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Impact of Climate Change on Wind Energy Generation in Kagbeni, Nepal using RegCM

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Abstract:
Renewable energies, the promising technologies for the mitigation of climate change, are strongly climate dependent. This research was done to study the impact of climate change on energy generation from wind resources in Kagbeni, Nepal, where the present wind speed and wind power density at 75 m agl are 8.15 m/s and 851 W/m^2 respectively.

In this research, RegCM-4.4.1 regional climate model was used to downscale the future wind resources with a resolution of 10 km x 10 km. The model was validated in the region using five year observed wind resources from 2001-2005 and further it was used to downscale the wind resources for time period of 2030-2050 using HadGEM2 GCM output of scenario RCP 4.5.

This research predicts a 5.3% increase in the wind speed with 13.4% increase in the wind power density at 75 m agl for the time period of 2030-2050. The turbine selected was SUZLON S-52 having hub height of 75 m with 600 KW power rating. The capacity factor of the turbine for the time period of 2030-2050 increases by 15% compared to base year 2001-2005.

Keywords: Wind Energy, Climate Change, RegCM

1 Introduction

Climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, ocean and other bodies of water and living things. Change in the interactive system is climate change or simply the change in average weather condition or climate pattern is climate change. Climate change, change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods [1], is stated as the greatest threat of 21st century. Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen [2]. The planet is already experiencing its impact on biodiversity, freshwater resources and local livelihood [3]. From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale [4].

Renewable energy, energy resources that occur naturally and repeatedly in environment and can be harnessed for human benefit, a promising technology for the mitigation of climate change generates 19.1% of global final energy consumption in 2013 and its growth continued to expand in recent years [5].

The use of wind energy (WE) in electricity generation is nowadays widely spread, and the total wind power capacity installed worldwide has grown from 121 GW in 2008 to 371 GW in 2014. More than 50 Giga watts of capacity were added during the year 2014 which shows market volume was 40% bigger than in 2013 [6].

Renewable energy is highly driven by the weather and climate conditions. Parameters like wind velocity, monsoon, cloud cover, humidity etc. climate driven causing impacts on the generation of electricity from renewable resources. So, question arises, how much the potential of renewable energy is affected by the climate change and this research tries to answer the question from the case study of Nepal. The small changes like 5% or 10% in renewable energy resources have the greater impact to the energy farms causing the vast profit or ultimate failure of the project [7].

In this thesis an attempt is made to identify how future climate change might impact on energy generation from wind. As wind is driven by climatic conditions, it is important to assess projected climate change that may have an impact on energy generation from wind. Major two impacts of climate change on wind power plant are:

- Change in wind speed
- Increase in the maximum wind speed for which wind power plant is designed-this influences reliability and safety of the plant equipment [8]

2 Study Location

Figure 1: Domain for RegCM

Solar and Wind Energy Resource Assessment in Nepal (SWERA) analysis shows that 3000MW of electricity could be generated from wind energy. This includes the conclusion 10% of Nepal has a potential of 300 W/m^2 [9]. The study by DANGRID, Danish consulting firm in 1992 reported a potential to generate 200MW of electrical power with an annual energy production of 550GWh from the wind resources along the valley between Kagbeni and Chausasang in Mustang district. Mustang is suitable for harnessing wind energy especially for the purpose of utility scale electricity generation. From 2001 to 2005 the annual average wind speed and power density 75 m above ground level at Kagbeni are 8.05 m/s and 851W/m^2 respectively [10]. As, Kagbeni has potential to tap the wind resources, it is selected as the study location.

RegCM-4.4.1 was selected as the regional climate model which was developed by ICTP. EIN15 reanalysis data having horizontal resolution of 1.5 degree x 1.5 degree was downscaled in the resolution of 90 km x 90 km and it was nested twice in resolution of 30 km and 10 km respectively and finally it was validated with the ground observed data collected by Alternative Energy Promotion Centre (AEPC) from 2001 to 2005. HadGEM2 GCM data of RCP4.5 scenario was used to project the future wind resources and it was also downscaled in resolution of 90 km and nested twice in the in 30 km and 10 km resolution. The figure 1 shows the domains and the nested domain.

3 Observed Data

The observed data shows the average of 6.7 m/s of wind speed at 10 m above the land surface. Figure 2 shows the monthly average for time period of 2001-2005. The Figure 3 shows the wind speed increases from month January and peak at the month of June and then declines. At June, the average wind speed is 8.7 m/s at 10 m above ground level.

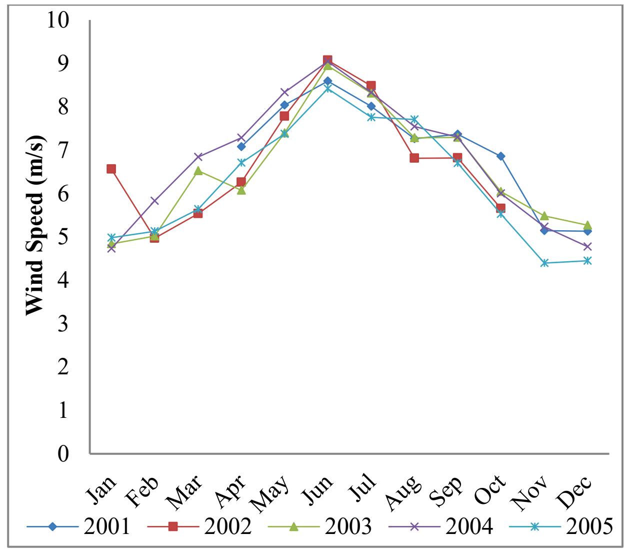

Figure 2: Average wind speed 2001-2005

4 Model Setup

RegCM4 uses the radiation scheme of NCAR CCM3 and BATS as the land surface model. Physical setting, i.e. physicsparam setting, of the model is very important for the correct model setting for the selected region. Generally, sensitivity test is done to get the best output from the model. In this thesis literatures have been reviewed for finding the best model setting. Relaxation, exponential technique scheme was used for lateral boundary conditions while Hostslag PBL scheme was used for planetary boundary layer. Emanuel scheme was selected for cumulus convection over land and same scheme was selected for cumulus convection over ocean. Explicit moisture scheme was selected for moisture scheme and Zeng et al scheme was selected for ocean flux scheme.

5 Validation of Model

EIN15 reanalysis data was downscaled in the resolution of 10 km x 10 km and was compared with the ground-based data. The monthly mean for the time period of 2001-2005 was compared and the result is shown in figure 3.

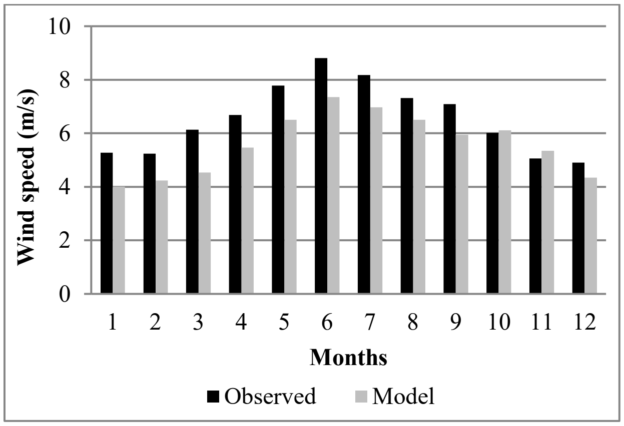

Figure 3: Monthly average of observed vs model

The model output was able to show similar characteristics with observed data and the RMS value for observed and model is 0.8 m/s. This shows that model can represent the ground-based data accurately.

From the figure 4 plotted between observed data and model data, shows that model can represent the observed data. Model data has similar pattern with the observed data which finally concludes that model is verified in Kagbeni, Nepal. After verification of the model, future wind projection was conducted.

6 Results and Discussion

Wind turbine class, average annual wind speed on site, was taken as the important parameter for the selection of the wind turbine. As the site belongs to II class turbine of this class was selected. Market availability and existing turbine companies were assessed and finally SUZLON S-52 turbine of rated power 600 kW was selected for the site.

6.1 Wind Speed

The bar with pattern shows the averaged wind speed for the base scenario i.e. 2001-2005 while color bar shows the five yearly average wind speed from time period 2030-2050. This result shows that, under RCP 4.5 scenario, the modeled wind speeds from year 2030-2050 have increased wind. Averaged wind speed was projected to increase to 8.47 m/s from 8.05 m/s and the increase is 5.28 % from the base year period to the future period of 2030-2050.

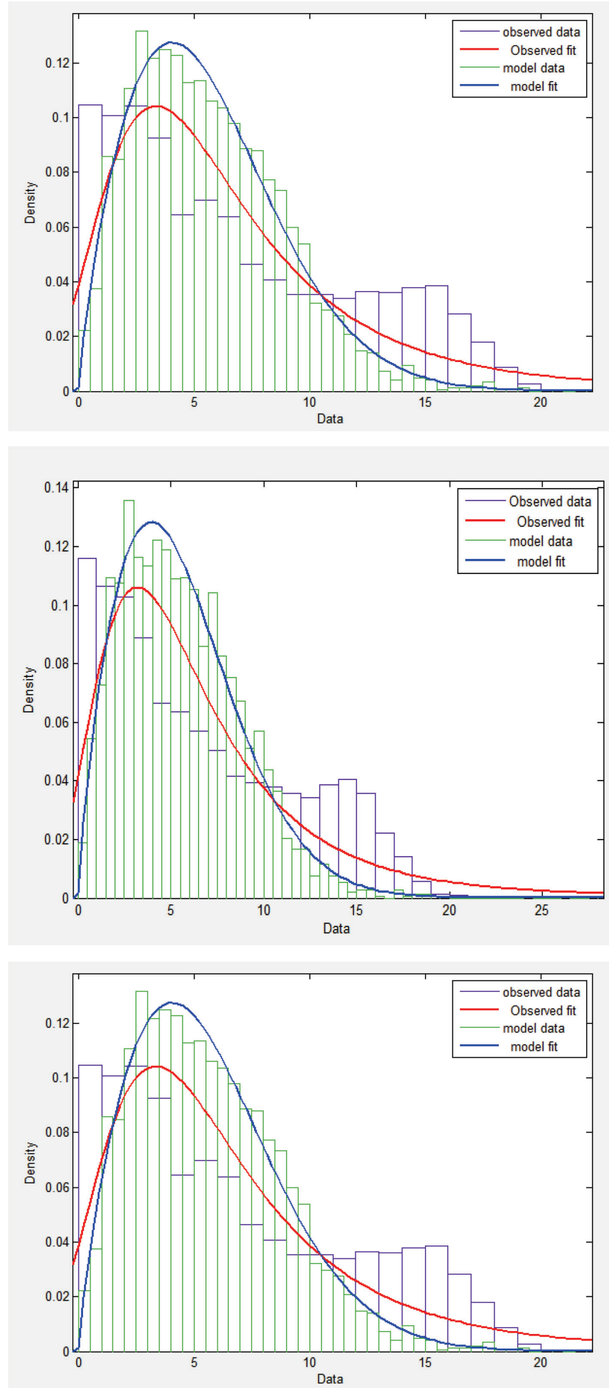

Figure 4: Probability density plot for 2003, 2004 and 2005 respectively

Table 1: Average five yearly wind speed

Year	Average wind speed (m/s)	Percentage Change
2001-2005	8.05	Base year
2030-2035	8.69	8.01%
2035-2040	8.13	1.03%
2040-2045	8.56	6.37%
2045-2050	8.51	5.71%
Average of 2030-2050	8.47	5.28%

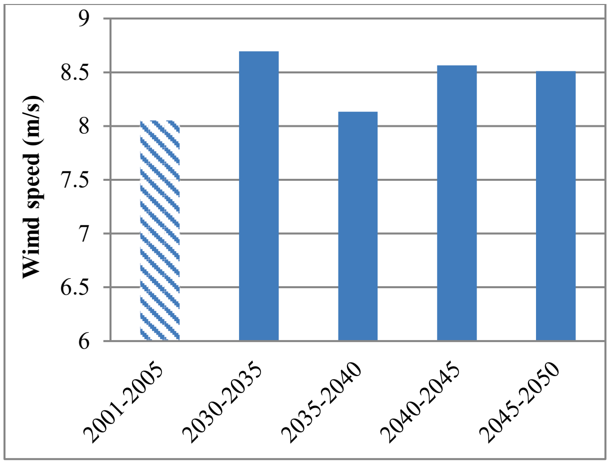

Figure 5: Average wind speed

6.2 *Wind Power Density*

Table 2: Five yearly averaged WPD

Year	Wind power density(W/m^2)	Average increase in WPD
2001-2005	851	Base data
2030-2035	1074.5	26.26%
2035-2040	872.5	2.52%
2040-2045	954.82	12.2%
2045-2050	960	12.8%
Average of 2030-2050	965.98	13.45%

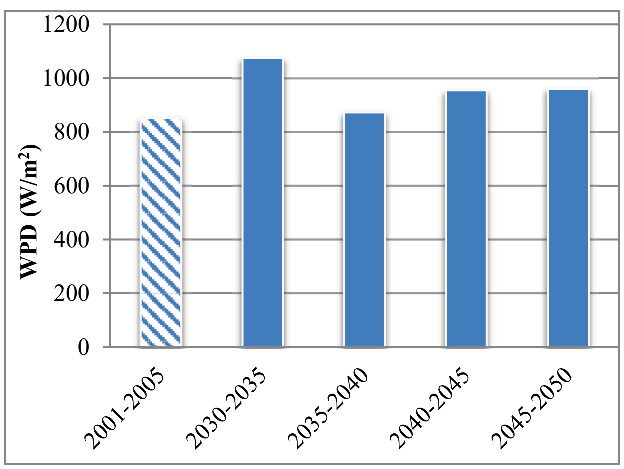

Figure 6: Wind power density

The Figure 6 shows the gradual increase in WPD from 2035-2050 while it has maximum value for time period of 2030-2035. The figure 5.3 has almost same pattern as Figure 5.2 except for the time period of 2045-2050, where average wind speed for the time period is slightly decreased compared to 2040-2045. This concludes that, only averaged wind speed doesn't show much clear picture. Higher wind speeds up to the range of 34 m/s was simulated for future scenario while 27 m/s was the maximum wind speed found in observed data. These shows increased wind speed in the future which will also affect the turbine design parameters.

6.3 *Capacity Factor*

Table 3: Five year average capacity factor

Year	Capacity Factor
2001-2006	36.32%
2030-2035	44.8%
2035-2040	32.7%
2040-2045	45.21%
2045-2050	44.5%
Average for 2030-2050	41.8%

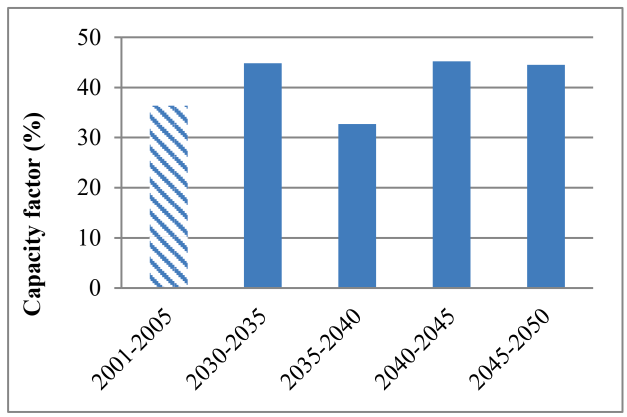

Figure 7: Capacity factor

From the figure 7 and table 3, it is found that capacity factor has different pattern than average wind speed and average WPD, which shows overall increase of 15.1%. Capacity factor for the time period 2030-2035 is lower than the base scenario as the time period contains less intensity of higher wind speed and maximum intensity of wind speed lies in range of 4-7 m/s. These results were obtained using RCP 4.5 scenario, different results would be obtained if different other scenarios were used.

7 Conclusion

EIN15 reanalysis data was used as initial and boundary condition to RegCM for the time period of 2001-2005 and the output result was compared with the observed data and the comparison found the data are in similar pattern having RMS value of 0.8 m/s concludes model is verified in Kagbeni, Nepal.

Near future (2030-2050) wind resource was projected using HadGEM2-ES GCM output of RCP 4.5 scenario.

The average wind speed for the time period was modeled increase to 8.5 m/s from 8 m/s, base scenario (2001-2005), which is an increase of 5.3 % from base scenario.

Wind power density was also calculated for the base scenario as well as for future scenario for Kagbeni, Nepal which shows WPD increased to 965.5 W/m^2, increase by 13.5%, from 851 W/m^2 (base scenario).

Capacity factor for the selected wind turbine in the study location is modeled to be averaged increased to 41.8% for the future scenario from 36.3% of base scenario and the rise is 15.1%.

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