Injection of Renewable Power on a large scale
and
its effect on the stability of the Transmission Grid
and
operational cycle of conventional Thermal Power Plants

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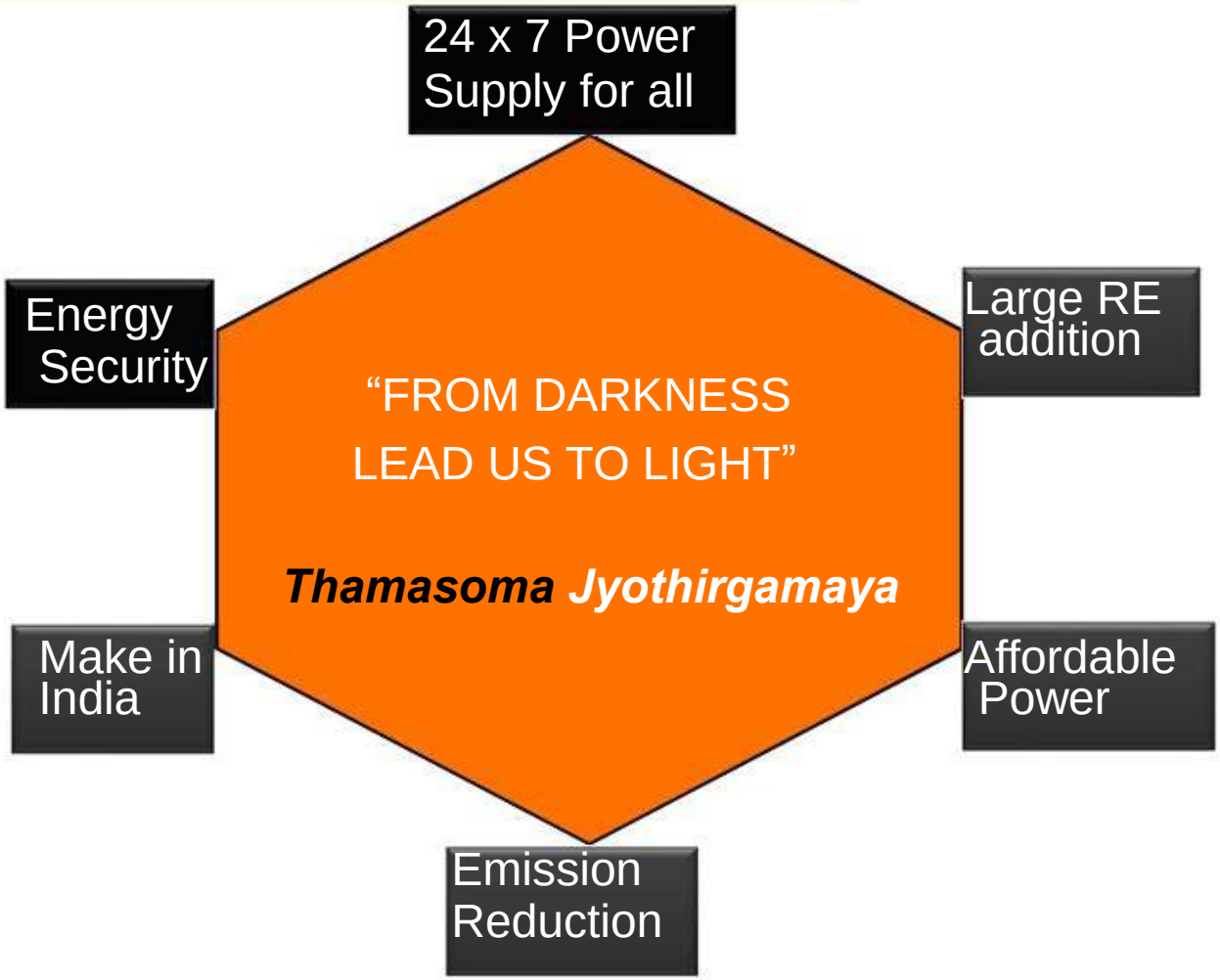
ted Mission of Ministry of Power



listic, system-level view required to manage the pulls and pressures

Commitment to 24 x 7 reliability and energy security

Renewable power in India

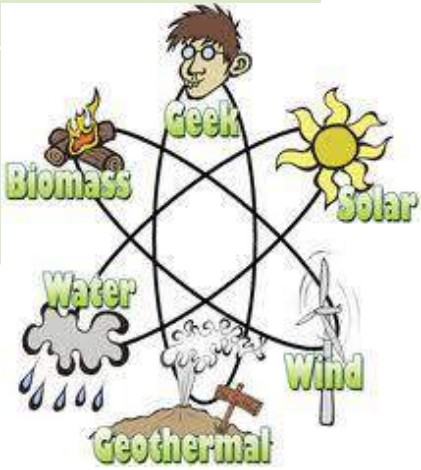
- Since 9th Plan, share of renewable capacity has increased from 2% to 13% as on today (about 6 fold % increase).
- Electricity generation due to renewable has also increased to about 6% in overall electricity generation mix as of today.
- With such multifold growth, penetration of renewable power in Indian grid has increased.

Installed Capacity and generation

Source	CAPACITY (MW) 1 April, 2015	Generation in 2014-15 In BU
Renewable energy sources	**35776.96**	**61.78**
Conventional sources	235945.22	1048.67
Total	271722.18	1110.458

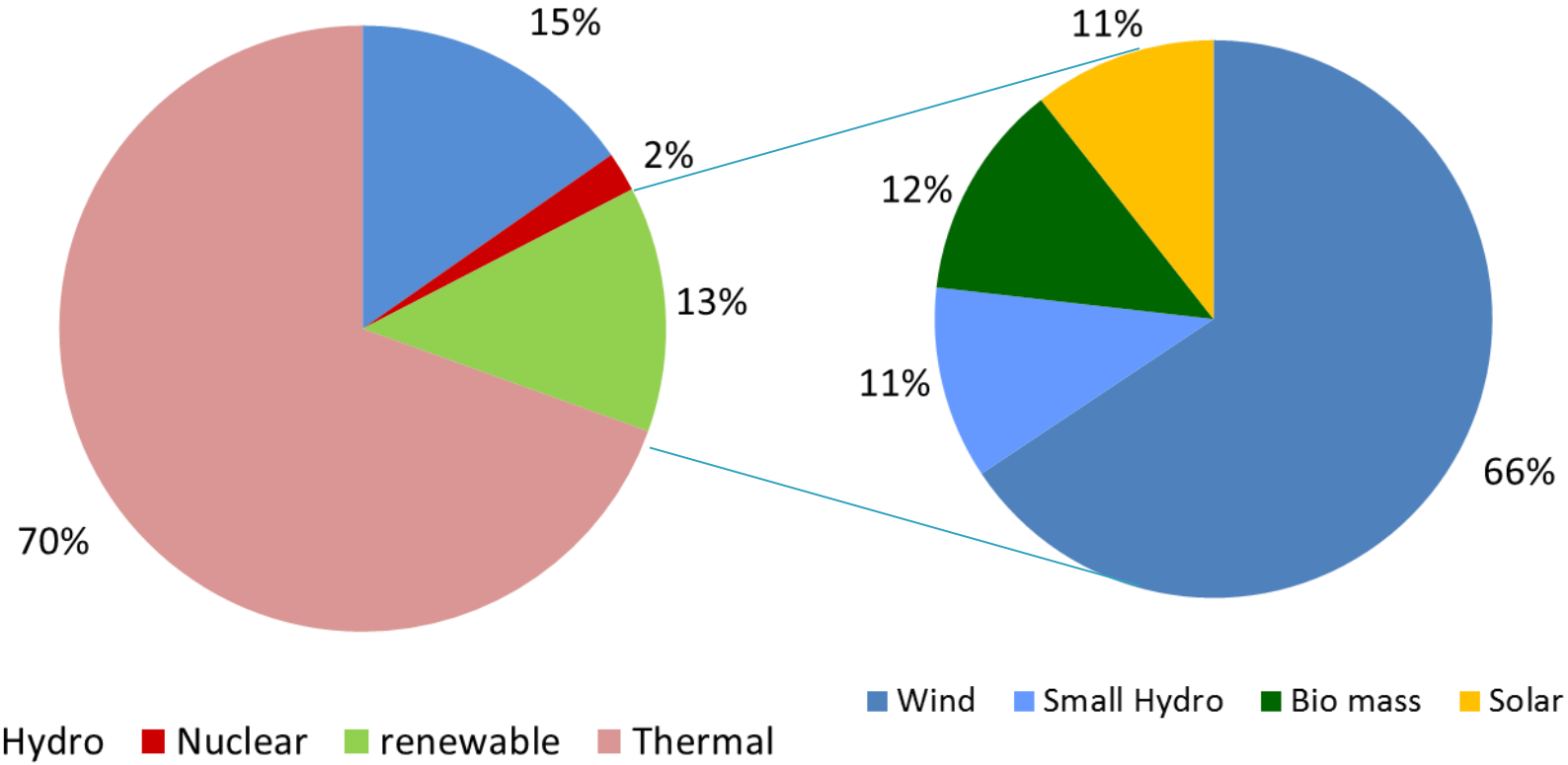
Renewable Energy sources

Source	Potential (MW)	Achieved (MW)
Bio-mass	62,000	1410.20
Wind-power	45,000	23444
Small Hydro-power	15,000	4,055.36
Co-generation - Bagasse	5000	3008.35
Waste to energy	5000	115.08
Solar Power Total		3743.97 35776.96 As on 31.3.2015



Indian Power Sector

Power Installed Capacity = 275 GW



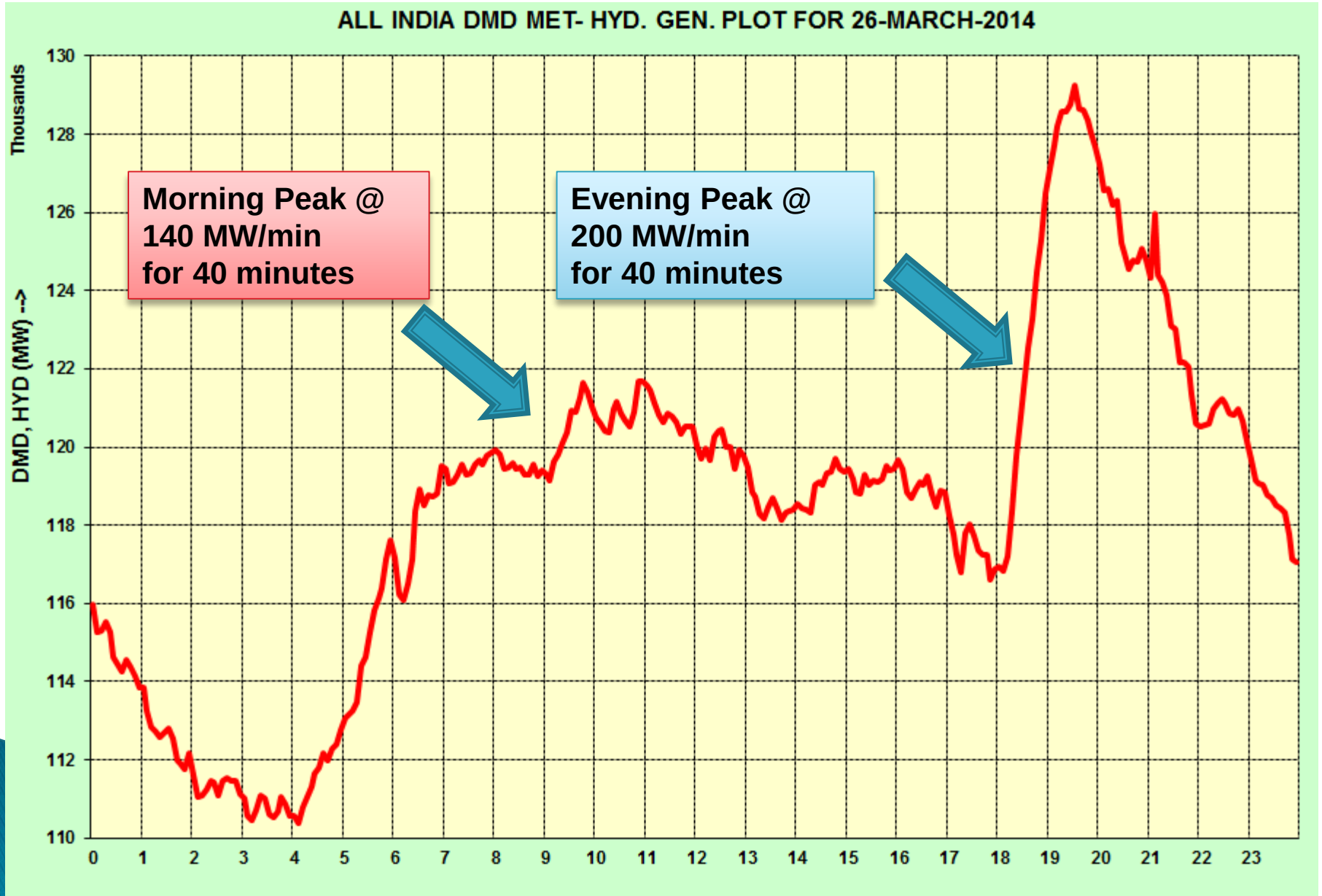
Thermal	Hydro	Nuclear	Renewable	Total
191 GW	42 GW	6 GW	36 GW	275

Wind	Small Hydro	Solar	Biomass	Total
23.5 GW	4 GW	3.8 GW	4.5 GW	35.8 GW

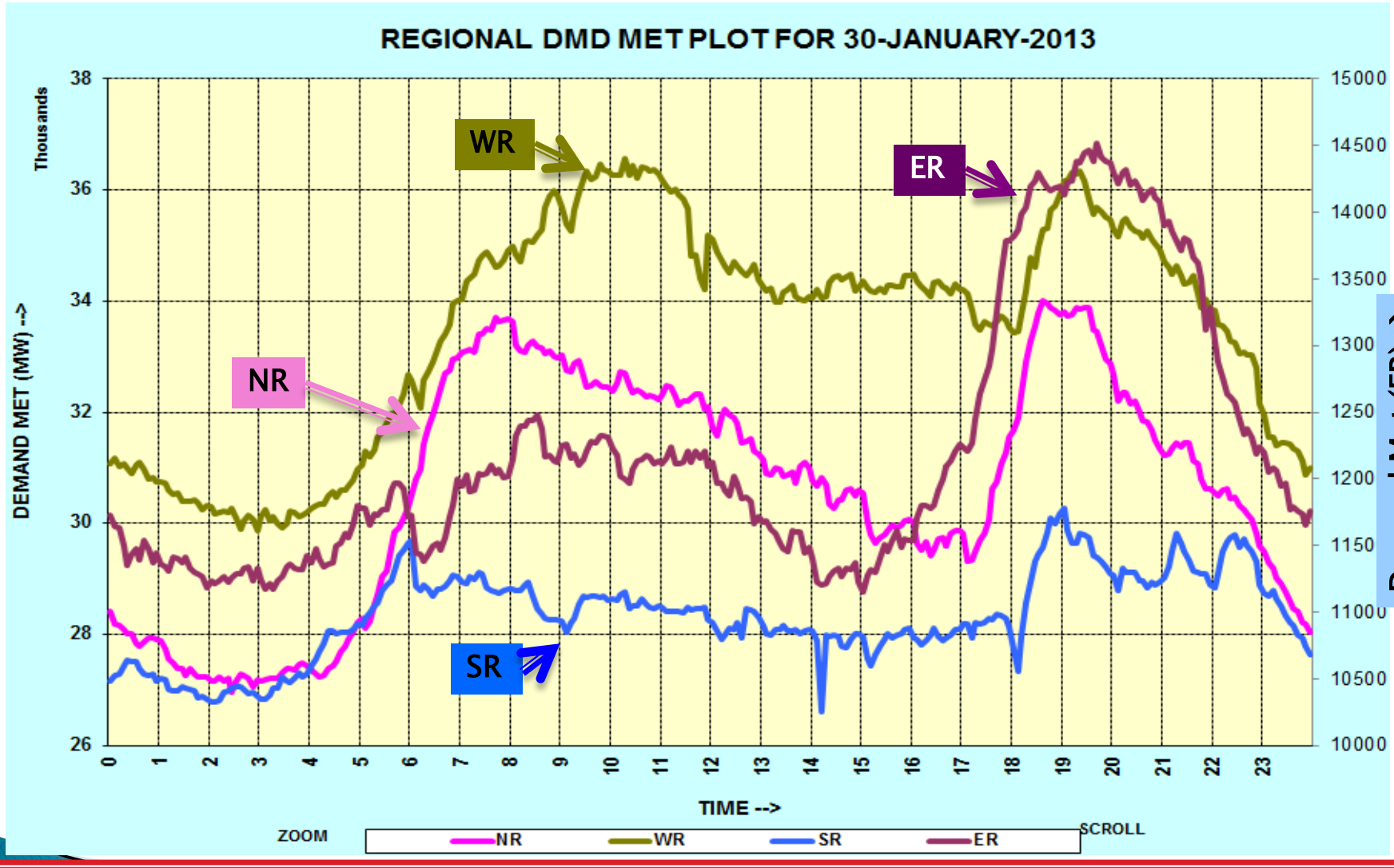
India's Renewable energy program

- The Govt. of India is targeting a capacity of 100GW solar, 60GW wind, 10GW biomass and 5 GW other renewable sources by 2022 through various big and small initiatives.

Typical Load Curve

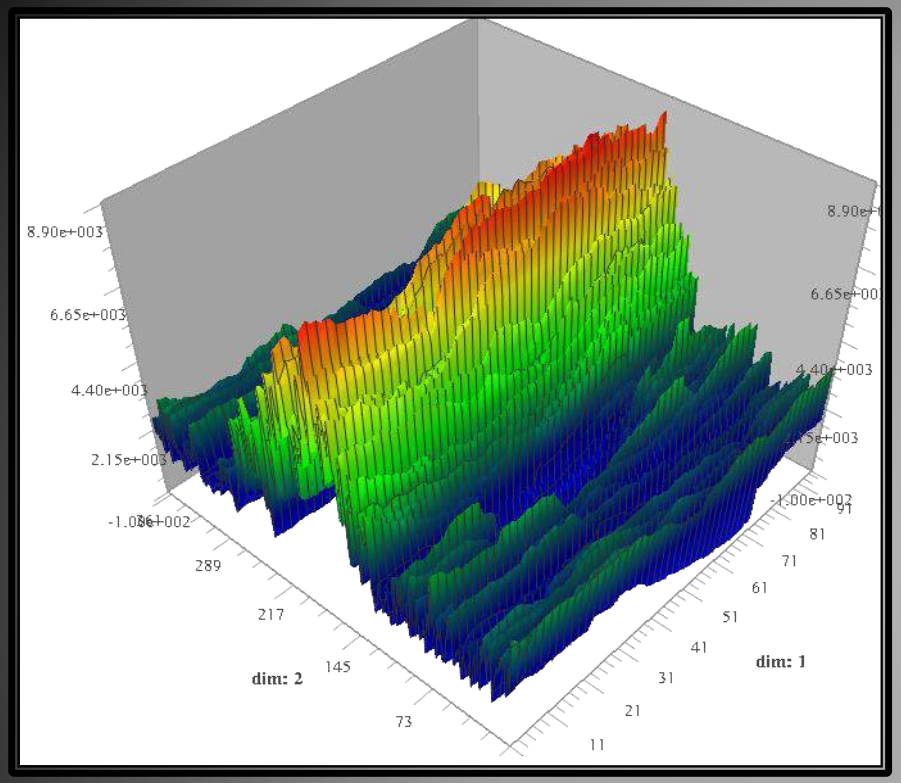


Regional Geographical Diversity

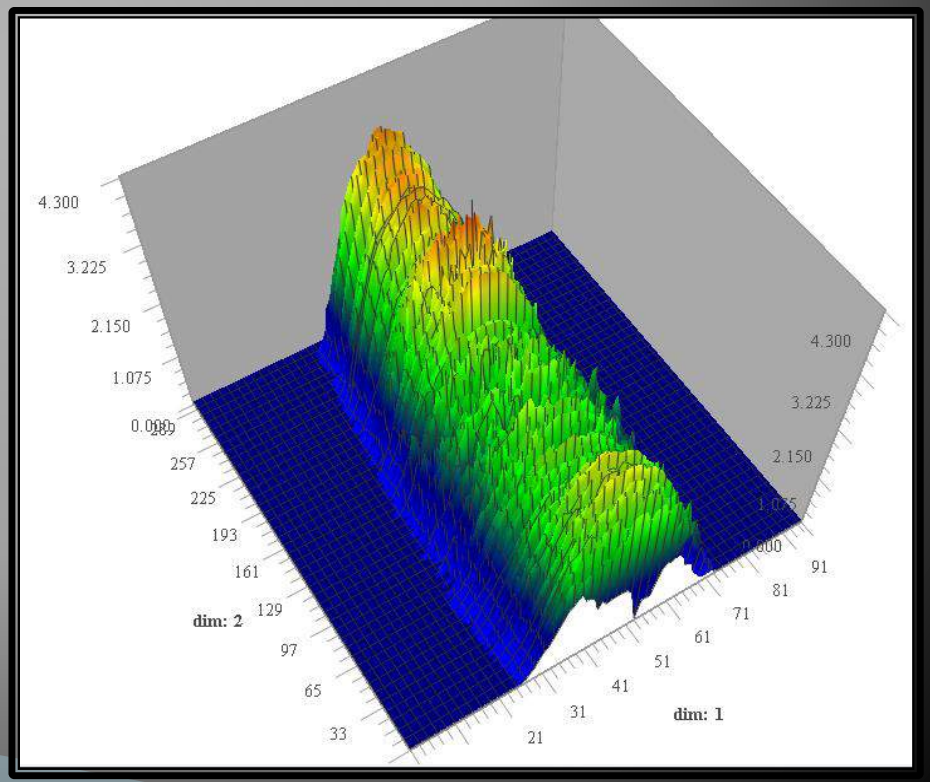


Diversity on account of geographical location, seasons, time of day, load, etc.

Pattern of Renewable Generation in India



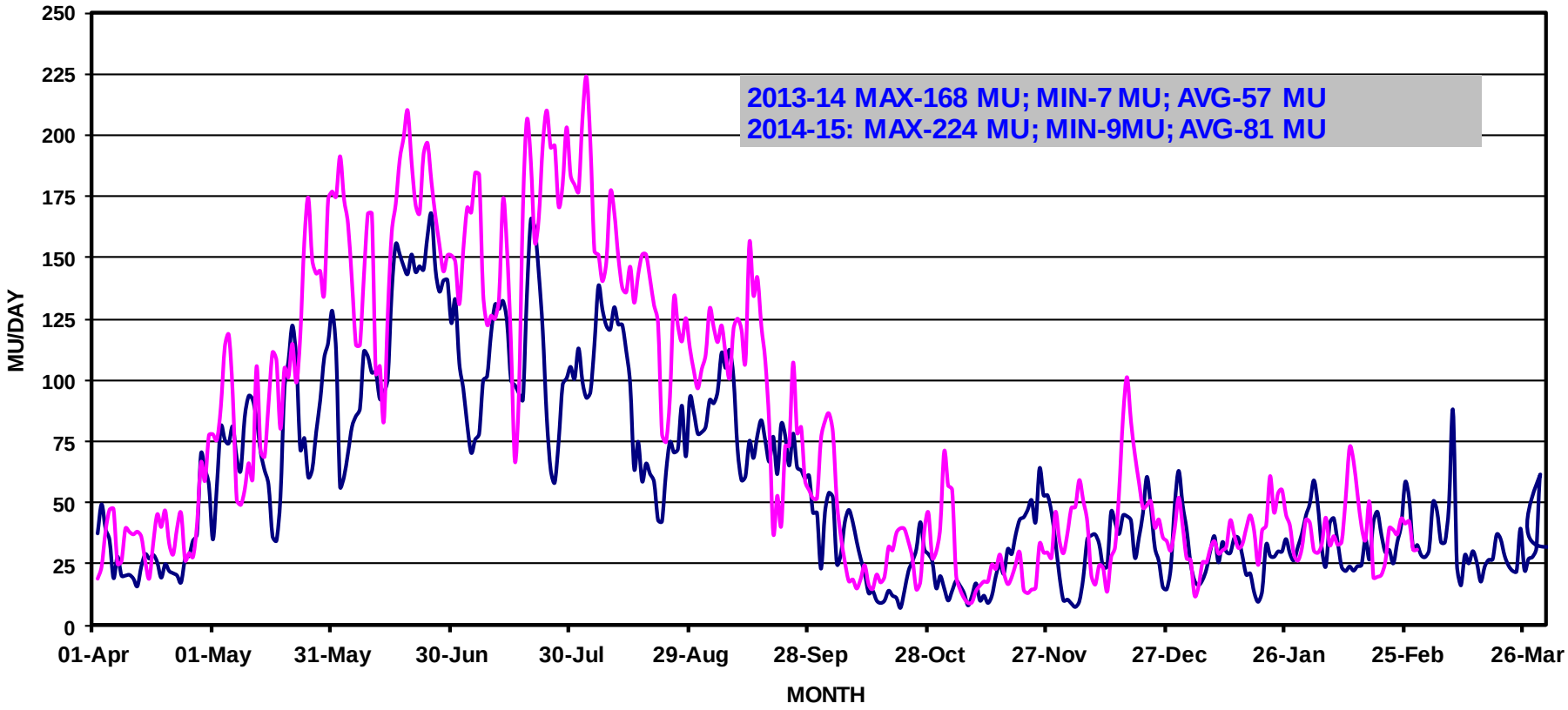
Annual Wind Generation



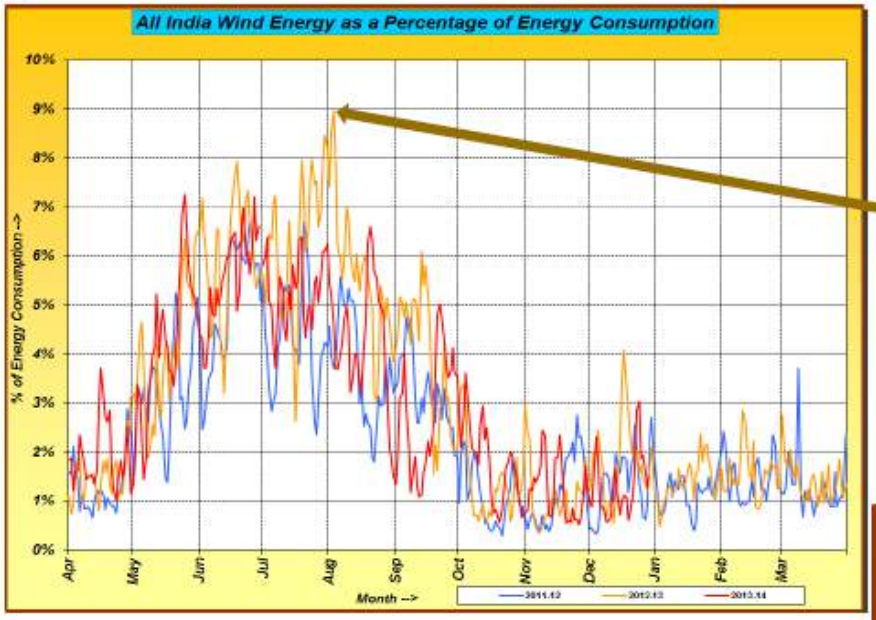
Annual Solar Generation

*SCADA Data

ALL INDIA WIND ENERGY GENERATION



All India Wind Penetration (in Energy terms)

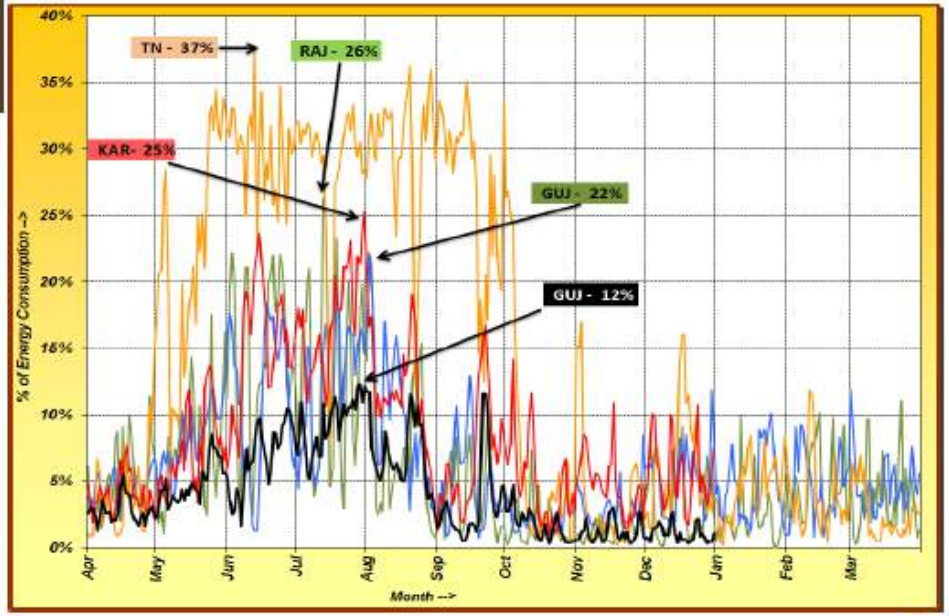


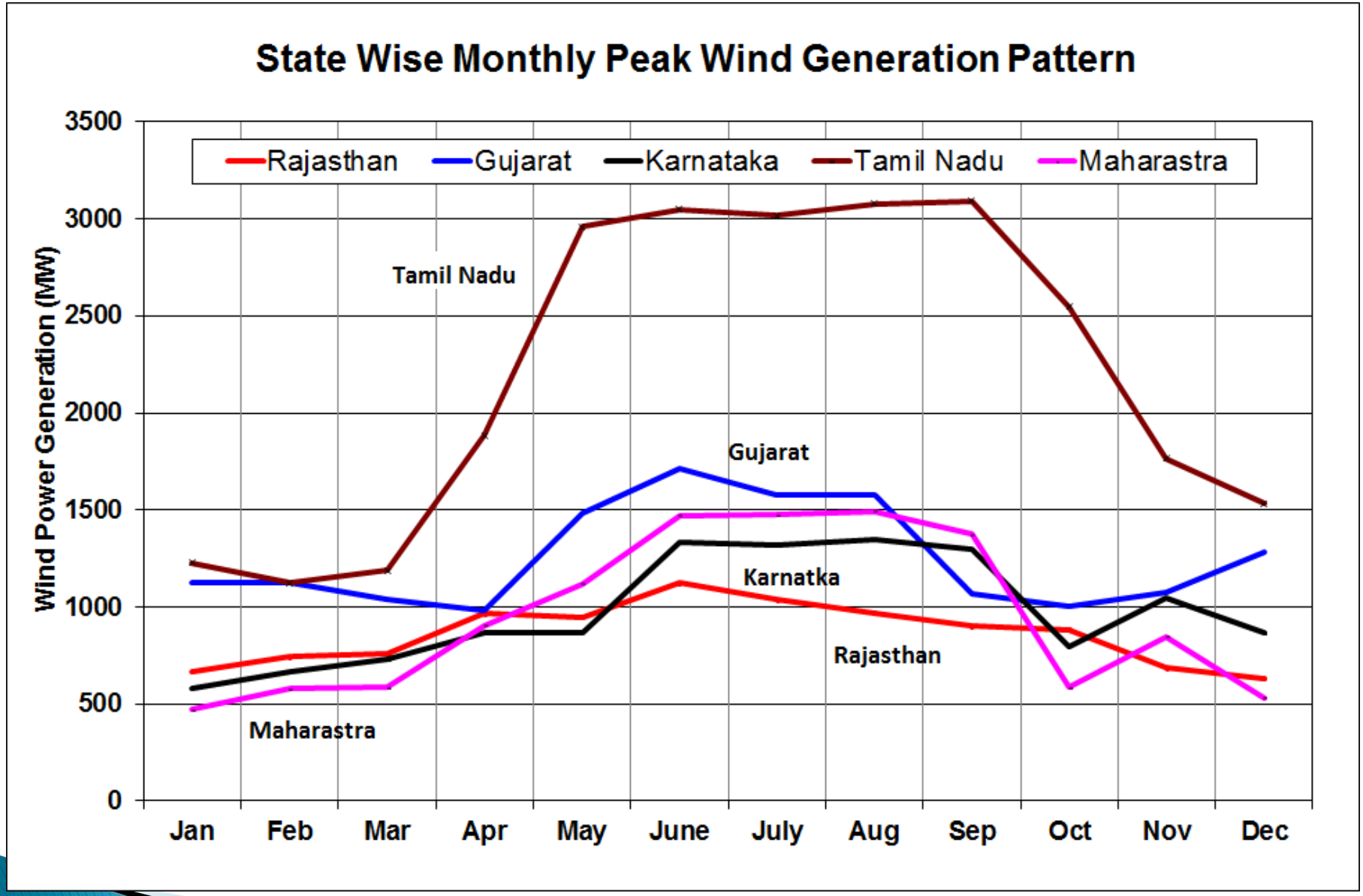
→ High Wind generation during June to August.

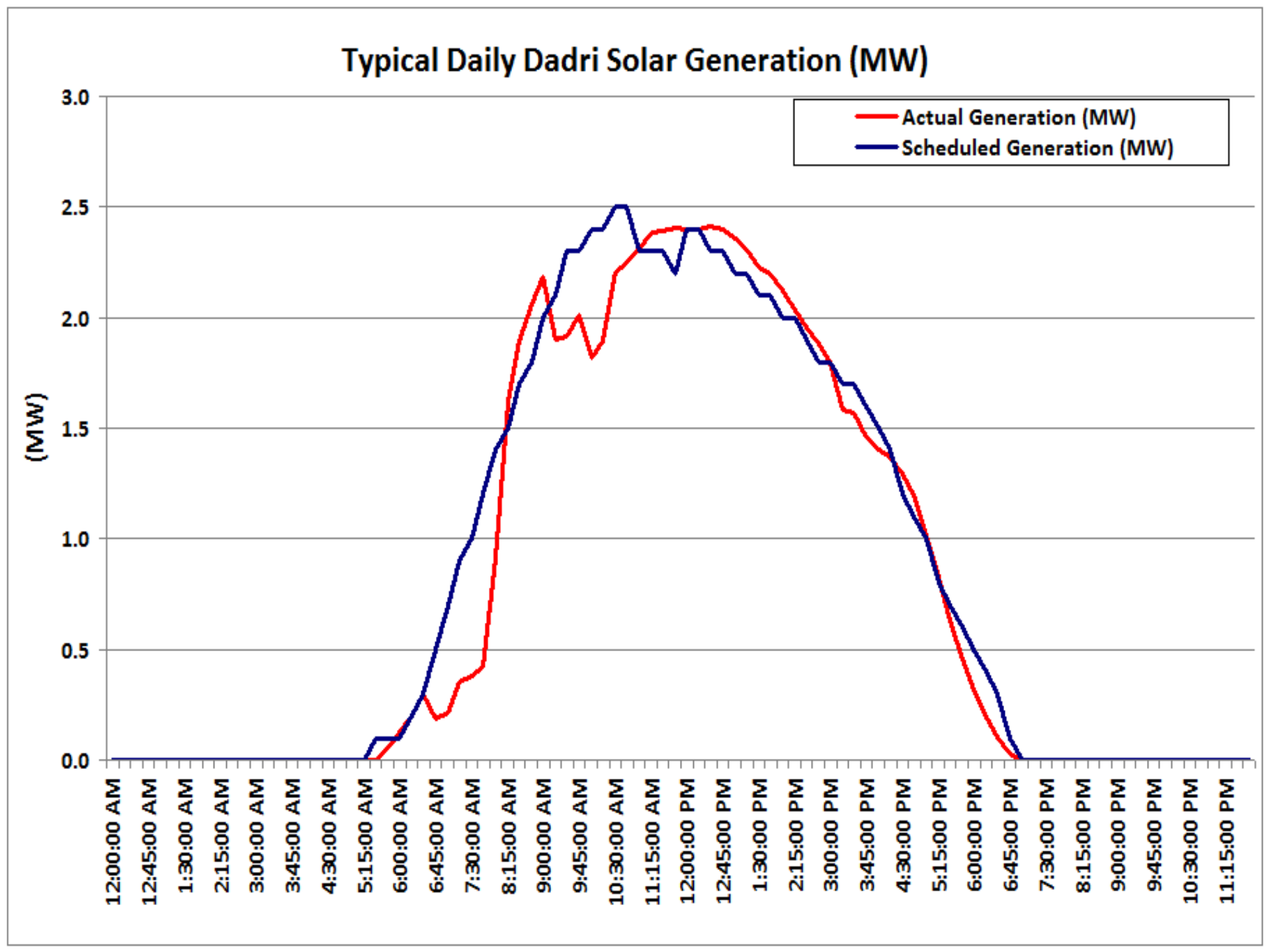
→ All India level penetration – 9% (max achieved)

→ High Penetration in States:

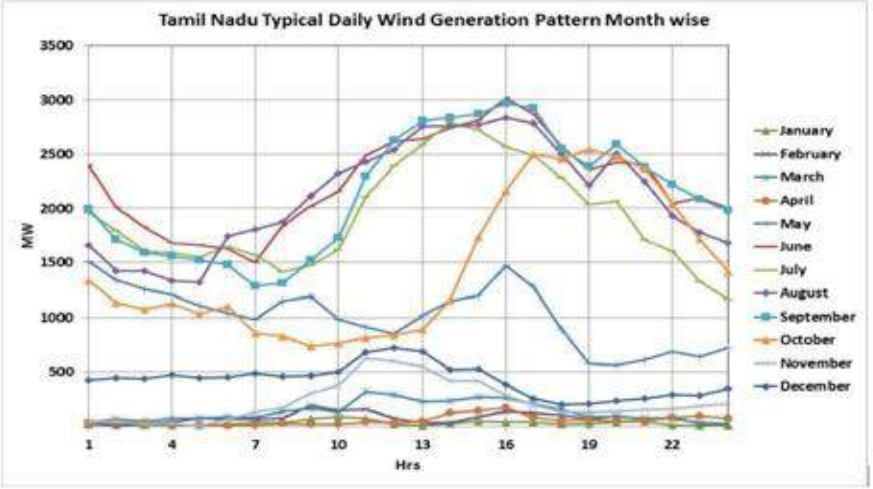
1. Tamil Nadu
2. Rajasthan
3. Karnataka
4. Gujarat
5. Maharashtra

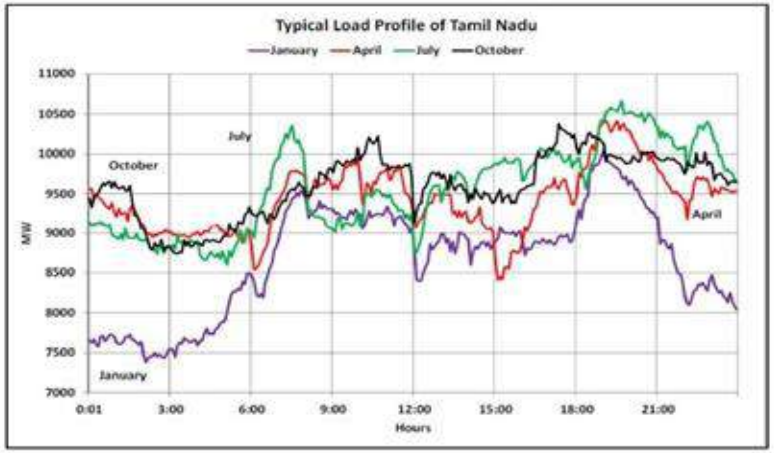



State Wise Monthly Peak Wind Generation Pattern
Wind Power Generation (MW)
3500
3000
2500
2000
1500
1000
500
0
Rajasthan
Gujarat
Karnataka
Tamil Nadu
Maharastra
Tamil Nadu
Gujarat
Karnatka
Rajasthan
Maharastra
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec


Typical Daily Dadri Solar Generation (MW)
Actual Generation (MW)
Scheduled Generation (MW)
(MW)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
12:00:00 AM
12:45:00 AM
1:30:00 AM
2:15:00 AM
3:00:00 AM
3:45:00 AM
4:30:00 AM
5:15:00 AM
6:00:00 AM
6:45:00 AM
7:30:00 AM
8:15:00 AM
9:00:00 AM
9:45:00 AM
10:30:00 AM
11:15:00 AM
12:00:00 PM
12:45:00 PM
1:30:00 PM
2:15:00 PM
3:00:00 PM
3:45:00 PM
4:30:00 PM
5:15:00 PM
6:00:00 PM
6:45:00 PM
7:30:00 PM
8:15:00 PM
9:00:00 PM
9:45:00 PM
10:30:00 PM
11:15:00 PM

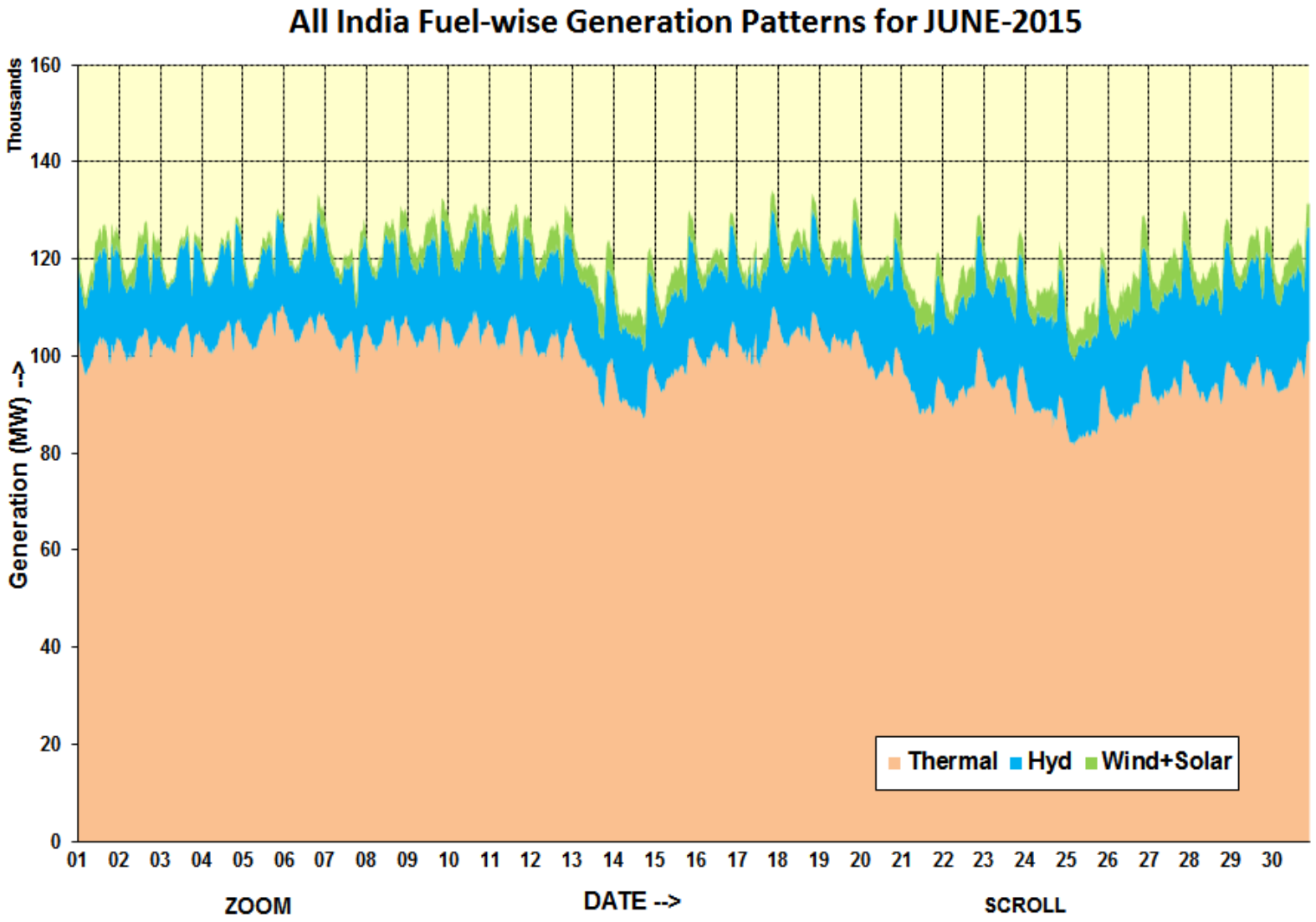
Wind generation profile vs overall demand profile



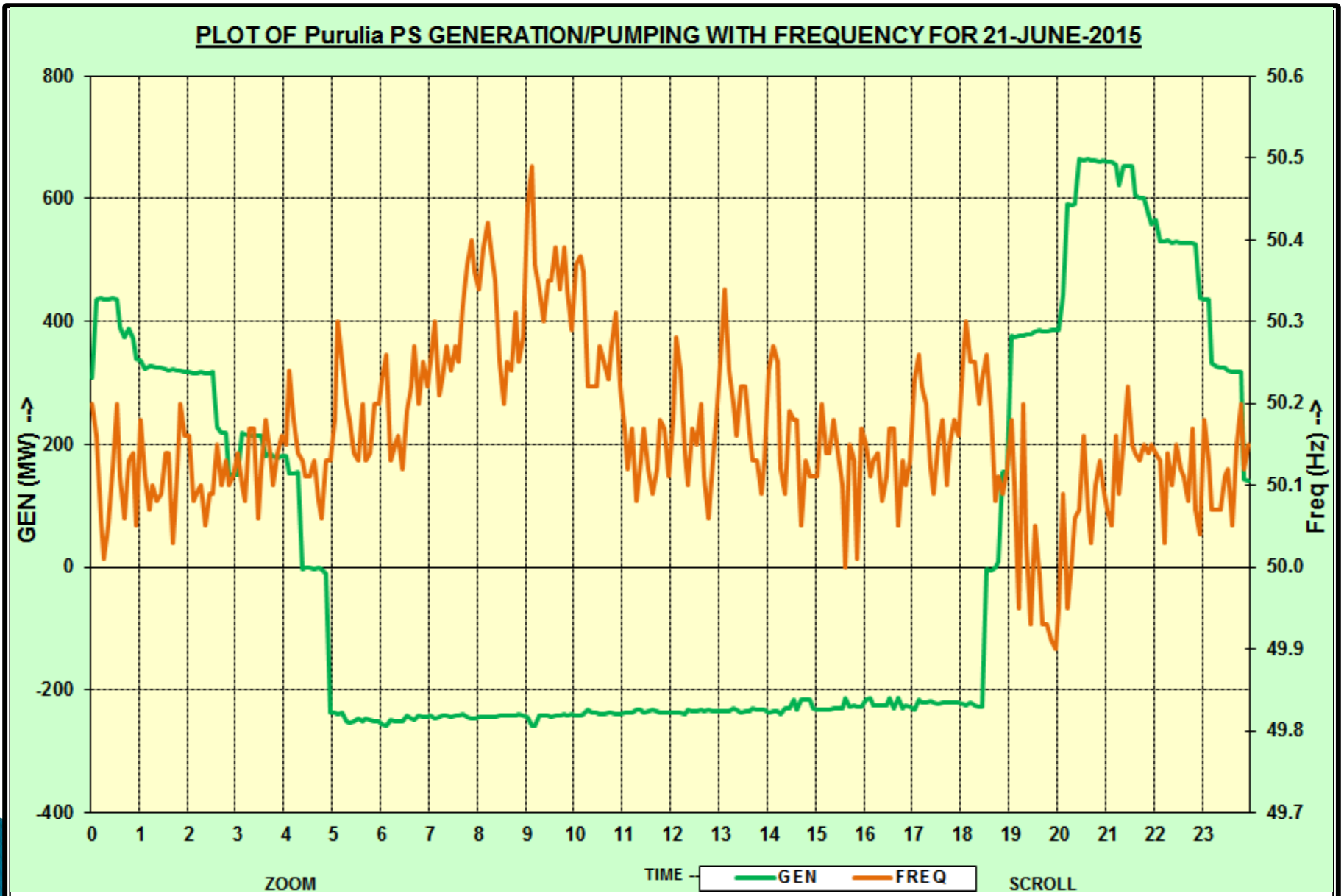


- Wind generation not in sync with demand cycle
- Daily and seasonal variation
- Wider transmission/green corridor will help but cannot balance the load.
- Balancing requirement must be studied for 8760 x 4 time blocks

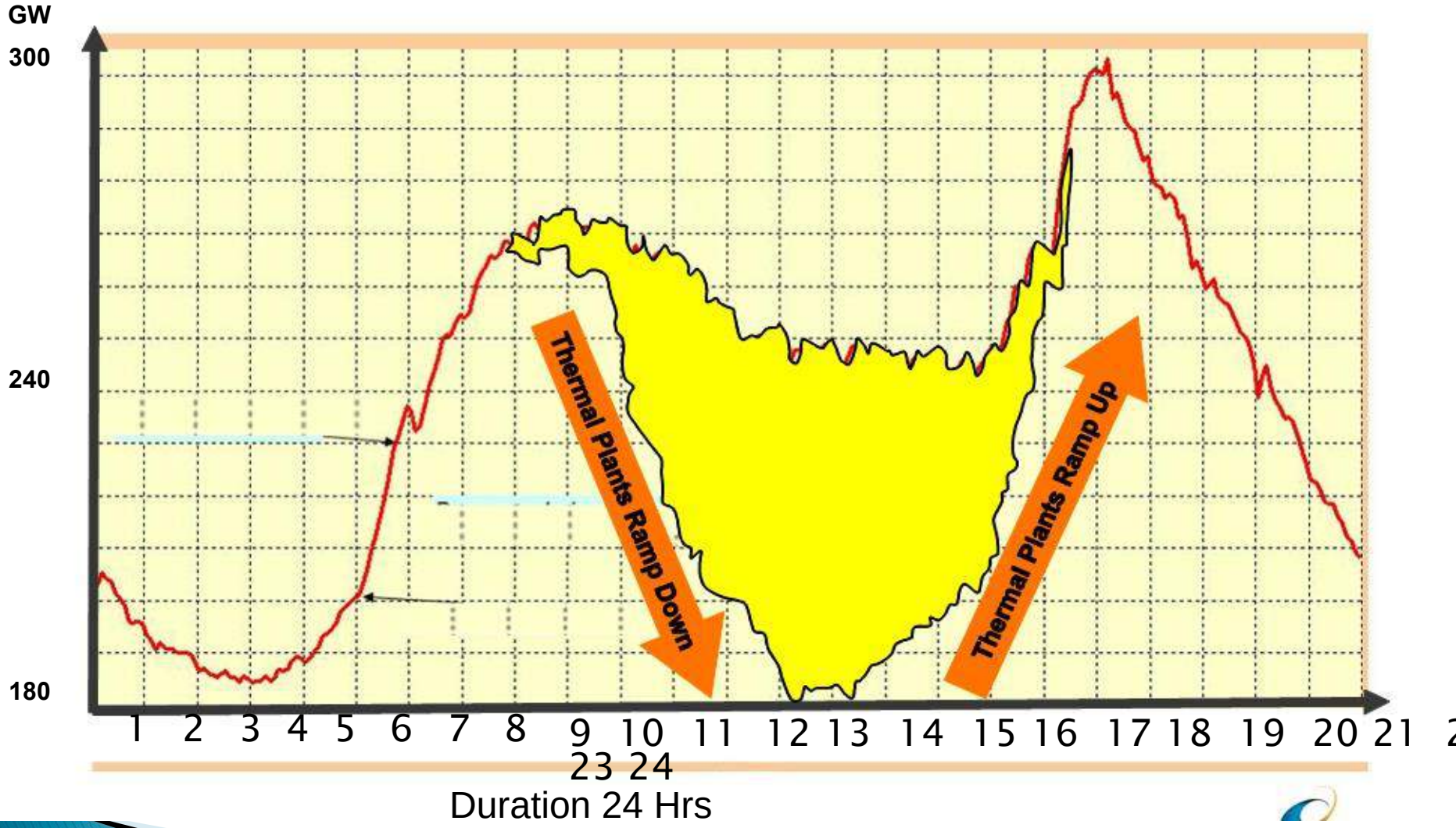
Utilisation of Hydro and thermal generation for balancing of RE generation



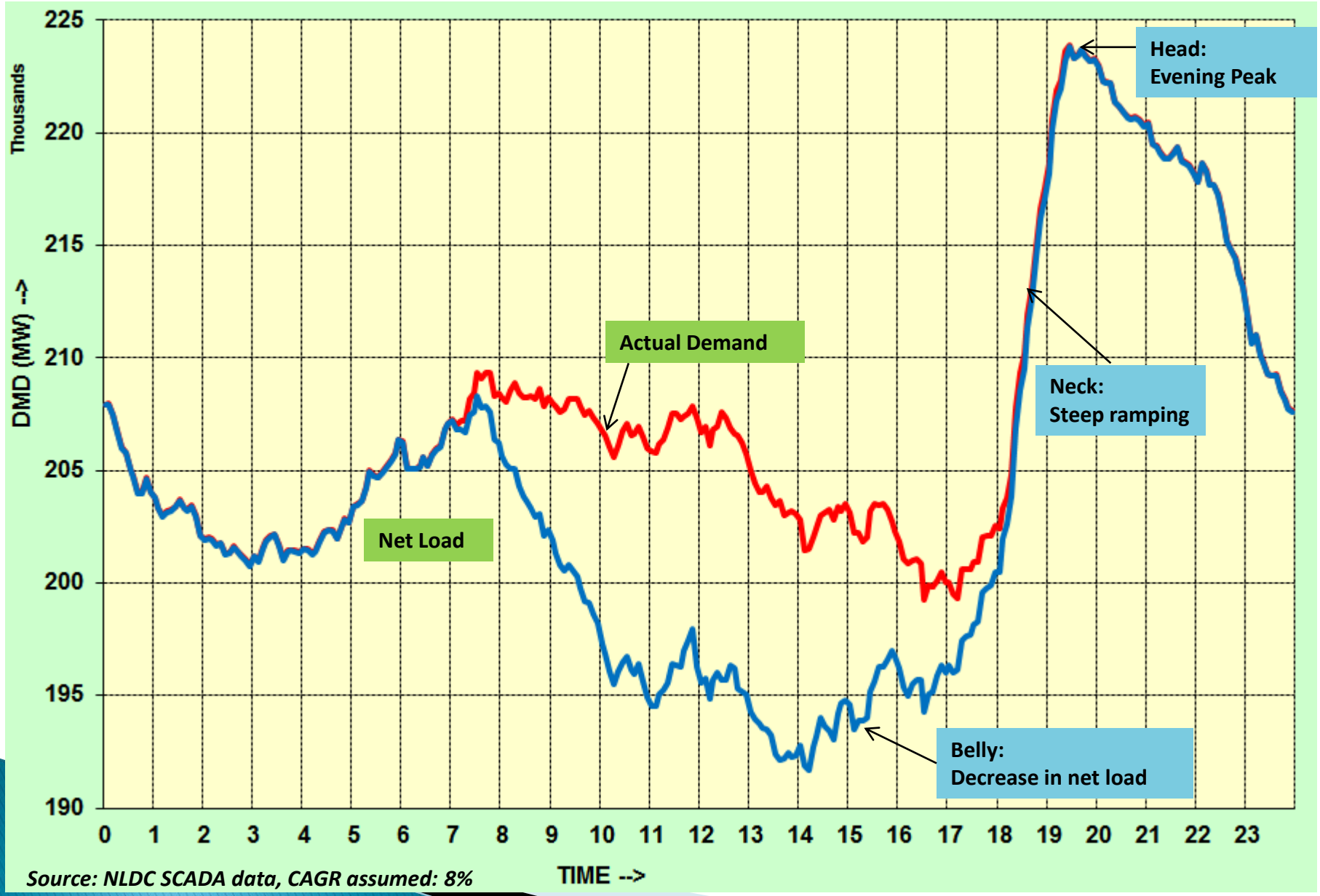
Pumped storage power plant



India: Load curve in 2022 (Illustrative) : Balancing Challenge

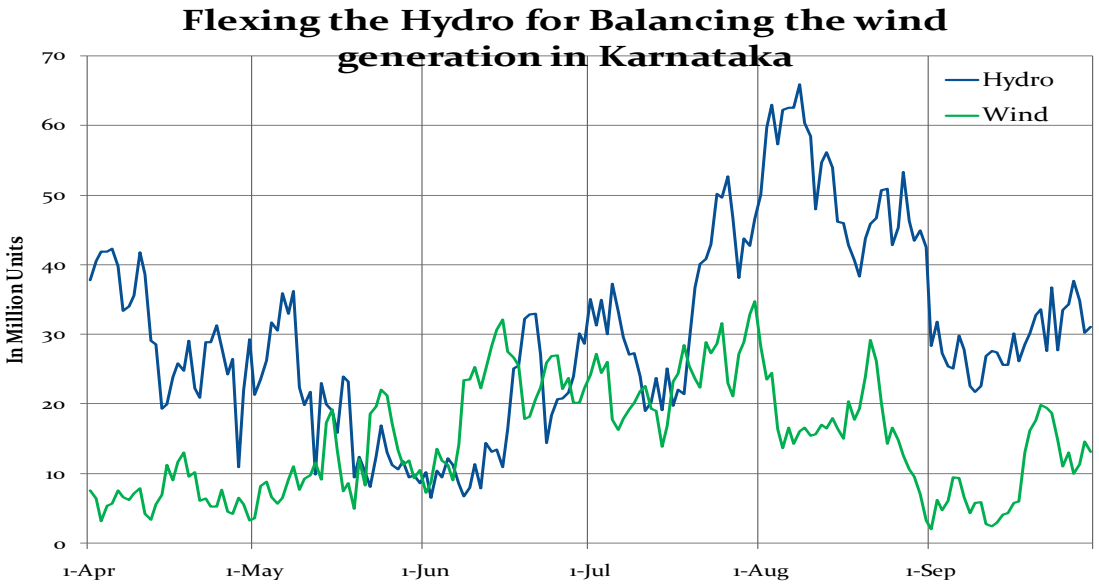


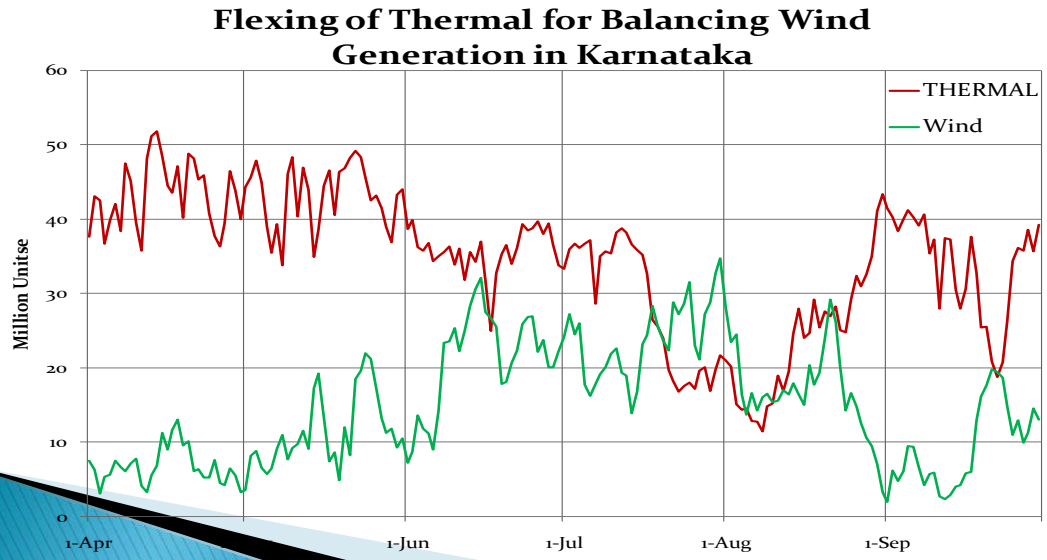
Expected All India Duck Curve



Source: NLDC SCADA data, CAGR assumed: 8%

Balancing Renewable Generation





- **Challenges**
  - Variability, intermittency and ramping
  - Sudden onset or offset of wind generation
- **Remedies**
  - Generation balancing by the conventional energy sources.
  - Greater the penetration, greater the balancing requirement.
  - Forecasting of renewable generation (Solar and wind)
  - Ramp forecast is also essential.