Re-inventing Renewable Energy Grid Integration (India)

Transmission and Distribution Division,
Source Advisory

Table of Contents

Table of Contents

- **Chapter 1: India – the land of hidden potential**
- **Chapter 2: The heavy power consumers**
- **Chapter 3: The balancing algorithm**
- **Chapter 4: Optimizing generation and demand**
- **Literature review**
- **References**

Chapter 1: India – The land of hidden potential

Renewable Energy Potential

Total Deployable renewable resources including hydro, solar and wind account approximately equal to 1000 GWs. The availability of such resources is scattered throughout the country. While the north and the north east are rich in hydro, the west and the south are rich in wind and solar.

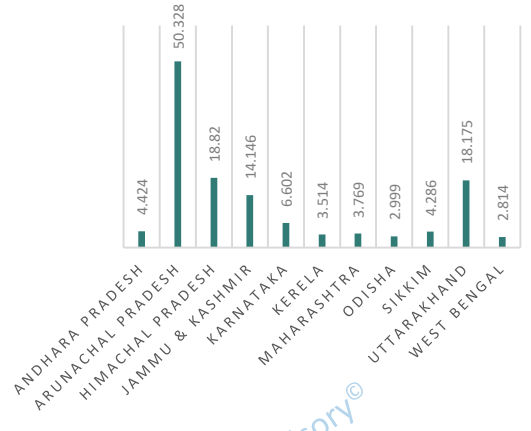
Solar power among all other renewable resources has the highest potential of about 750 GW. Next in the line is wind potential of about 300 GW at 100 m above the ground level, followed by hydro energy potential of ~150 GW.

Based on this information the report classifies the Indian sub-continent into hubs of potential renewable energy. The Potential renewable energy hubs are of 4 kinds, namely –

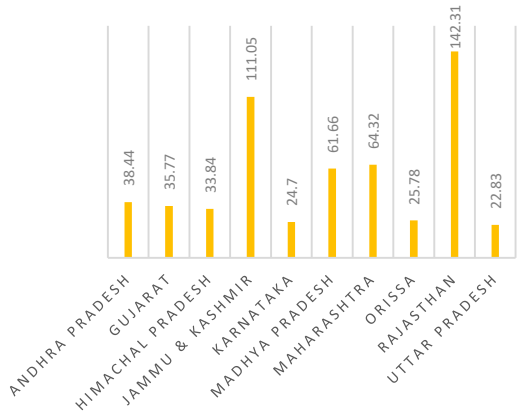
1) Potential Solar Hubs: States with conceding boundaries having solar potential of >= 20GW
2) Potential Wind Hubs: States with conceding boundaries having wind potential of >1GW
3) Potential Hydro Hubs: States with conceding boundaries having hydro potential of >=2GW
4) Potential Hybrid Hubs: States with conceding boundaries having a combination of any of the above.

On the following page the infographic show the renewable hubs in India.

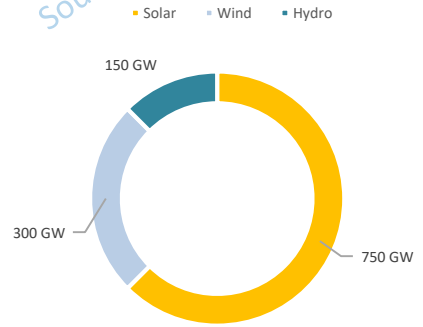
Indian states with highest wind potential (@100m above ground level)[1]



Indian states with highest hydro potential[1]

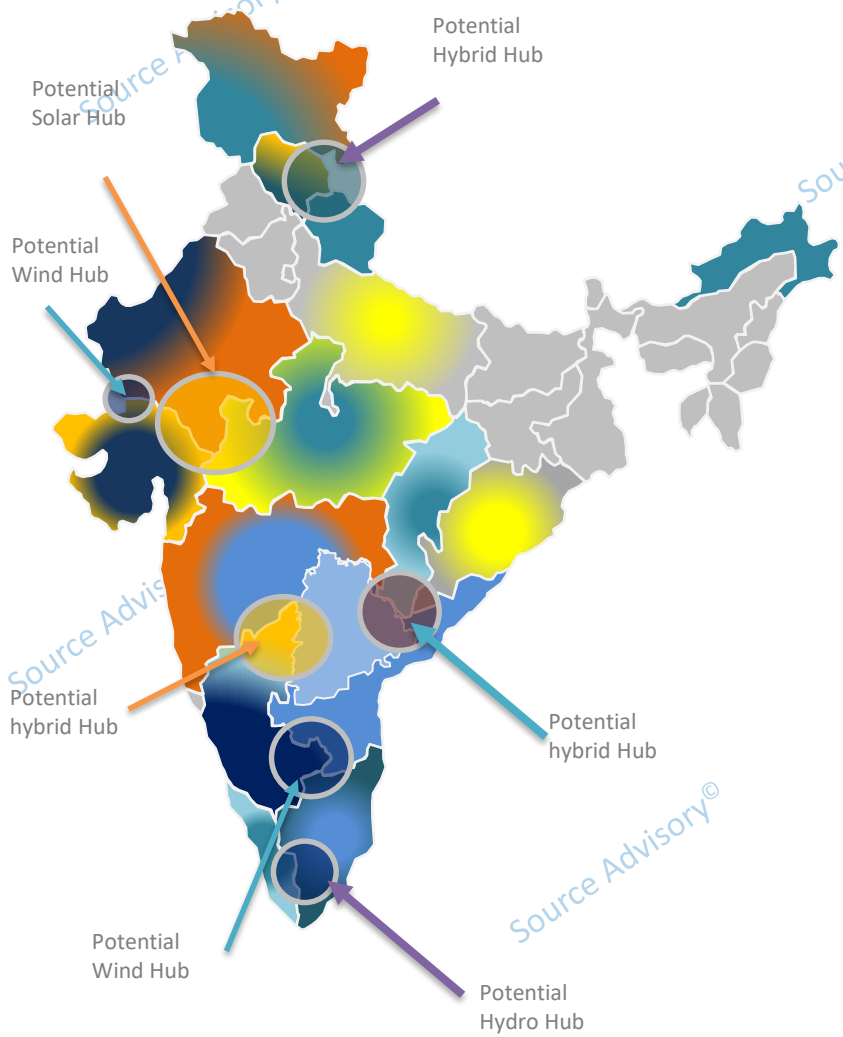


Indian states with highest solar potential[1]

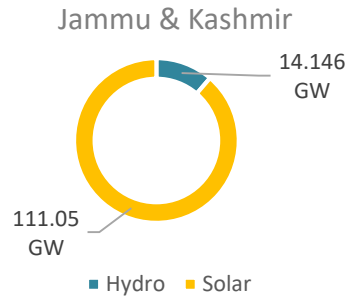


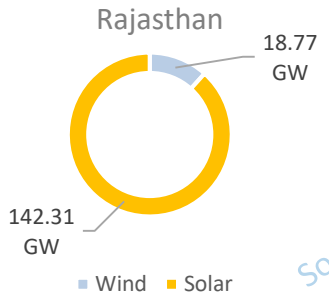
Total deployable renewable potential[2]

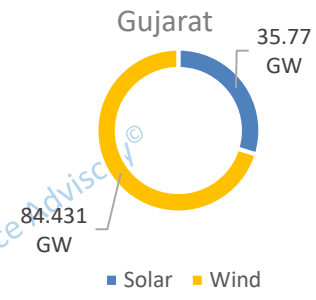
References:
[1] MNRE

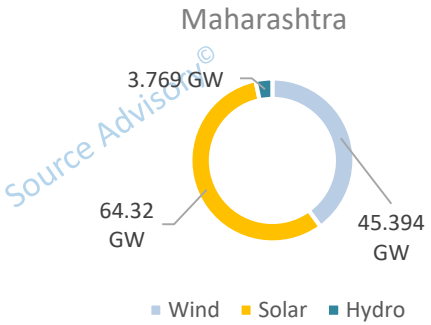


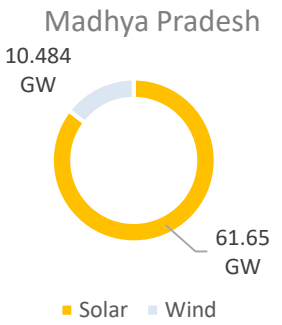
Indian renewable hubs[2]

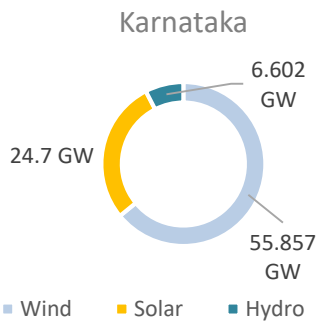


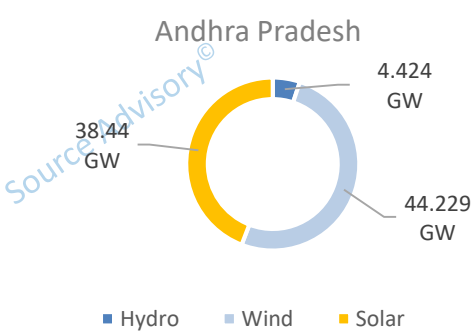


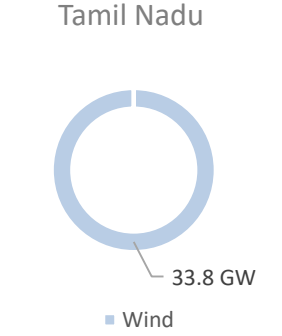


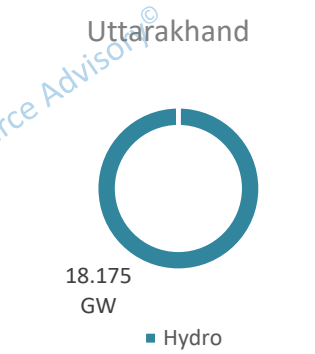


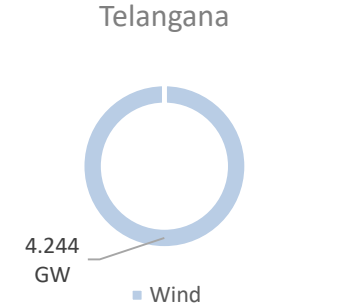


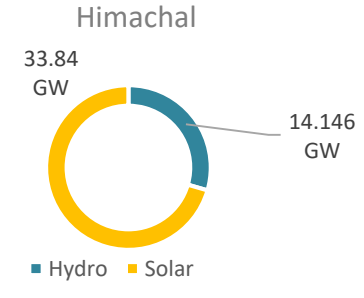


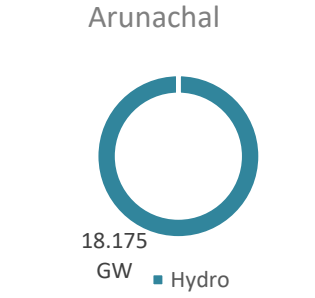












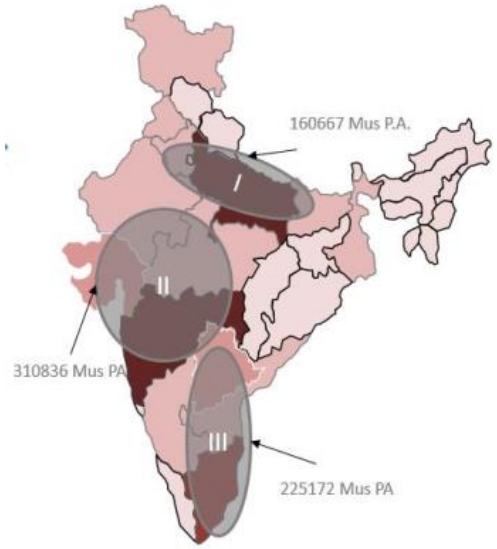
Chapter 2: The heavy power consumers

The fat Indian consumer

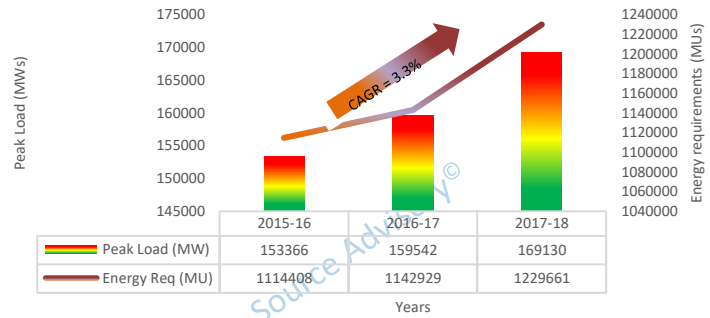
Large consumers, no surprise have the largest industrialization, urbanization and commercialization. The adjacent heat map shows some of the largest power consuming states in India. This report groups and classifies the states into heavy load centers based on their geographic location –

- The largest consumption hub in the west includes – Maharashtra, Gujarat, Rajasthan and Madhya Pradesh consumes about 310GWh per annum.
- This is followed by southern consumption hub including – Karnataka, Tamil Nadu and Andhra Pradesh consumes 225GWh on average throughout the year.
- Lastly, the northern hub including – Uttar Pradesh, Delhi and Haryana consuming ~160GWh per annum.

Theses plump boys consume power rising at a CAGR of ~3.3%p.a. The bar chart clearly presents the peak consumption rising each year.



Heavy load centers[2][2]



Peak load and energy consumption[2][3]

References:
[2] Source Advisory Analysis
[3] Load Generation Balance Report, CEA

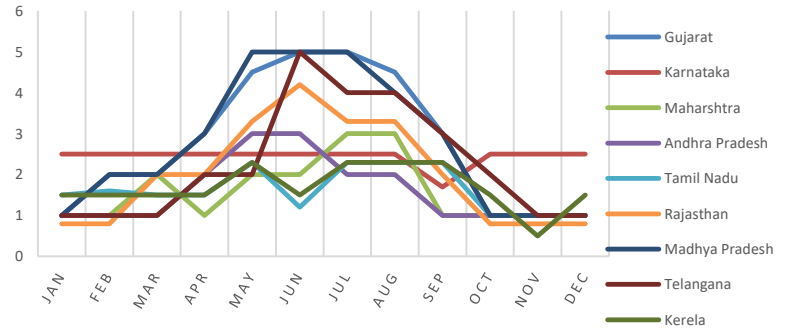
Chapter 3: The balancing arithmetic

Chaos theory mechanism

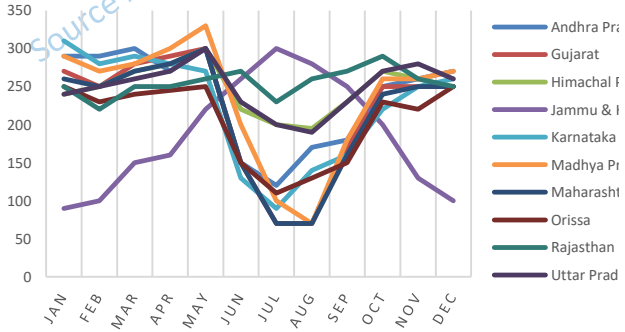
In theory, renewable energy plants are not very reliable. However, reasonable assumptions and the analysis in this report suggests that the wind and solar resources complement each-other. A renewable portfolio of wind and solar power according to the analysis is supposed to support and average out the dilution and scattering effect of individual technologies.

A practical example could be seen on the following page. Where the report tries to classify the graph into three regions, based on the months of the year. If observed carefully, it can be noted that the time of the year when wind speeds re not favorable, sun hours in the same region are quite favorable for satisfying the power requirements.

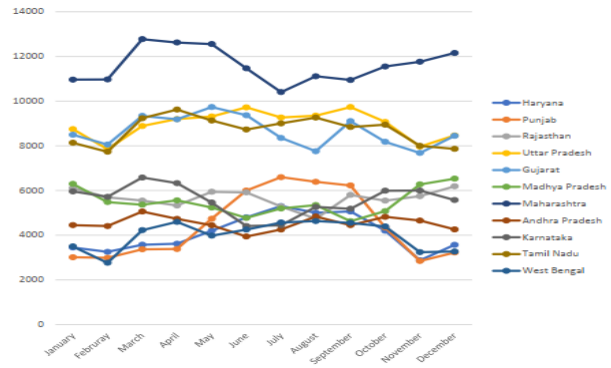
This ensures year-round ability of renewable plants to fulfil the requirement of power throughout the country. The study does not only suggest the complementing nature of the renewable energy sources, but also their potential to balance the load variations in various regions of the country throughout the year even if only 10% of the total renewable energy potential is deployed.



Average annual wind-speeds (m/s) for highly potent states [4]

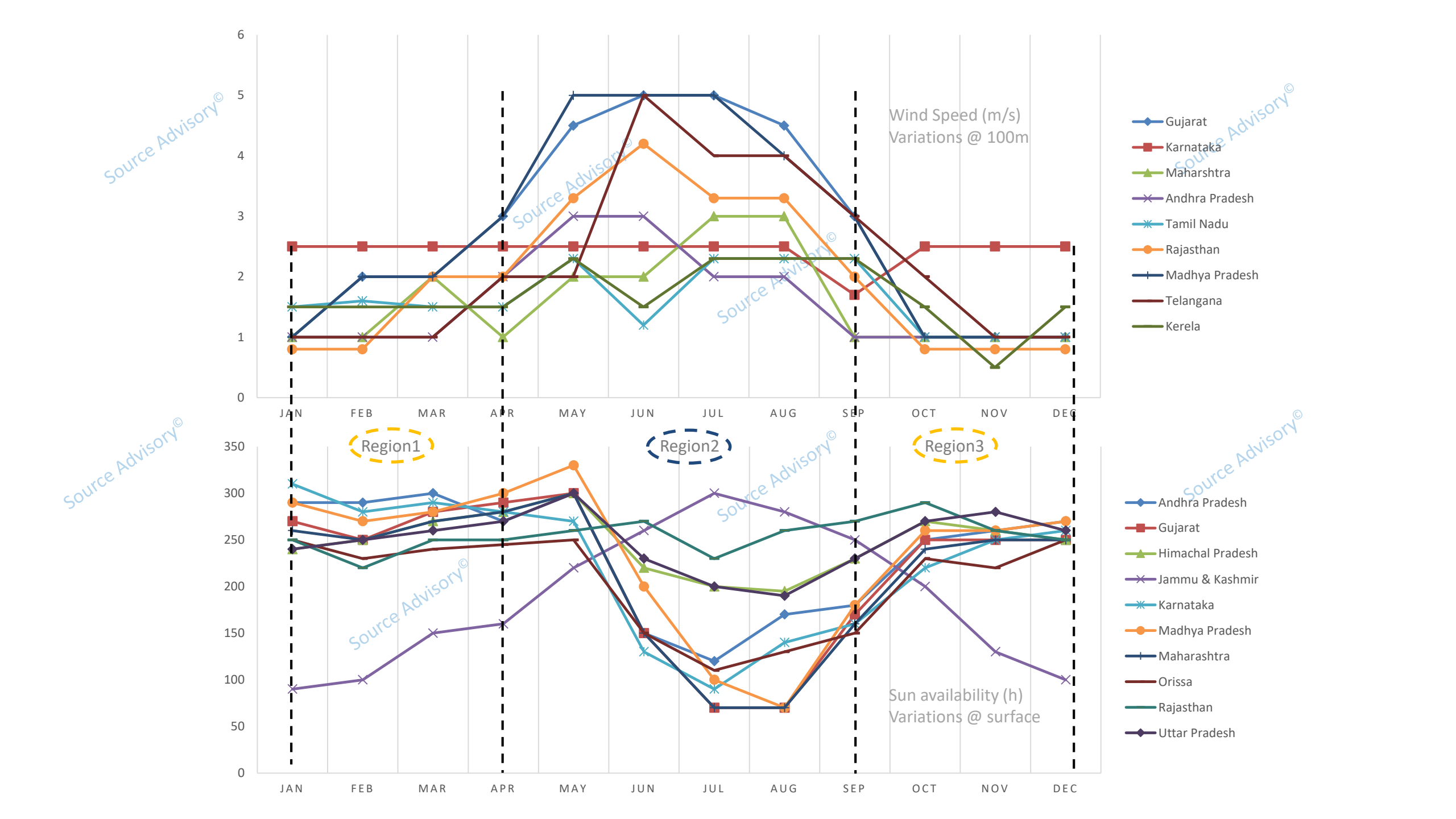


Average annual solar-hours (h) availability for highly potent states [4]



Average annual load variations for states with huge concentration of load [3]

References:
[4] Meteorological Department of India


Wind Speed (m/s)
Variations @ 100m
Gujarat
Karnataka
Maharshtra
Andhra Pradesh
Tamil Nadu
Rajasthan
Madhya Pradesh
Telangana
Kerela
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Region1
Region2
Region3
Sun availability (h)
Variations @ surface
Andhra Pradesh
Gujarat
Himachal Pradesh
Jammu & Kashmir
Karnataka
Madhya Pradesh
Maharashtra
Orissa
Rajasthan
Uttar Pradesh
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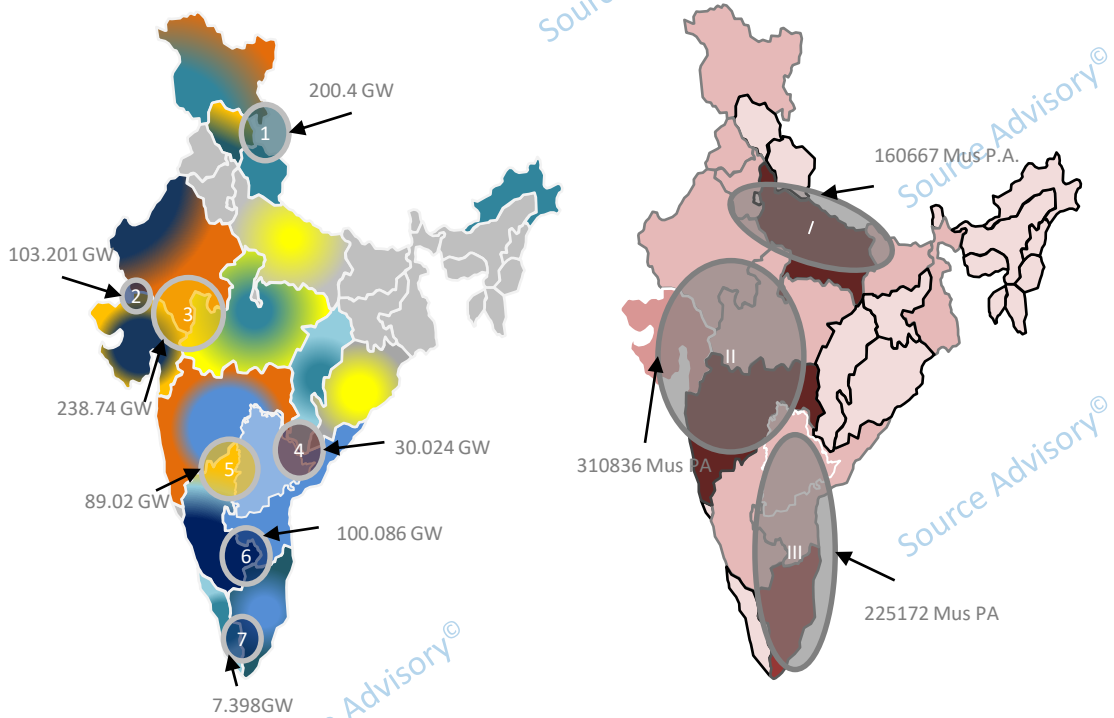
Chapter 4: Optimizing the generation and demand



Region of Supply (10% of deployable potential at 20% average PLF for 300 days * 12 hours a day)	Region of Demand (demand post 10 years at CAGR of 3.3%)
Region 1 (14428.8GWh p.a.)	Region I (311GWh p.a.)
Region 2, 3, 5 (30960GWh p.a.)	Region II (428GWh p.a.)
Region 4, 6, 7 (9885.6GWh p.a.)	Region III (211GWh p.a.)

References:
[4] Meteorological Department of India

Literature review

- *June 2011*, ***Marcelino Madrigal*** *(Senior Energy Specialist, Energy Anchor Unit, World Bank) and* ***Steven Stoft*** *(founder and director, Global Energy Policy Center)* a paper on "Transmission Expansion for Renewable Energy Scale-Up"

- *November 2013*, **CEA**, "Large-scale Renewable Integration"

- **Black and Veatch, "***A case study on Transmission planning for Renewables in the United States.***"**

References

- *LGBR, CEA*
- *Renewable Energy Potential, MNRE*
- *Wind Speed, Meteorological Department of India*
- *Sun-hours, Meteorological Department of India*
- *Source Advisory Analytics*

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