for locally available energy sources is a decentralised solution for energy crisis problem and to reduce the transmission and distribution losses. This aids in achieving both economic growth and healthy environment in the region.

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