Re-assessment of India's on-shore Wind Power Potential

POLICY NOTE

Background

India currently ranks 4th globally, in terms of wind power capacity, with an installed onshore capacity of 26 Giga Watts (GW). In March 2015, Renewable Energy (RE) sources formed 12% of India's total installed capacity of 268GW. Of this, the share of wind energy was the highest at 9%. Between 2006 and 2015, the wind industry added between 1.5-3 GW per annum. On-shore wind technology has been commercially viable for more than a decade now, and forms a key constituent of India's energy basket today. Hence, the Government of India (GoI) in 2015 had announced a target of installing 60GW of wind by 2022.

Introduction

Until last year, the on-shore wind power potential in India was officially estimated to be 102GW at a hub height of 80m[1]. However, there are multiple independent re-assessment studies that estimate the potential to be much higher, as much as 2,000GW, for onshore wind farms at 80m hub height. From a policy perspective, it has become imperative to re-assess India's technical wind potential to implement effective policies for achieving the target.

Even in the global arena, recent re-assessments conducted in some countries (U.S. and China) have found much higher energy potential with advancements in technology[2]. Internationally, it is well established that a systematic analysis based on Geographic Information Systems (GIS) provides an accurate way to identify land with the potential for developing wind power. Recognising the significance that potential estimates bear on the outlook for the wind sector, the Ministry of New and Renewable Energy (MNRE) constituted a Committee - with an objective to re-assess India's onshore wind power potential for all major land types at hub heights of 100 and 120m. As part of this Committee, WinDForce Management Services (WFMS), Shakti Sustainable Energy Foundation (SSEF), and Center for Study of Science, technology and Policy (CSTEP) conducted the re-assessment exercise using two separate mesoscale datasets and a common GIS methodology.

[1] *This was recently revised to 302GW for a 100 m hub height.*

[2] *China's official wind power potential has increased by 800% and that of the U.S. by 50%.*

[3] *The layout for space between turbines; D denotes a 100m rotor diameter of a representative turbine 2MW capacity*

Results

Wind Power Potential: The technical wind power potential estimated from the two data sets used by CSTEP and WFMS is summarised in Table 1 below. The capacity is based on a 5D x 7D[3] array configuration which has shown to cause the least amount of losses due to interference between the turbines. It results in a capacity density of 5.7 Mega Watt (MW) per sq. km.

Table 1: Total Wind Power Potential

Hub Height (metres)	Estimated Wind Potential-CSTEP (5D x 7D layout) (GW)	Estimated Wind Potential-WFMS (5D x 7D layout) (GW)
100	2,759	2,161
120	2,959	2,540

Figure 1 below maps wind speed in the Indian states considered for estimating the potential, at a 100 m hub height, without reference to land availability.

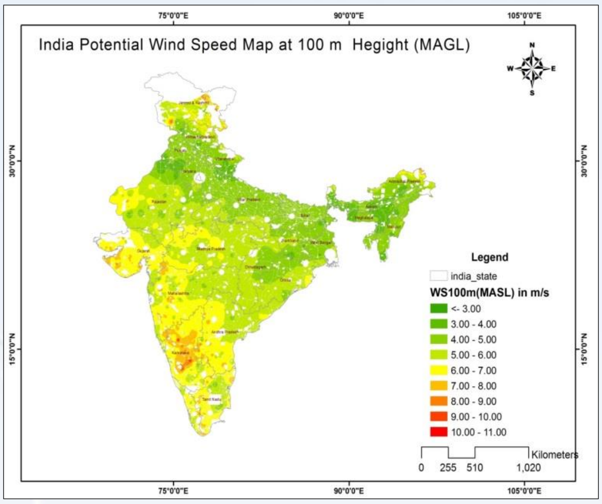

Figure 1: India Wind Speeds at 100 m Hub Height

Potential by land type: Waste land is ranked most suitable for development (rank 1), followed by agricultural and forest lands. Most of the potential lies in agricultural land and waste land, namely ranks 2 and 1 respectively. Close to 50% of the estimated potential lies in agricultural land, with most of the remaining in waste lands. A maximum of 17% of the potential is in plantations, evergreen areas, and deciduous forests (Table 2).

Table 2: Potential for 3 Land Categories at 80, 100, and 120 m Hub Height

	GW Potential - CSTEP		GW Potential - WFMS	
Land Rank	100 m	120 m	100 m	120 m
Rank 1 (Waste Land)	1,001	1,149	591	653
Rank 2 (Agricultural Land)	1,279	1,409	1,222	1,435
Rank 3 (Forest Land)	479	401	349	453
TOTAL	2,759	2,959	2,162	2,541

There is a substantial amount of potential (up to 2,500GW) to be harnessed in ranks 1 and 2 categories of land. On waste land alone, there is a minimum of about 590GW, with up to a maximum of 1,000GW of potential estimated at a hub height of 100m, as shown in Table 3 below:

Table 3: GW Potential for Waste Land and Agricultural Land

	GW Potential - CSTEP		GW Potential - WFMS	
Land Rank	100 m	120 m	100 m	120 m
Rank 1	1,001	1,149	591	653
Rank 2	1,279	1,409	1,222	1,435
TOTAL	2,280	2,558	1,813	2,088

An estimate based on a more optimal 3D x 5D layout is also calculated in this study, which represents the most optimistic estimate of the technical potential in the areas considered. This densely packed layout results in a capacity density of 13.3MW per sq. km, and increases the technical potential to 6,439GW and 6,905GW at 100 and 120m respectively for CSTEP's results.

For the second set of results from WFMS the potential increases to 5,043GW and 5,927GW at 100 and 120m respectively. In actual projects, the layout of the turbines may differ, depending on what is suitable for the region-specific terrain. For instance, in regions with gradual hillocks, the turbines may be spaced on top of the hillocks and spaced as a linear string. Since the assessment of region-specific terrains is out of the scope of this study, the two layouts mentioned above are assumed to represent the range of possible layouts for turbines.

Hybrid Potential: The two sources of solar and wind have been observed to have complementary resource profiles. Hence, this report also examines the technical potential in co-located wind and solar sites across the country. It is estimated that nearly 10 GW of solar-wind hybrid potential is available. As an illustration, Figure 2 below shows the hybrid sites in Karnataka.

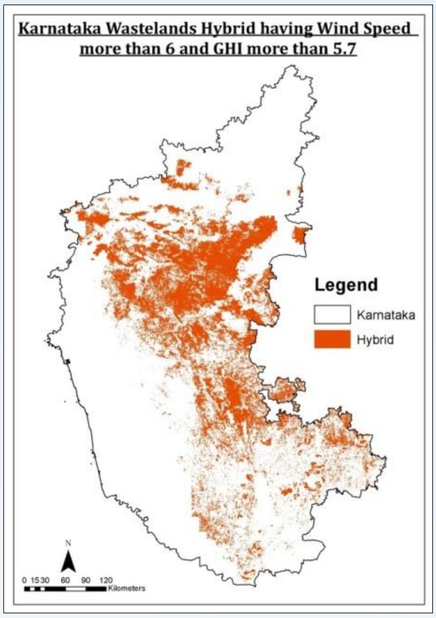

Figure 2: Karnataka Hybrid Potential Sites

Estimated CUF Ranges: Electricity generated at a particular site is largely dependent on the choice of turbine in addition to the resource quality at the site. For this study, a representative turbine with 2 MW capacity, and 100m rotor diameter was chosen. The minimum Capacity Utilisation Factor (CUF) obtained, by intersecting the wind speed profile (with weibull shape parameter k = 2, for a minimum wind speed of 6 m/s) was 24%. Most of the estimated wind potential lies in the CUF range of 24-34%. A very small percentage of the estimated potential has a CUF of 42-44%. The following results (Table 4) show the wind power potential corresponding to CUF>20%.

	WFMS			CSTEP		
Hub Height (m)	Area (sq. km)	Potential with 5D x 7D (GW)	Potential with 3D x 5D (GW)	Area (sq. km)	Potential with 5D x 7D (GW)	Potential with 3D x 5D (GW)
80 m	-	-	-	133,710	762	1,778
100 m	259,043	591	1,378	175,692	1,001	2,337
120 m	286,200	653	1,523	201,568	1,149	2,681

Land Utilisation: Most of the potential is concentrated in the seven states of Tamil Nadu, Andhra Pradesh, Telangana, Karnataka, Rajasthan, Gujarat, and Maharashtra. If 100% of the higher estimate of the potential in these states is tapped, the total land area under wind farms will be ~15% of India's total land area in case of a capacity density layout of 5D x 7D (Table 5) with a footprint of 0.8%. To harness the potential in only seven wind-rich states, the land required would be 28.3% of the total area of these states, with a footprint of 1.6%.

		5D x 7D	3D x 5D
Capacity installed per sq. km.	MW/sq. km	5.71	13.33
Wind power potential at 100 m	MW	2,759,703	
Total footprint area	sq. km	27,597	
India's total land area	sq. km	3,287,263	
Total land required for tapping the full potential	sq. km	482,948	206,978
Total land required as % of India's total land	%	14.7	6.3
Footprint area as % of India's total land	%	0.8	
Potential in 7 wind-rich states	MW	2,332,912	
Total land required as % of the total area of 7 states	%	28.29	12.13
Footprint area as % of total area of 7 states	%	1.6	

This requirement reduces to less than half for a 3D x 5D layout. This range is indicative of the limits of the actual requirement which may lie between the two extremes depending on site-specific conditions.

Policy Implications

Some of the major implications for policy and planning for harnessing the potential are as follows:

- There is very high potential available on waste land alone, up to 1,000 GW. Nodal agencies in the states with high wind potential can identify some of the high potential waste lands and expedite clearances for them.

- In order to utilise this vast potential, it is essential that the resource data regime improves. India needs to ensure public access to credible and updated to encourage investments in the sector. GoI may consider innovative models which channel private sector investments to accelerate the deployment of met masts and the process for data validation.

- There is an opportunity to unlock some of the high potential lands in states which have been occupied with low-capacity and low-efficiency wind turbines from the early stages of development in wind power in the country. Appropriate incentives for repowering these sites can enhance capacity in some of the known high potential sites.

- As the potential is mostly concentrated in the southern and western states, there needs to be mechanisms to enable inter-state trading of wind power, requiring coordination among load dispatchers and transmission utilities.

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