Welcome

Ishan Sharan & Vikram Singh

Central Electricity Authority

Ministry of Power

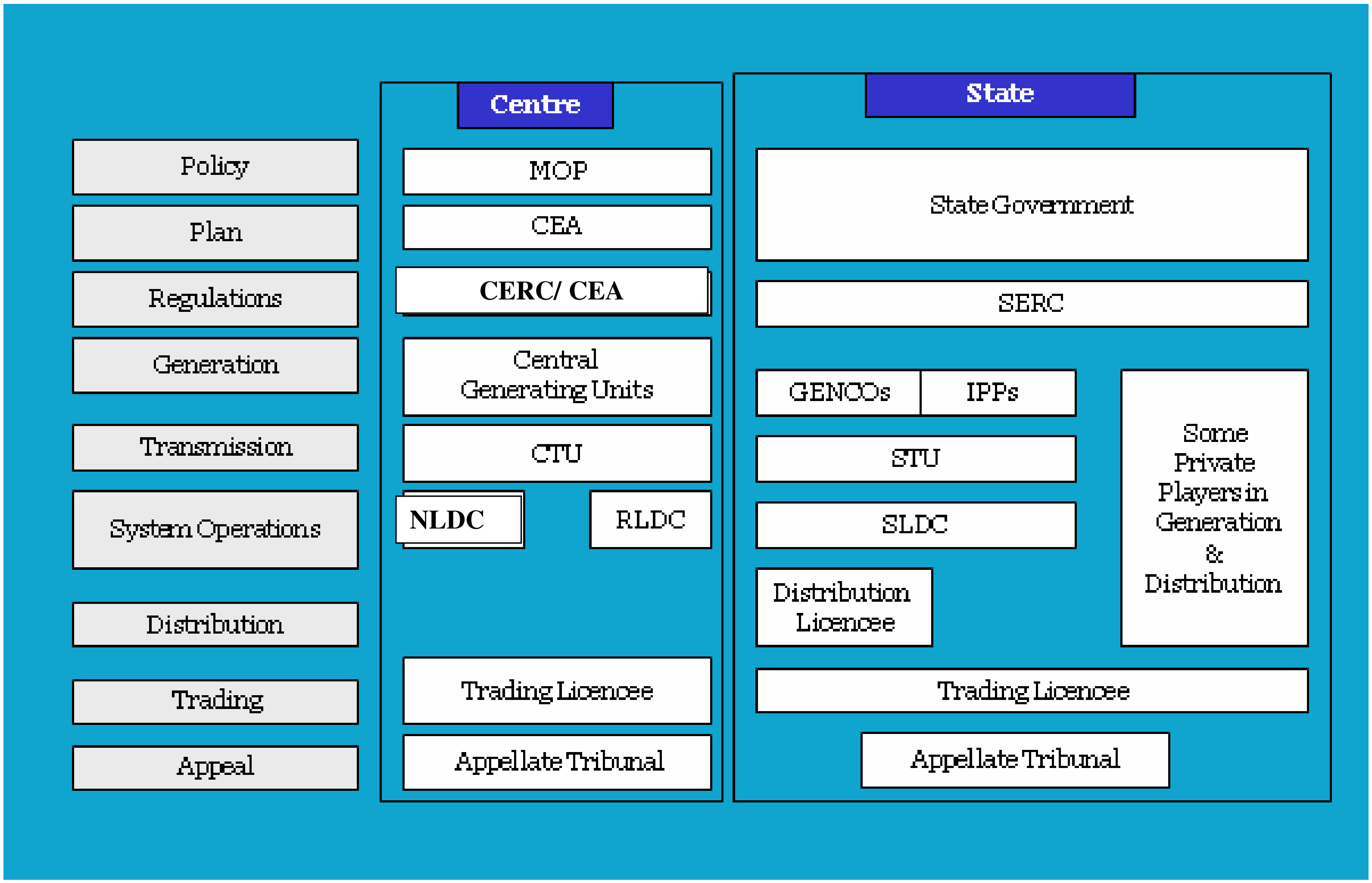
India

(www.cea.nic.in)

Outline of Presentation

- Brief of Power Sector in India
- Prevailing Practices pertaining to Generation Planning

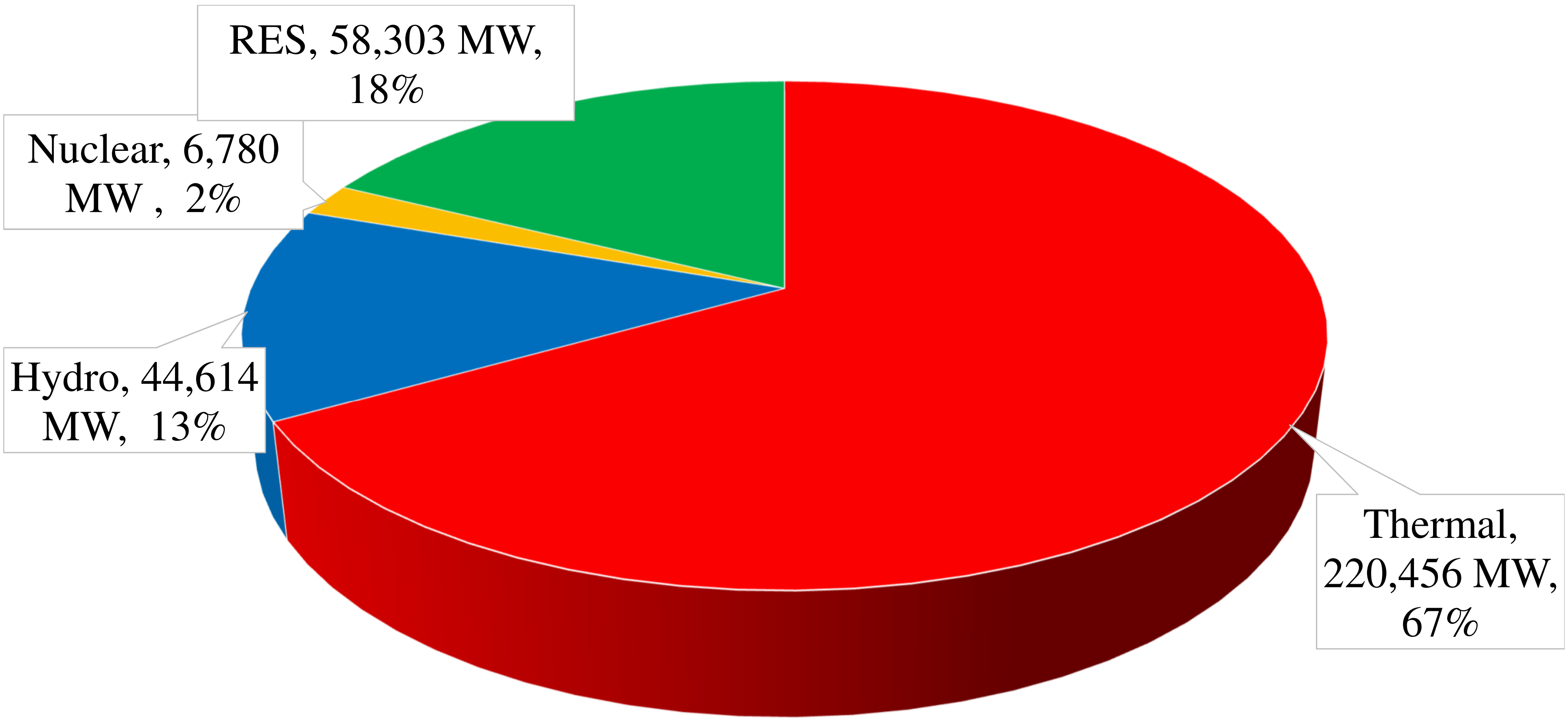
Power Sector Structure



Power Sector-an Overview

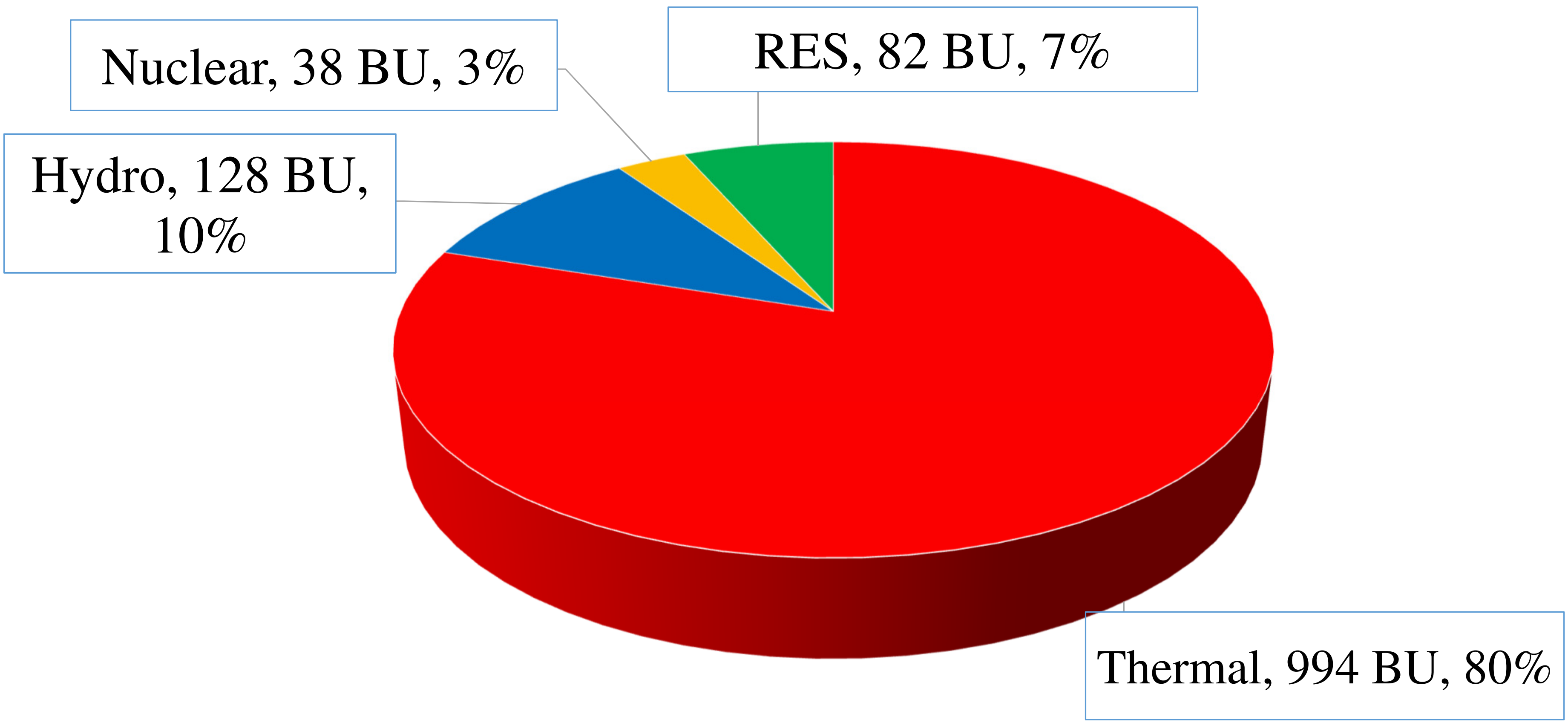
- Electricity - 'Concurrent Subject' : joint responsibility of State and Central Governments.
- Distribution and supply of electricity to end consumers lies with State Utilities.
- Conventional Generation - blend of thermal, hydro and nuclear sources.
- Coal based thermal power plants and in some states hydro power plants - mainstay of electricity generation.
- Natural gas and nuclear power accounts for smaller proportion of power.
- Thrust is being given to electricity generation from non-conventional energy sources i.e. solar, wind etc.

Installed Electricity Generating Capacity as on July 2017



Total Installed Electricity Generation Capacity: 330,000 MW

Electricity Generation during the year 2016-17



Total Electricity Generation: 1,242 BU

1 BU= 10^9 kWh

Length of Transmission lines & Sub-station Capacity (as on July, 2017)

- Length of Transmission lines

Voltage level	Length (Ckm)
765 kV AC	32,572
400 kV AC	163,630
220 kV AC	164,459
+/- 500 kV HVDC	9,432
+/- 800 kV HVDC	6,124
Total	376,217

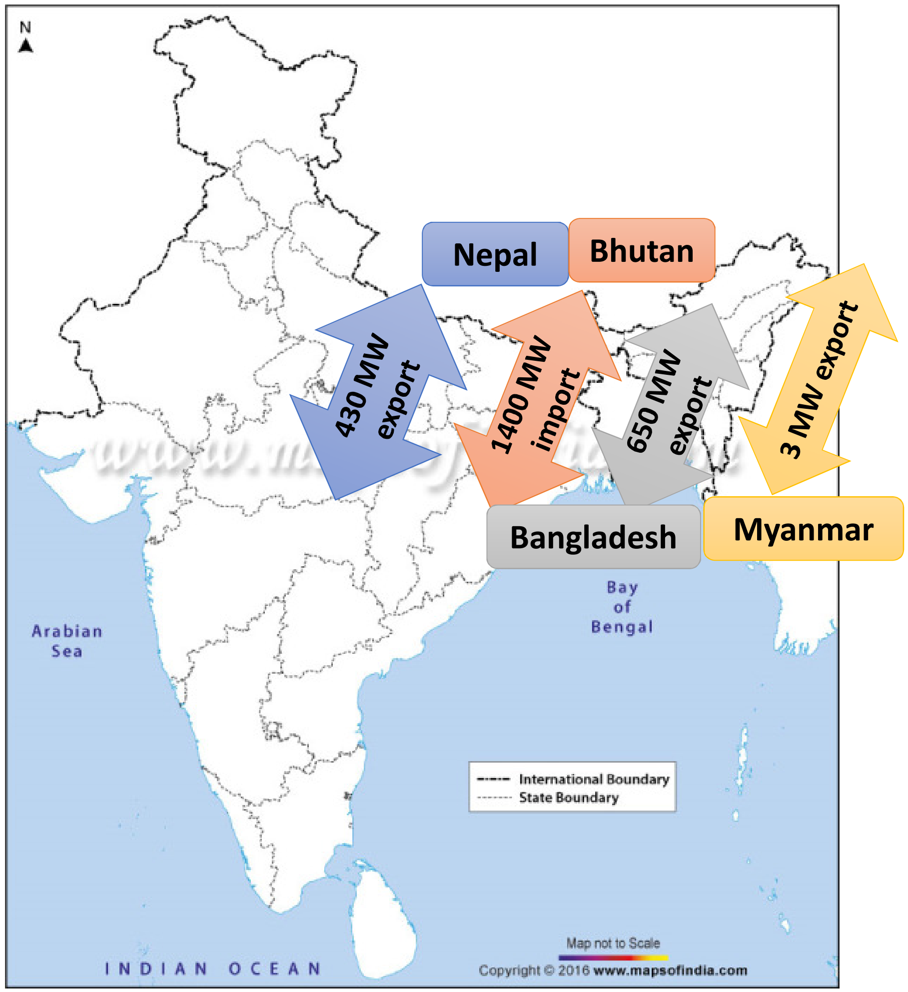
- Sub-stations

Voltage level	MVA/MW
765 kV AC	174,500
400 kV AC	255,347
220 kV AC	319,968
+/- 500 kV HVDC	13,500
+/- 800 kV HVDC	7,500
Total	770,815

Per Capita Consumption of Electricity

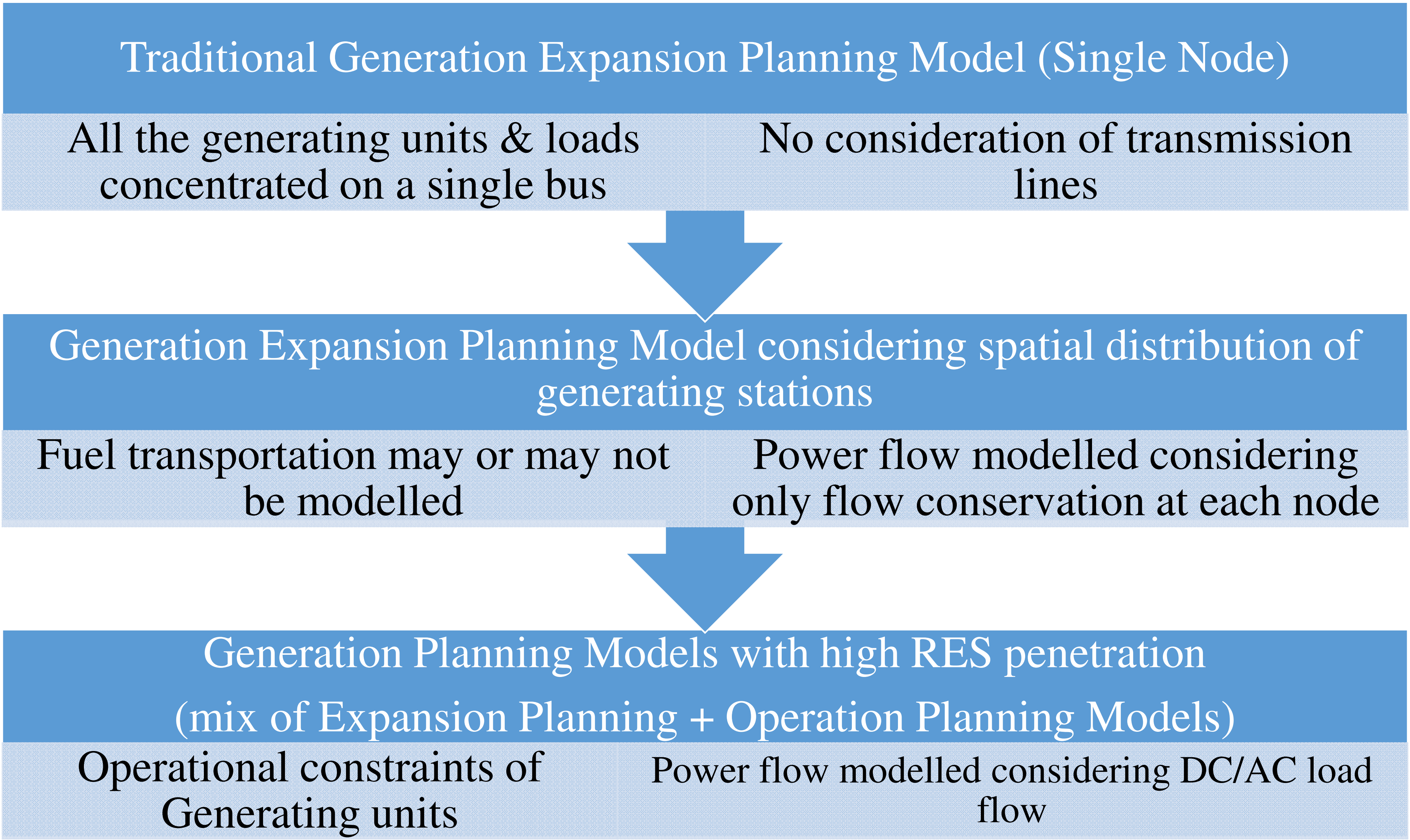
Year	Per Capita Consumption (kWh)
2011-12	884
2012-13	914
2013-14	957
2014-15	1010
2015-16	1075
2016-17	1120

Electricity Exchange with neighbouring countries



Basics of Generation Planning

- As the electricity demand increases, generating capacity is required to be added in the system.
- Generation capacity is also required to be added to cater to retirement of existing generating units
- Generation expansion planning is concerned with:
  - when to add the generating units (time)
  - the type of generating units to add (base load, peak load etc.)
  - location at which the generating units are to be added (spatial distribution)
- Operational constraints of generating units is not considered in traditional generation expansion planning models
- Transmission network is also generally not considered


Traditional Generation Expansion Planning Model (Single Node)
All the generating units & loads concentrated on a single bus
No consideration of transmission lines
Generation Expansion Planning Model considering spatial distribution of generating stations
Fuel transportation may or may not be modelled
Power flow modelled considering only flow conservation at each node
Generation Planning Models with high RES penetration
(mix of Expansion Planning + Operation Planning Models)
Operational constraints of Generating units
Power flow modelled considering DC/AC load flow

Generation Planning with high penetration of Renewable Energy (wind& solar)

- World wide thrust is being accorded to electricity generation from RES.
- RES Installed Capacity by the year 2022 in India ~ 175,000 MW
- RES being intermittent in nature, electricity generated from RES (wind/solar), shows variation throughout the day and through the seasons.
- There are periods/seasons of very low electricity generation/no electricity generation from RES

Generation Planning with high penetration of Renewable Energy (wind& solar)

- The objective of installing RE generators in the grid is its maximum utilization.
- As the power output of RE generators increases, conventional generators (non RE) would have to reduce their power output and as the power output of RE generators decreases, other generators would have to increase their power output ~ **determined by the ramp rate of generators**
- To what extent a conventional generating unit can ramp down ~ **depends on its minimum operating limit.**
- If a generating unit needs to be shut down to accommodate the power output of RE generators ~ **does it meet the minimum up time criteria and if it meets the minimum up time criteria, it can be shut down only if it is not required for the duration of its minimum down time.**

Operational Parameters of Conventional (non-RE) Generators affecting utilization of RE Sources

- The capacity of RE generators to be installed and utilization depends upon:
  - Ramp-Up/Ramp-Down Rate of conventional generators
  - Minimum operating limit of conventional generators
  - Minimum up-time/down-time of conventional generators
- In a system dominated by non-flexible coal based or CCGT generating units, penetration of wind/solar will be limited, and generation from wind/solar would have to be curtailed.

Generation Planning with high penetration of Renewable Energy (wind& solar)

- High penetration of wind/solar power may change the capacity mix in the system in terms of requirement of more flexible generating units and it may also result in change in operational strategy of coal based generating units, increasing the need of cycling them.
- With high penetration of RES, operational constraints of conventional generating units need to be considered in Generation Planning~ the planned system must be feasible from operational aspects

Generation Planning with high penetration of Renewable Energy (wind& solar)

- RE generators are concentrated in specific areas. Electricity generated by RE generators needs to be transmitted to other areas, if it cannot be consumed locally.
- Further, gestation period of RE generators is small as compared to the gestation period of transmission lines.
- With high RE penetration in the grid, planning of conventional generators, RE generators, flexible generators and transmission lines must be coordinated; otherwise it will lead to curtailment of wind power due to transmission constraints or operational issues and advantage of RE generators may not be realised.

Generation Planning with high penetration of Renewable Energy (wind& solar)

- With high RES penetration, reserve requirement in the system increases.
- In addition to the reserve required to take care of unpredicted increase in electricity demand or forced outage of generating units, reserve is also required to cater to unpredicted increase/decrease in RE generation.
- A system with high RE penetration must plan for both
  - Up Spinning Reserve (USR)-to cater to unpredicted decrease in RE generation
  - Down Spinning Reserve (DSR)- to cater to unpredicted increase in RE generation

.

Generation Planning with high penetration of Renewable Energy (wind& solar)

- There may be negative co-relation between electricity demand and power output from RE generators ~ high electricity generation during period of low electricity demand.
  - Problematic as most of the coal based (base load) electricity generating units may be operating near/at their minimum operating limit during period of low electricity demand and some of these may be required to shut-down in the event of increase in RE power.
  - There would be insufficient DSR in the system during low load condition~ a generating unit has to be in operation to provide DSR
  - To provide DSR, commitment of generating units may be required to be changed~ commit flexible generating units during period of low electricity demand

Generation Planning with high penetration of Renewable Energy (wind& solar)

- In big power systems involving fuel transportation over long distance, fuel transportation network along with associated constraints must be modelled in generation expansion planning exercise.
- Planning of transmission lines also needs to be integrated in the generation planning model. At least, the base transmission network must be modelled.
- Strengthening of transmission network from system security point of view, design of suitable compensation schemes etc. would be taken up at the time of detailed transmission network planning.
- Instead of sequential approach of first planning generation expansion and then planning the transmission network, integrated approach must be followed in the planning process.

Generation Planning for the year 2021-22

Installed Capacity of Renewables in the year 2022

	Installed Capacity (MW)
Solar	100,000
Wind	60,000
Small Hydro	5,000
Biomass	10,000
Total	175,000

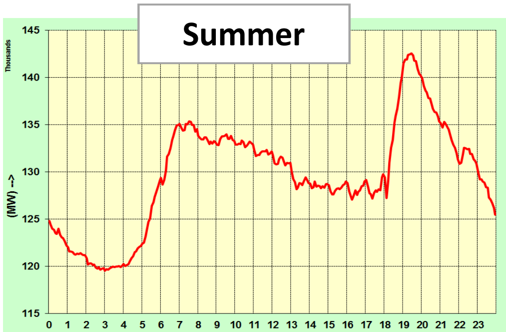
Installed RES based Capacity in July 2017: 58,300 MW

Projected Electricity Demand in the year 2022

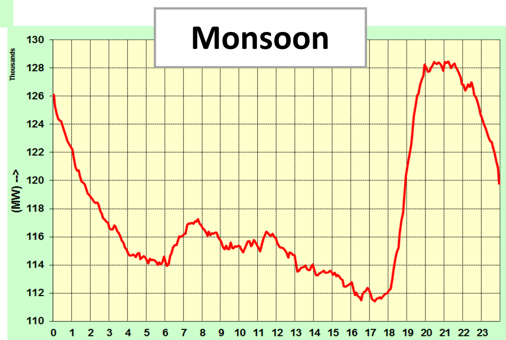
	2016-17	2021-22
Electrical Energy Requirement (BU)	1143	1566
Peak Electricity Demand (MW)	160,000	226,000

- Electricity Demand forecast is carried out by combination of time-series and end-use method
- Bottom up approach focusing on end-use or final electrical energy needs of different categories of consumers.
- Forecast is carried out for different consumer categories viz. domestic, commercial, public lighting, industries etc.

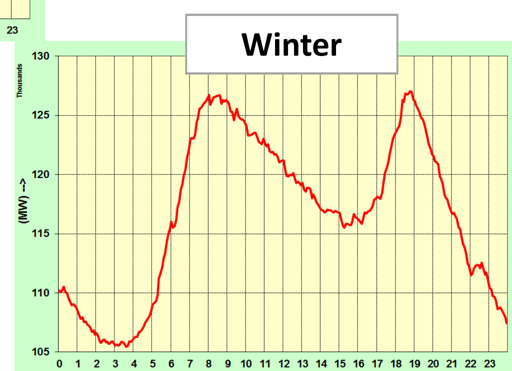
Typical daily load curve



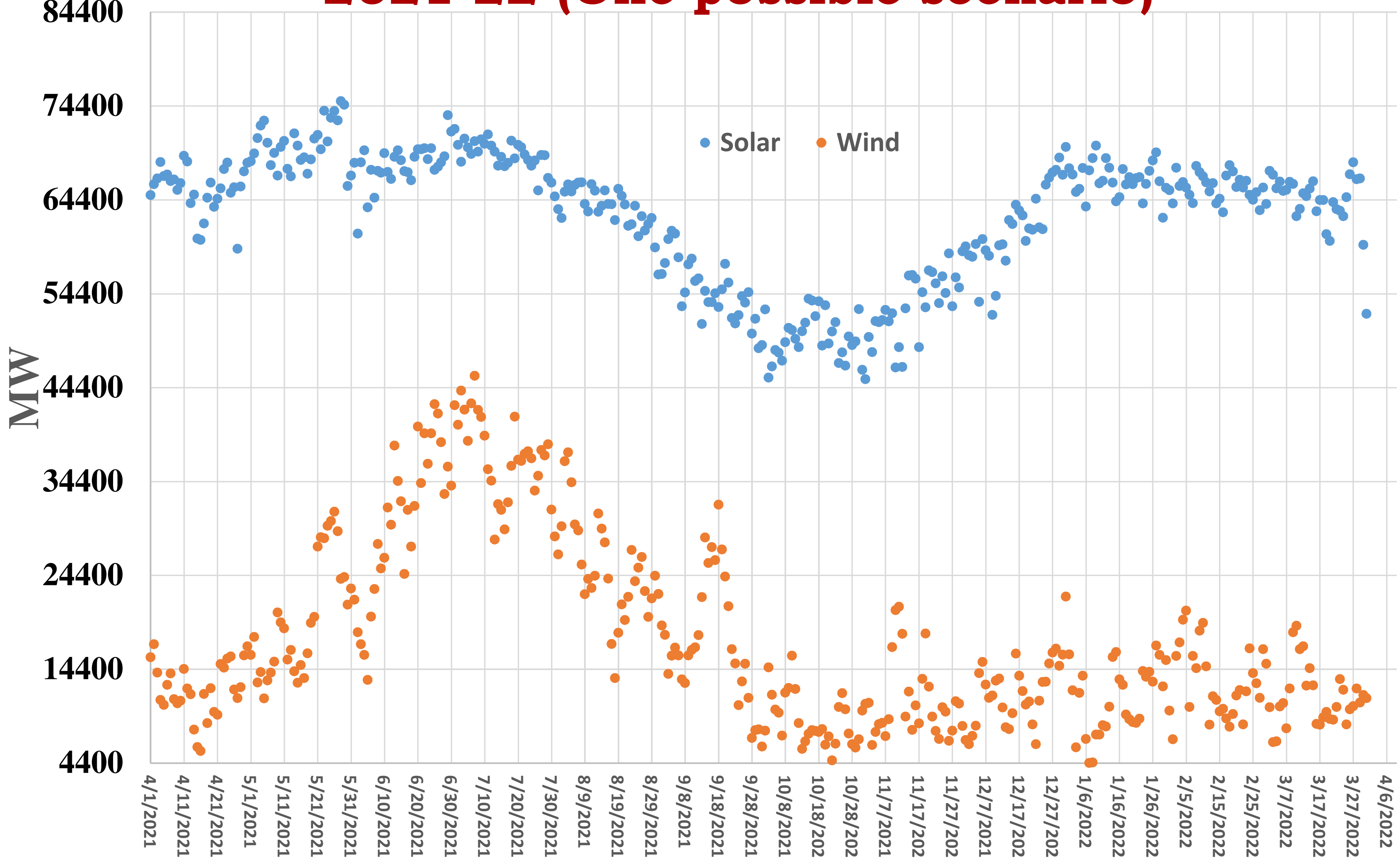
Diurnal Variation

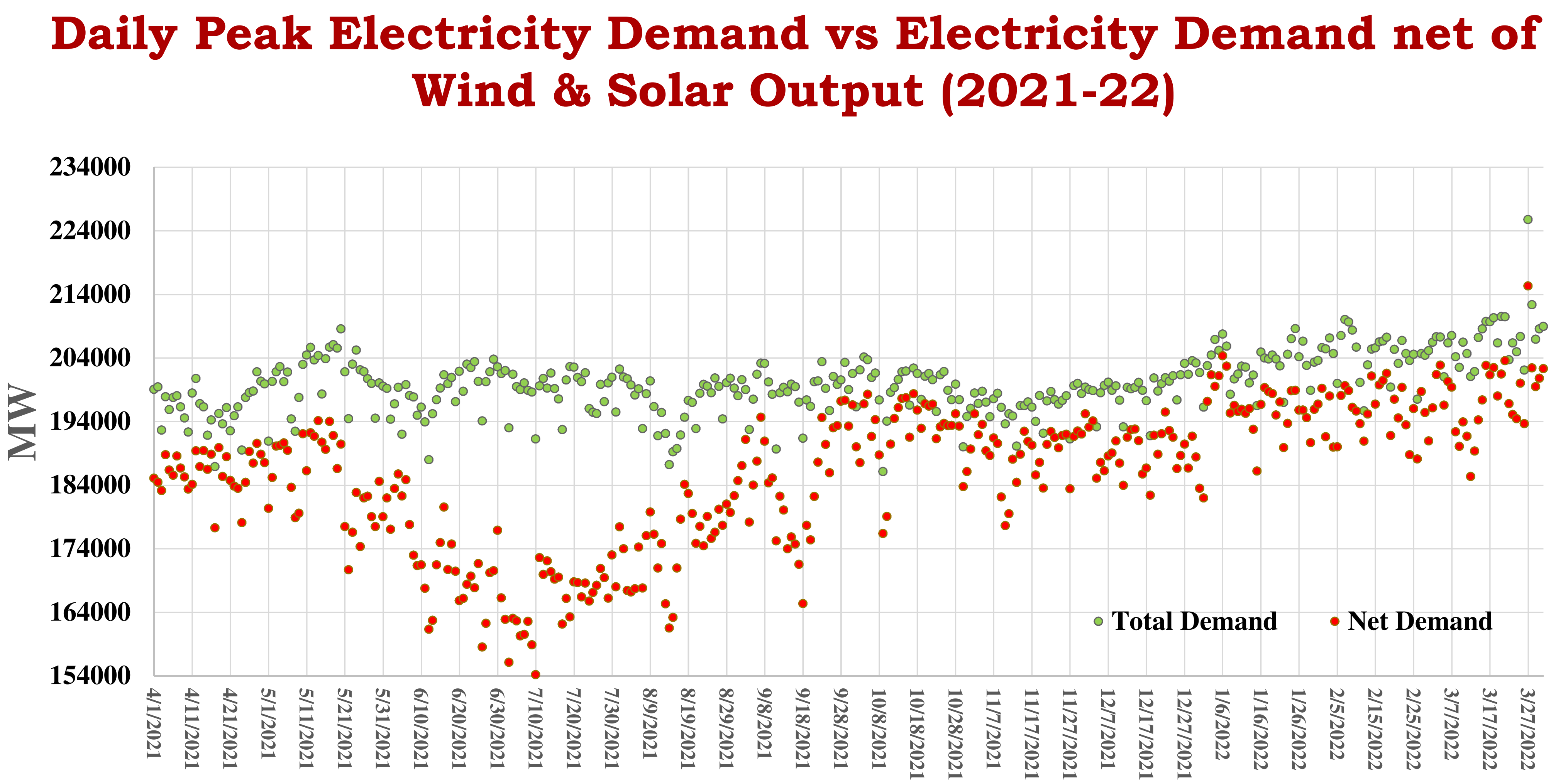


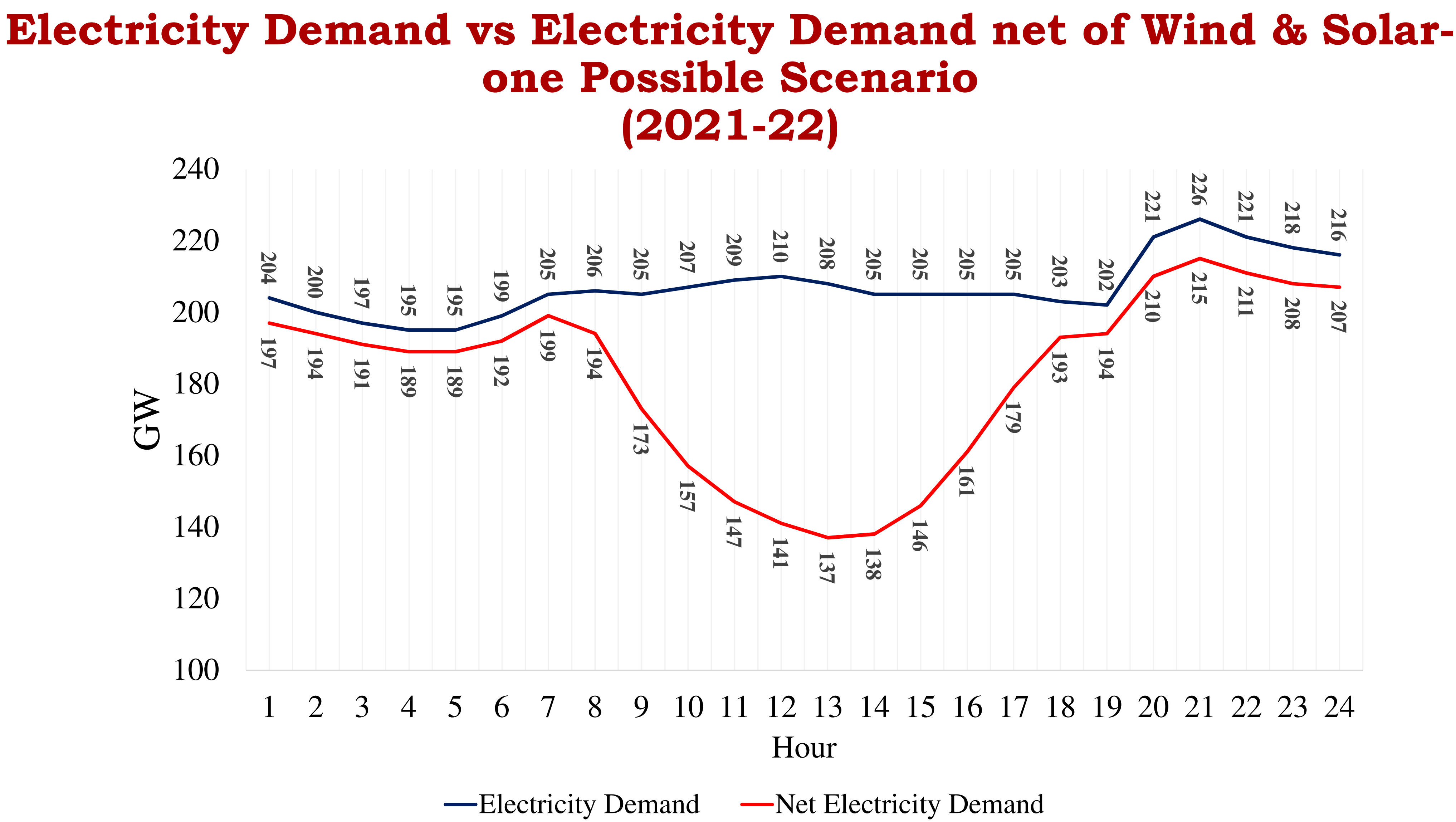
Seasonal Variation



Daily Maximum solar & wind output over a year in 2021-22 (One possible scenario)

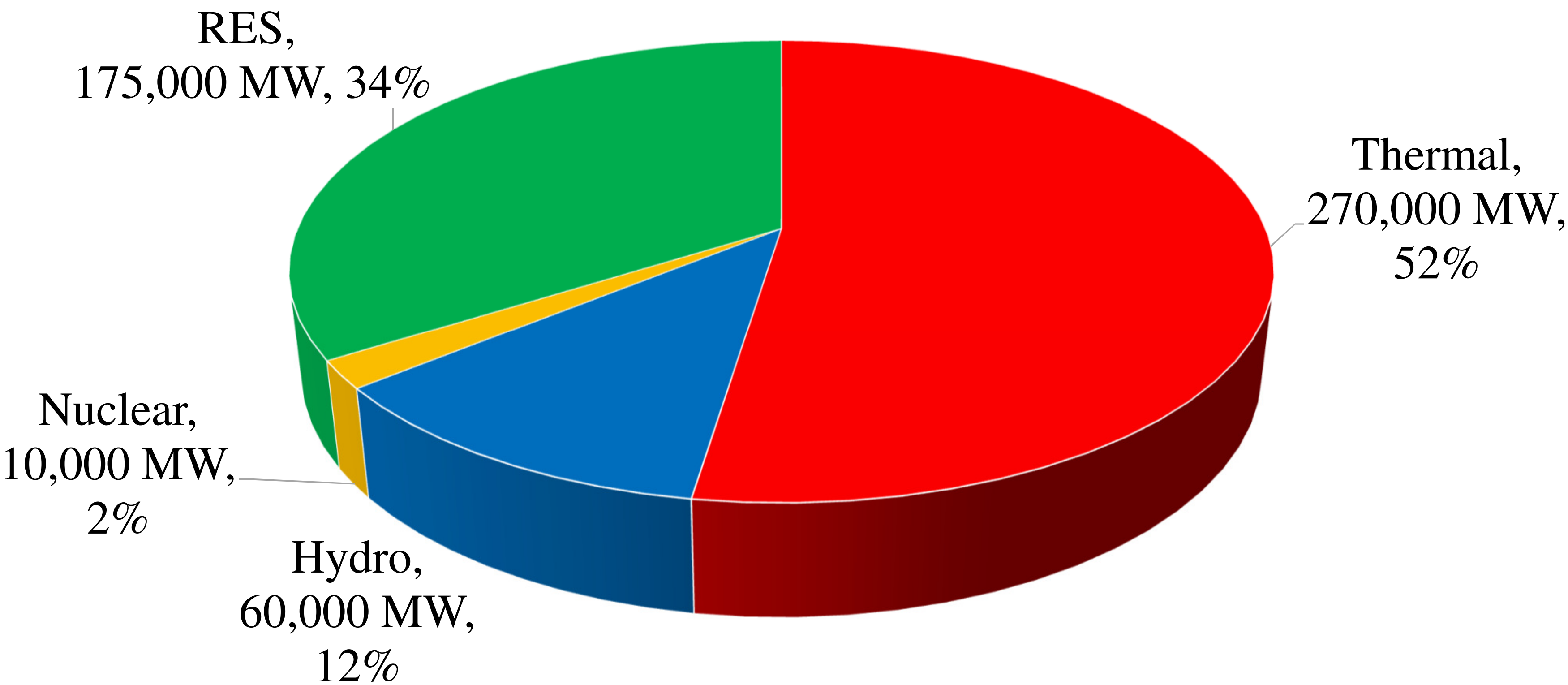



Daily Peak Electricity Demand vs Electricity Demand net of Wind & Solar Output (2021-22)
MW
234000
224000
214000
204000
194000
184000
174000
164000
154000
Total Demand
Net Demand
4/1/2021
4/11/2021
4/21/2021
5/1/2021
5/11/2021
5/21/2021
5/31/2021
6/10/2021
6/20/2021
6/30/2021
7/10/2021
7/20/2021
7/30/2021
8/9/2021
8/19/2021
8/29/2021
9/8/2021
9/18/2021
9/28/2021
10/8/2021
10/18/2021
10/28/2021
11/7/2021
11/17/2021
11/27/2021
12/7/2021
12/17/2021
12/27/2021
1/6/2022
1/16/2022
1/26/2022
2/5/2022
2/15/2022
2/25/2022
3/7/2022
3/17/2022
3/27/2022



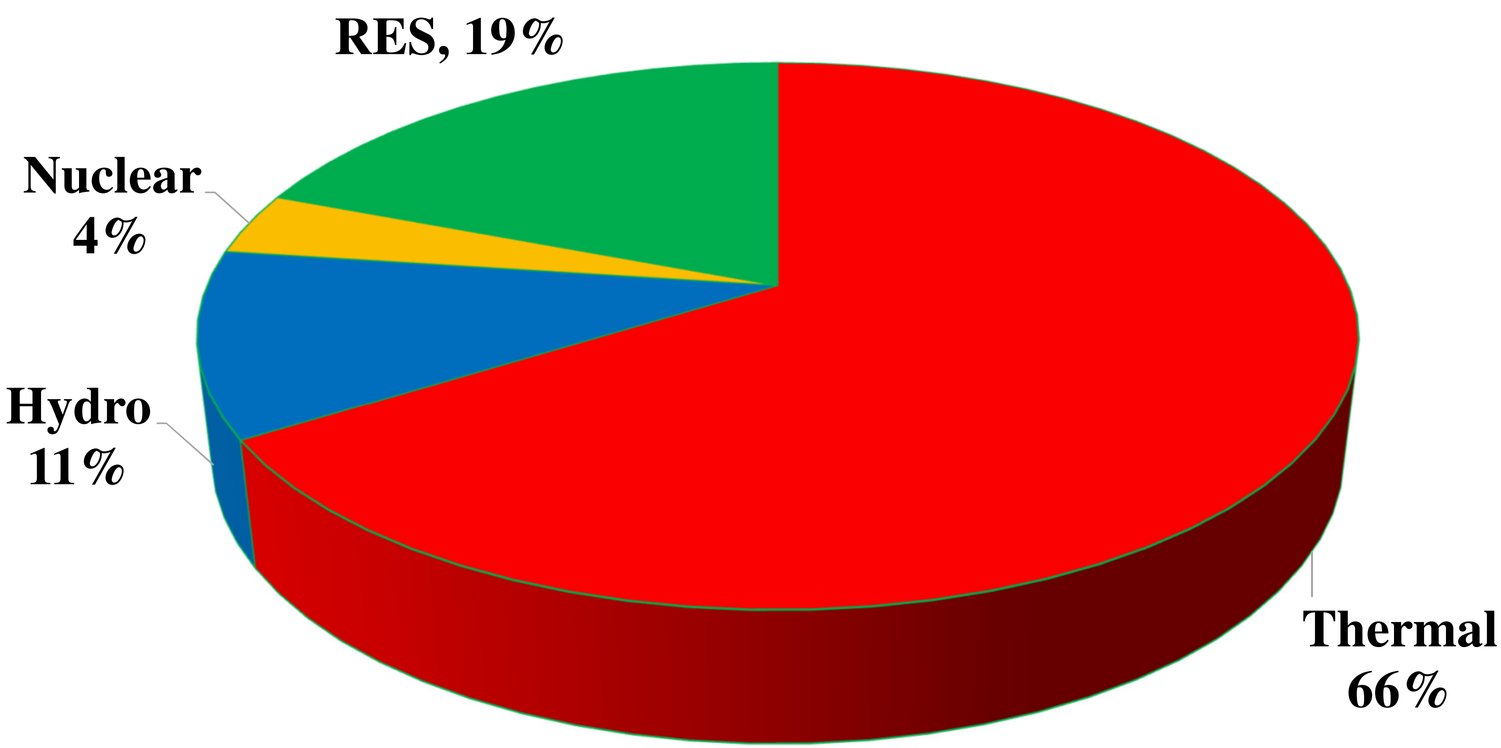
Electricity Demand vs Electricity Demand net of Wind & Solar-one Possible Scenario
(2021-22)
GW
Hour
240
220
200
180
160
140
120
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
204 200 197 195 195 199 205 206 205 207 209 210 208 205 205 205 205 203 202 221 226 221 218 216
197 194 191 189 189 192 199 194 173 157 147 141 137 138 146 161 179 193 194 210 215 211 208 207
Electricity Demand
Net Electricity Demand

Likely Installed Capacity in 2021-22
(One possible Scenario)

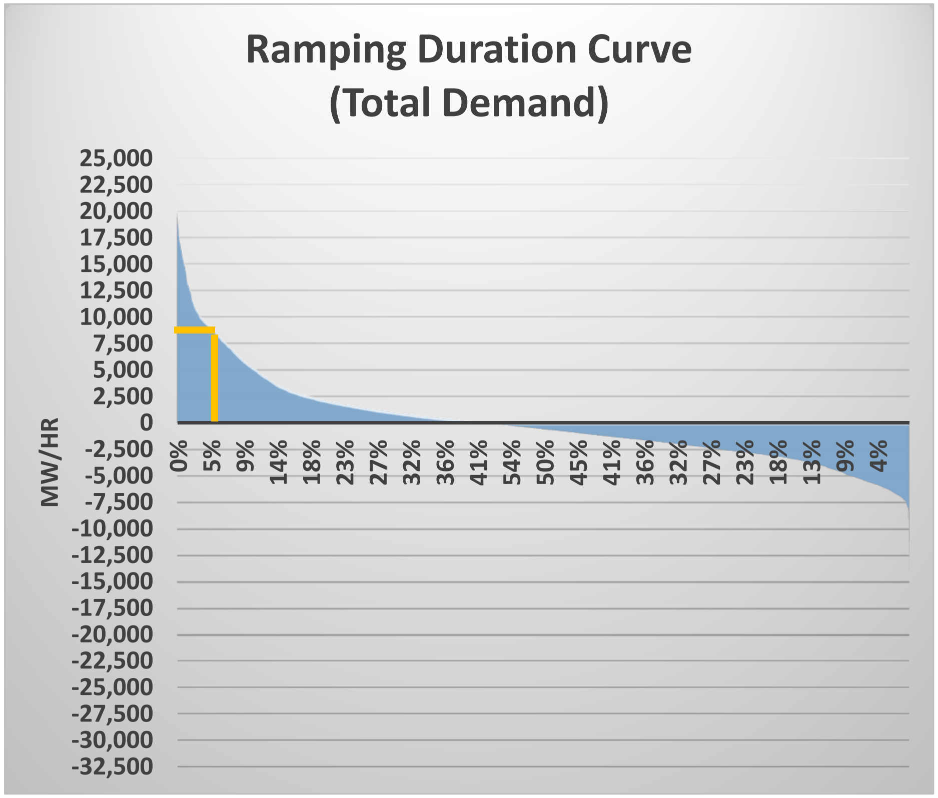


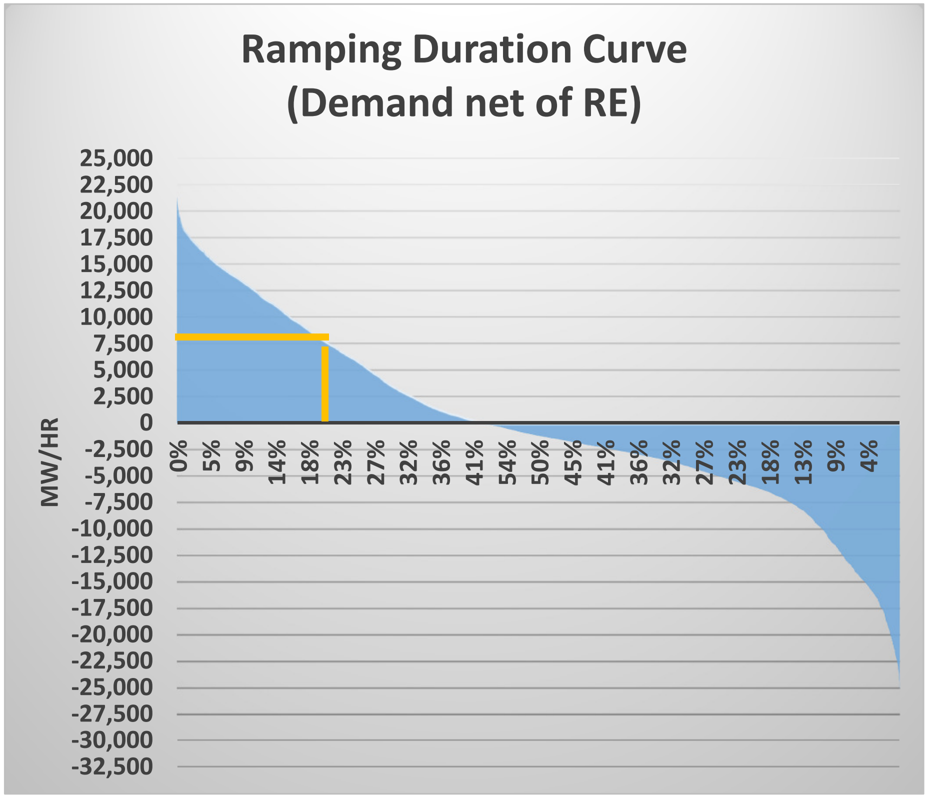
Installed Capacity: 515,000 MW

Source-wise electricity generation in 2021-22 (One possible Scenario)



Ramp Duration Curves (one possible scenario)





Conclusions

- With high penetration of RES in the electricity grid, basic Generation Planning philosophy has changed.
- Operational characteristics of conventional generating units, generally considered in operation planning study, have to be considered in the generation planning exercise.
- With high penetration of RES, the generation planning model must have the features of expansion planning as well as operation planning models.
- RE generators cannot be planned in isolation.

Conclusions

- Planning of RE generators, base load generators, flexible generators and transmission lines needs to be co-ordinated to avoid curtailment of electricity generated by RE generators due to transmission constraints or operational issues.
- With high penetration of RES, requirement of flexible generating units in the electricity grid increases.
- Lack of flexible generating units may lead to cycling and increased stop/start of base load coal based generating units.
- Storage technology is one possible solution for RE integration. However, feasibility of storage technology needs to be studied.

Thank You

Ishan Sharan	Vikram Singh
i.sharan@nic.in	vikramsingh-cea@gov.in
9868021344	9868893051